The Impact of a High-speed Railway on Residential Land Prices

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Abstract

By using the case of the high-speed railway scheduled to open in 2027 in Japan, this study examines whether the value of transport innovation is capitalized in land prices immediately after the construction plan is announced. We adopt a hedonic approach to measure value, using balanced panel data on residential land prices from 2008 to 2015 in Japan. We find that residential land prices where the time distance to the Tokyo metropolitan area reduces rose, except where the population is decreasing. This result implies that the benefits are capitalized in land prices when demand to shorten the time distance exists.

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1. INTRODUCTION

High-speed railways benefit society by greatly reducing the time distance between cities and by transporting more people than alternative public transportation modes such as airplane and long-distance bus. The development of these railways promotes industry accumulation in urban areas, develops tourism in rural areas, and, in some cases, changes the residential distribution of people. However, such railways are expensive to build owing to the enormous sunk costs such as the cost of track and expenses for land acquisition. Moreover, the basic plans of high-speed rail construction are often canceled because of budget limitations. Thus, policymakers must be clear that the construction justifies the investment.[1]

A hedonic approach is often used in evaluating the overall economic benefit of railways. While many studies have evaluated the impact of transportation infrastructure development, there are few studies sufficiently considering some estimation problem from the viewpoint of causal inference (e.g. Imbens and Wooldridge, 2009; Imbens and Rubin, 2015). In the impact evaluation of transportation infrastructure development on land price, there are mainly three estimation problems; namely omitted variable bias, location selection bias, and the timing of the treatment. The definition of the treatment groups is also a major problem when evaluating

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[1] Since JR Tokai that is a private company constructs the LCS applied by this research, it may seem that it is not valid as evidence of policy decision-making. However, JR was originally a state enterprise. The plan of all Shinkansen lines in Japan was formulated by the government. This is the reason that national and local governments have been spending money on the construction of the Shinkansen operated by JR. For example, the central government and local governments spent 50% of the construction cost of the Hokuriku Shinkansen (operated by JR East), where the service was extended from Nagano Prefecture to Ishikawa Prefecture in 2015. In Addition, there is a debate that the central government will finance the budget in extending LCS from Nagoya to Osaka in 2016. In this way the government may influence the construction of the Shinkansen as an implicit context in Japan.

the impact of large-scale transportation infrastructure.

This study investigates whether the benefit of high-speed railways is capitalized in residential land prices applying a method of impact evaluation (e.g. Angrist Pischke, 2009, 2010 ; Gertler et al. 2016) to hedonic model.[2] We focus on the case of the Linear Chuo Shinkansen train (LCS hereafter) in Japan, the construction of which was announced in 2011 and which is scheduled to open in 2027.[3] An analysis of the relationship between the construction of LCS and the rise in land price has useful features for making clear the issues to be considered in the hedonic approach. This study aims to present one solution to the three estimation problems and definition problem of treatment group by using balanced panel data on residential land prices from 2008 to 2015 and information on the time distance to large cities in Japan.

This research measures a partial benefit in meaning it does not include the synergy with urban development newly planned after the analysis period until the start of LCS service. However, the focus of this study allows us to measure the total benefits due to shortening the time distance in the sense that it can eliminate the influence of regional development, which is carried out together with the construction of a large-scale transportation infrastructure.[4]

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[2] The method of impact evaluation adopted by this research may seem to be performing only a simple regression analysis. However, this impact evaluation method aims to examine the difference between the conditional expectation of the outcomes of the treatment group and the control group, considering the allocation mechanism and the potential outcome. This approach relinquishes efforts to explore functions that are generating data to measure strictly how strong the impact occurred.

[3] Since it is difficult to measure all the benefits of the LCS that have not yet been realized, this study does not estimate its cost-effectiveness.

[4] Moreover, because of the start of operation is planned to be ten years after, we believe the estimation

This study thinks three questions by focusing on the rise in land price due to the LCS construction plan decisions. First, we evaluate the impact of high-speed railway construction on land price. Most of the studies that examined the relationship between railway and land prices are investigating the relationship between local railways and housing prices. Empirical evidence of the valuing high-speed rail is limited in developed countries because of the small number of cases of high-speed railway construction and the availability of land price panel data. This study provides valuable evidence on the economic value of high-speed railways.

Second, we measure the impact heterogeneity of railway construction. Because high-speed rail is aimed at shortening the time distance of geographically distant areas, the benefits generated in each area may differ greatly. In the case of LCS, most of the benefit of the area of the terminal station is shortening the time distance to the opposite terminal. In addition, the areas where is at the intermediate station includes not only areas with large economic scale but also areas where the economic scale declines. The fact that the size of the total benefits of residents varies greatly depending on the socioeconomic situation of each region will be important evidence for the decision making of the station construction and urban development in the area where high-speed railway passes.

Third, we will clarify the timing when the benefits of high-speed railway are capitalized

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results have important implications for preliminary evaluation such as using CGE. Although we evaluate using data before opening, the analysis of this research is ex post evaluation because using data including after information disclosure of the LCS construction decision. This an ex-post evaluation is made possible by paying attention to land asset prices.

in land prices. This study evaluates the value of high-speed railway before the opening the high-speed railway services. Even before railway service is started, the land price as asset will be risen by the effect of time distance shortening by high-speed railway. The question is when this land price rise will occur. In the verification of the capitalization hypothesis, it is necessary to clarify the timing when capitalization begins. At the same time, impact evaluation must be carried out with sufficient control of macro asset market effect. By using propensity score matching with difference-in-difference estimation (called a matching DID, or MDID herein), this study eliminates the heterogeneous macro effects due to the socio - economic background of the area affected by high-speed railway construction. If capitalization has started immediately after the decision of the construction plan, it is suggested that the method of investigating the change in the housing asset price before and after the start of the railway service, which some studies focused on, may underestimate the value of the railway. The estimation results[5] show that residential land prices in the area where the time distance to the Tokyo metropolitan area reduces rose, except in the area where the population is decreasing. This result implies that the benefits are capitalized in land prices when there is demand to shorten the time distance. The estimation results also suggest that the benefits of transport innovation are capitalized in asset prices immediately after the infrastructure construction decision. In addition, we confirm the importance of examining

[5] The estimation results report the value including the indirect effects of transport innovation such as expectations of urban development (see Bowes and Ihlanfeldt, 2001).

whether “a natural experiment” is an experimental situation.

The remainder of the paper is organized as follows. Section 2 presents the background of the impact evaluation of transport infrastructure and of the LCS. Section 3 provides an overview of the dataset. Section 4 describes the estimation strategy. Section 5 reports the estimation results. Section 6 concludes.

2. BACKGROUND

Problems of transport infrastructure evaluations

Many researchers have evaluated the impact of transport infrastructure construction on land price. However, studies typically suffer from three estimation problems, while the definition of the treatment group is also a challenge in the case of large-scale transportation infrastructure projects. If at least one problem is not solved, the reliability of the estimation results and the value of the policy implications derived therefrom will be low. Actually, research on the relationship between the construction of transport infrastructure and the land price has hardly any research that solved all the above problems. In this chapter, we will sort out the estimation problem to consider and describe how to solve this problem in this study.

The first problem in empirical studies is omitted variable bias. Under hedonic approaches, goods are regarded as being composed of a number of attributes and the price of goods is considered to be a bundle of the potential economic value of each attribute. In the case of land prices, land has myriads of unobservable attributes at any time that can even be correlated with each other. Further, the estimators in the hedonic approach are often biased because unobservable attributes are correlated with the treatment variables. For example, it is assumed that land prices around a railway station are higher and thus that the area around a railway station is more developed. However, land prices are affected by both the benefits of the railway links and the benefits associated with the convenience of the developed area. Identifying both benefits is often challenging because it is impossible to observe all the elements of the convenience of the developed area.

Recent research that has examined the relationship between land prices and distance from the train station has considered omitted variable bias. There are two approaches depending on the dataset structure when controlling time-invariant omitted variables. In generally, Studies using cross section data adopts the method of adding observable variables (e.g., Bowes and Ihlanfeldt, 2001) and the method of considering the spatial structure to eliminate similar omitted factor in the spatially close proximity (e.g., Efthymiou and Antoniou, 2013). Another approach is increasing the amount of information and control omitted factors more strongly by constructing panel data. Many studies adopt the fixed effects model, including first-difference model like a repeated sales model, to control for the time-invariant and common factors in the neighborhood (e.g., Baum-Snow, Kahn, and Voith, 2005; Debrezion, Pels, and Rietveld, 2007). The present study also controls for time-invariant factors by adopting an individual fixed effects model and by using balanced individual panel data. An individual fixed effects is the strongest method to control individual time-invariant factors.

Panel data allows more intensive control of time-invariant omitted variables than cross-section data, but at the same time it should not forget to control time-variant omitted variables. Although there are approaches that add observable time-variant variables as in the case of cross section data, it is not the best strategy because there is a concern about bad control by concomitant variable (Rousenbaum, 1984; Angrist and Pischke, 2009; Chap. 3). Generally, DID method is adopted. DID measures the average treatment effect by defining a treatment group and a control group, which is similar to the treatment group but is not treated. DID takes the difference of the difference between the before and after treatment on the outcome of each group. If both groups are similar, the difference in outcomes before and after the treatment in both groups is considered to be due to the treatment. Recently, several studies investigating the relationship between railway and land prices have adopted DID method (e.g, Gibbons and Machin, 2005; Billings, 2011; Levkovich et al., 2016). This study deals with omitted variable biases by individual fixed effect and DID estimation.

When adopting DID, it is necessary to confirm the common trend assumption, which is required by DID method, of the treatment group and the control group. As validity of common trend, recent researches confirm that the outcomes of the treatment group and the control group had similar changes in the pretreatment period, and there is no statistically significant difference in the value of the covariate that may be related to the treatment assignment. Without these confirmations it can not be concluded that there is no bias in the DID estimator. Billings (2011) and Gibbons and Machin (2005) implicitly checks covariate balancing by propensity score matching. This study explicitly confirms the validity of the common trend.

Location selection bias is the second major problem with the impact evaluations of transport infrastructure. One purpose of transport infrastructure construction is to decrease transportation costs for local residents. Hence, transportation infrastructure is usually built in areas where it will be used by more people. Therefore, the observed impact of the infrastructure project includes the effects due to location selection (e.g., future development). Then, changing the outcomes includes the impact of the infrastructure construction and the effect of regional development. The problem of this location selection casts great doubt on the validity of the assumption of common trend when adopting DID.

There are two ways in which to overcome location selection bias. The first is by using an experimental approach to exploit a situation that the location choice is treated as-if random. Since the allocation of the treatment is as-if random, the attributes between the treated and untreated groups can be regarded as the same. For example, Billings (2011) measures the value of the light rail constructed in 2000 in Charlotte, North Carolina by adopting a natural experiment. The author defines the relevant control groups (i.e., two lines in the proposed construction plan). If the three areas where construction is planned are similar and one is chosen by chance, we can assume that the attributes of these control areas are similar to those of the construction area.

Several studies that have evaluated the impact of a large transportation infrastructure project have also exploited the natural experimental setting. Banerjee, Duflo, and Qian (2012) examine the relationship between access to transportation infrastructure and economic growth in China, exploiting the fact that transportation networks tend to connect historical cities linearly. Although such historical cities that house a terminal could be affected by location selection bias, areas in the geographical middle of these historical cities do not suffer from location selection bias because this is a geographically natural experiment. Therefore, location selection bias can be avoided by evaluating middle areas. In a similar fashion, Datta (2012) investigates the effects of highway improvements on firms in India. As the examined highway was built to connect four metropolitan cities, it can be considered that the intermediate areas through which the highway runs are not selected.[6]

The second approach to addressing location selection bias is by conducting MDID. Propensity score matching aims to control for unobservable attributes to exploit the observable variables. Propensity score matching can thus define a control group that

[6] In addition, Michaels (2008) investigates the effect of highway construction by exploiting the natural experimental setting of interstate highways in the United States.

resembles the treatment group to alleviate the location selection problem. Therefore, using propensity score matching aims to achieve covariate balancing to satisfy the common trend assumption of DID.

In this vein, Gibbons and Machin (2005) investigate whether the reduction in transportation cost by transportation innovation raises land prices in London. They use MDID to consider the location selection bias of transportation innovation as a robustness check. Xu and Nakajima (2015) study the relationship between accessibility to highways and industrial development in China. They use MDID to mitigate the location selection bias of highway construction.

The treatment effect of the intermediate stations of the LCS can be regarded as leading to small location selection bias in the same way as in Banerjee, Duflo, and Qian (2012) and Datta (2012). Although Banerjee et al. (2012) and Datta (2012) skillfully utilize natural experimental circumstances to avoid the location selection problem, the treatment group will exist spatially concentrated since the spatial proximity to the traffic infrastructure represents the strength of the treatment effect in these studies. As discussed below, the attributes of the treatment and control groups do not necessarily balance even if location selection bias is small. Therefore, in all estimations, this study alleviates selection bias by adopting MDID.

The third problem is the timing of the treatment. When measuring rising property values, it is necessary to consider the timing of the construction decision. Although the transportation services as a flow are provided after opening, the asset price as a stock rises when the service is reliably expected to be operating in the future. Obscuring this timing will underestimate the treatment effect when adopting DID. Several studies have considered this problem (McDonald and Osuji, 1995; McMillen and McDonald, 2004; Billings, 2011; Levkovich et al., 2016). McDonald and Osuji (1995) examine whether railway benefits are capitalized immediately after the construction information is published. The present study assumes that the time of the decision of the construction plan is at the beginning of the treatment similar to McDonald and Osuji (1995). The validity of this assumption is described in Section IIB.

In addition to these three estimation problems, the location of the treated group must be solved.[7] The LCS connects Japan's major cities at the world's highest speed, which creates a large time-shortening effect. This effect is spread widely through the traffic network. If the observational point is added to the control group candidate, although it should be defined as a treatment group, the DID estimator is underestimated. If an excessively broad area is defined as the treatment group, the treatment effect is also underestimated. Hence, to find the observation points where the time distance to metropolitan areas is reduced by using the LCS, we compare the time distance to these areas by using the LCS with that by not using this service.

In sum, this study adopts individual fixed effect and DID to eliminate omitted variables

[7] This point is often considered carefully in the field such as use-transport study (e.g. Ewing and Cervero 2010).

bias. In order to confirm the validity of the common trend assumption required by the DID estimator, we check the difference of land price trend between treatment group and control group before information exposure, timing of occurrence of land price rise, and the balancing of covariates. In addition, the big data about time distance is carefully used to define the treatment group. These methods deal with Four estimation problems. Furthermore, careful consideration is also given to the sample selection problem that has often ignored even the impact evaluation study of transport infrastructure that has addressed the location selection bias by utilizing the natural experimental situation.

History of the LCS

As noted above, the estimation includes two points; first, the direct benefit of the LCS is a time-shortening effect to large cities such as Tokyo and Nagoya; second, the decision to proceed with the construction plan is the start of the treatment. In this section, we explain the background to the construction of LCS including the opposing opinion on the cost burden of construction, Shinkansen construction announcement, and geographical factors.

The LCS, which is operated by JR Tokai in Japan, is expected start running services between Tokyo and Nagoya in Aichi prefecture in 2027, with services expanded to Osaka from Nagoya station by 2045.[8] Currently, the Tokaido Shinkansen (TS) operated by JR Tokai

[8] The length of the line between Tokyo station and Nagoya station is 286 km and that between Tokyo station and Osaka station is 438 km.

connects Tokyo station and Osaka station. The TS is the oldest, most famous, and most densely scheduled high-speed railway in Japan. In 2013, 155 million people used the TS. Although the main stations of both Shinkansens (Tokyo, Shinagawa and Nagoya, Osaka) are located at the same station, the intermediate stations of the LCS are built elsewhere (Figure 1).

Insert Figure 1

The construction of the LCS is designed to reduce the time distance between the Tokyo metropolitan area and the Osaka metropolitan area from two and a half hours to just one hour. The LCS is the highest speed railway powered by a linear motor at present in the world.[9] The capacity of each train is about 1000 people, which is approximately twice the size of the largest domestic airplane. Therefore, the reduced time cost of the LCS will create a huge consumer surplus. The other purpose of the construction of the LCS is to provide an alternative route to the TS. The TS, which was opened in 1964, is scheduled to undergo a large-scale renovation because of the risk that a large earthquake called a Tokai earthquake will occur.[10] Since travelling between Tokyo and Osaka has huge demand, the economic loss

9 In 2015, the LCS achieved 603 km per hour in a manned test run, the world's highest speed for land transportation (see http://jr-central.co.jp/news/release/_pdf/000026466.pdf, published in April 21, 2015, in Japanese, last access February 26, 2016).

10 In 2011, the Ministry of Education, Culture, Sports, Science and Technology announced that the probability that an eight-magnitude Tokai earthquake would occur in the next 30 years is 87%.

of the TS not running is large. Hence, the LCS is a socially desirable alternative mode.[11]

In this regard, however, the construction cost of the LCS is high. The estimated construction cost is about nine trillion yen (¥9×10^{12}, which is equal to about 900 billion dollars, one dollar is roughly equivalent to 100 yen), including the cost of rolling stock and excluding interest. In addition, the total construction cost of the four intermediate stations is about 330 billion yen (¥330×10^{9}, about 33 billion dollars). Usually in Japan, the government accepts two-thirds of the construction cost of high-speed railways and the local government accepts the rest. However, surprisingly, JR Tokai accepted all the construction costs of the LCS, as the discussion on the cost allocation for each government was prolonged.[12] Then, JR Tokai decided a phased construction plan, constructing the line between Tokyo and Nagoya in the first stage and that between Nagoya and Osaka in the second stage.

To reduce the construction costs of the intermediate stations, the renovation of existing stations and adjustment of connection facilities were postponed until the completion of the line between Tokyo and Osaka in 2045. Furthermore, intermediate stations will have no ticket office and no sales staff in order to reduce operating costs.[13] That is, JR Tokai will build the

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[11] There is a possibility that the residential land along the Tokaido Shinkansen will be affected by LCS, but we can not predict whether it is positive or negative. Therefore, we removed the observations along the Tokaido Shinkansen from the control group participants and analyzed. As a result, there was a tendency for the estimated value not using the propensity score matching to rise, but there was no major change in the MDID estimation result.

[12] Although JR Tokai is a large company whose total assets were 5.2 trillion yen in 2014, accepting the full amount of construction costs alone is still a challenge (see http://jr-central.co.jp/news/release/_pdf/000013337.pdf, published in November 21, 2011, in Japanese, last access February 26, 2016).

[13] Trains will adopt a pre-reservation system for all seats.

intermediate stations without considering a transportation network in neighboring regions. A park-and-ride system will be necessary to use the LCS in intermediate stations because access to a nearby railway station will be inconvenient.

Next, we describe when the treatment effects of the LCS started. Although the LCS was initially conceived in 1973, it was not until May 2011 that the Ministry of Land, Infrastructure and Transport approved the construction plan.[14] In August 2011, JR Tokai published the location of the intermediate stations and the rationale for selection in an environmental impact statement at the planning stage,[15] only between Shinagawa station in Tokyo and Nagoya station in Aichi prefecture. In Japan, the construction of Shinkansen remains undetermined even though the basic plan has been announced. Only seven of the 17 Shinkansen listed in the basic plan published in 1973 have actually been built. Further, the date of completion is unknown at the time listed in the basic plan. In other words, the construction of the LCS was determined after the information disclosures in 2011.[16]

Focusing on geographical factors allows us to verify the validity of the natural experiment. The route of the LCS is almost a straight line between Tokyo and Nagoya and is expected to take 40 minutes. The minimum radius of the curvature of this route is 8000 m

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[14] See "The determination of the construction plan of Chuo Shinakansen" http://www.mlit.go.jp/common/000145486.pdf (published in May 26, 2011, in Japanese, last access February 26, 2016).

[15] See "Environmental impact statement at the planning stage of Chuo Shinkansen between Tokyo to Nagoya" http://company.jr-central.co.jp/company/others/assessment/_pdf/04.pdf (published in August, 2011., in Japanese, last access February 26, 2016)

[16] Of course, the market may have reacted for some reason before 2011. For information on what to do, this problem is described instead of the identification strategy.

compared with that of the TS of 2500 m, which is a major restriction on the maximum speed. Because of this problem, the minimum radius of the curvature of the Shinkansens built after TS in Japan is 4000 m.

3. DATA

Sample

This study uses official land prices, called *Kojichika*, from 2008 to 2015 to investigate whether the benefits of the LCS are capitalized in residential land prices after 2011. The Land Prices Public Announcement Act investigates official land prices in Japan. Although official land prices are not actual transaction prices, they are a value evaluated by experts by using actual transaction information taken from the Land Transactions Survey. Therefore, official land prices report a survey price that reflects changes in the market. Further, official land prices have a panel data structure since they are reported on January 1 every year.[17]

These panel data are superior to the panel datasets used by previous studies. First, they are individual panel data. In an analysis of land or asset prices, a researcher typically makes

[17] The observational point that becomes a new or drop during the analysis period will be excluded from the analysis when constructing complete panel data. The reason for joining the newly public land price evaluation point is that it is actively traded in the vicinity of that point or other special reason that can not be observed. The reason why dropping the observational point is also the same. These points are not suitable as a treatment group or a control group because it is difficult to control unusual factors that affect land prices. In the analysis of this study, these points are in principle excluded by propensity score matching. However since propensity score matching can not fully deal with the effects of unobservable factors, the procedure for constructing complete panel data eliminate these points. That is, we are deal with the estimation bias problem, which the Repeated Sales Model potentially faces by the structure of the sample selection, by sample selection with the principle that is opposite to the Repeated Sales Model.

pooled cross-section data and estimates values by using area fixed effects. However, our panel data can control for the unobservable time-invariant omitted variables by using individual fixed effects. Second, the measurement error is smaller than that in other datasets since experts have evaluated official land prices in order to reduce the information asymmetry in land transactions. For such a reason, information that is not traded is hard to contain.

Estimation using official land prices might have two bias. The first is the measurement error caused by the evaluator, and the second is the possibility of a lag before fluctuation in the transaction price is reflected in the official land price. For the first problem, we think that it can be eliminated the influence on the estimation result by using the individual fixed effect of observation point for analysis. It is difficult to deal with the second problem technically and it is necessary to respond carefully by interpreting the result. Since the official land price is to decide the price as of January 1 referring to the transaction price of the previous year, if the asset value fluctuates in the middle of the year like the construction announcement of LCS, the transaction price before the fluctuation is also reflected in the official land price.

Observations are selected as places that can build a house under the land use regulations.[18] However, observations are excluded for four prefectures, namely Fukushima, Toyama, Ishikawa, and Okinawa (Figure 2). First, we exclude Fukushima prefecture as it was

[18] 84% (14096) of observations 16745 in the first row and the second row of Table 3 are used as residential land. The remaining 13% (2295) is used for the service industry. The remaining 3% is used for other uses. The composition ratios of observations in the 3rd and 4th columns are almost the same. As shown in the table A3, commercial sites with high land prices are excluded from observations by propensity score matching. The distribution of residential land is almost the same as that in FIG. 2, so it is omitted.

affected by the Fukushima nuclear accident caused by the Great East Japan Earthquake in 2011. However, because radioactive substances were scattered outside Fukushima, the treatment group belonging to Shinagawa station will include affected points. The distance between Shinagawa station and the Fukushima nuclear power plant is 230 km.[19] As a robustness check, we estimate the average treatment effect on treated (ATT) of the redefined treatment group by distance from Shinagawa station. Second, we exclude Toyama and Ishikawa prefectures to remove the effect of the Hokuriku Shinkansen that opened in 2015. The Hokuriku Shinkansen connects Tokyo station and Nagano station (Figure 1). It extends from Nagano station to Toyama prefecture and Ishikawa prefecture. The construction plans of the Hokuriku Shinkansen were published in 2000.[20] The opening of the Hokuriku Shinkansen in 2015 would have increased land prices in Toyama and Ishikawa. Therefore, we exclude those areas from the analysis. Finally, Okinawa is excluded from the analysis. Other small islands also are excluded.

Insert Figure 2

Definition of the treatment group

The treatment group is defined as the shortening of the time distance to Tokyo station

[19] We estimated using samples including Fukushima as a robustness check. MDID estimators are almost same estimators in Table 3.

[20] The basic plan of the Hokuriku Shinkansen was published in 1973.

and/or Nagoya station. Five LCS trains an hour travel between Shinagawa station and Nagoya station, four of which do not stop at the intermediate stations. Therefore, we assume that the reduction in the time distance to the intermediate stations is not a benefit.[21] To find the observation point that shortened the time distance to the major city stations, this study uses spatial information about the railway, information about the travel time of all public transportation infrastructures, and spatial information on all road infrastructures.

We have to consider the effects of local railways when defining the treatment groups. Defining the treatment groups as the distance from the nearest high-speed railway station is unsuitable for evaluating the effects of high-speed railways. We must clarify how the benefits of high-speed railways spread. If we estimate the range of treatment effects too narrowly, the control group/participant candidates include treated observations. This study overcomes this problem of the definition of the treatment group by using a detailed timetable.

We define the treatment group as the point where the time distance to Tokyo station or Nagoya station by using the LCS is shorter than the current time distance. Therefore, we need information on the time distance to each city station using and not using the LCS, at each survey point. First, we determine the time distance to the city stations, which are Tokyo and Nagoya, in the case of not using the LCS. Each survey point of the official land price is

[21] In strictly, benefits for going to the intermediate station also included in benefit of treatment group. At this time, benefits for going to the intermediate station may affect the interpretation of the estimation result. However, it is expected that the shortening of the time distance to the intermediate stations will be a small benefit.

combined with the spatial information of the nearest local railway station. At this time, the time distance from the survey point to the nearest local railway station is defined as the travel time on the shortest time distance route based on the speed limit of the road infrastructure (i.e., the digital roadmap). After this, each survey point is given the time distance to each city station from the nearest station. The information on this time distance is based on YAHOO! JAPAN route information on October 21, 2011. In the case of changing the nearest train station after October 21, 2011, such as opening or shutting stations, we used information on May 1, 2015.[22] This time distance is the shortest travel time when using all public transportation modes to city stations from each station. This process provides the average waiting time and travel time for each route based on the timetable, and uses the shortest travel time for each transportation mode. Of course, if the survey points of official land prices are far from the metropolis, the transportation mode of airplane is selected. In a word, we define the time distance from the survey points to city stations when not using the LCS as the sum of the shortest travel time from survey points to the nearest local railway station and the shortest travel time from the nearest local railway station to the city station using existing transportation modes.

Next, we describe how to determine the time distance to the city station in the case of using the LCS. Each survey point of the official land prices is combined with the nearest

[22] Because we did not have digital information on May 1, 2015, we exploit the information on 2011.

station of the LCS. Here, the method of calculating the time distance to the terminal or intermediate stations is different. First, we describe how to determine the time distance to the terminal stations. For the treatment group belonging to Nagoya station, the time distance is shortened only for Tokyo station. The route from this treatment group to Tokyo station using the LCS is taking the LCS from Nagoya station and transferring to a local train to Shinagawa station. Hence, we define the time distance to Tokyo station of the treatment group belonging to Nagoya station as the sum of the time distance to Tokyo station from Nagoya station using the LCS and the time distance already calculated from the survey points to Nagoya station. Conversely, the treatment group belonging to Shinagawa station is the point where the time distance is shortened to Nagoya station. We define the time distance to Nagoya station as the sum of the time distance to Shinagawa station via Tokyo station from the survey points because Shinagawa station is close to Tokyo station and the time distance to Nagoya station from Shinagawa station using the LCS. There is a point that the time distance is shorter going directly to Shinagawa station; however, the effect of this measurement error in defining the treatment group is limited.

Second, we describe how to determine the time distance to the intermediate stations. We define the time distance to each city station from the treatment group belonging to an intermediate station as the sum of the time distance to the nearest intermediate station of the LCS from the survey point by car and the time distance to city stations from intermediate stations. The time distance from the survey points to intermediate stations is adopted as the shortest time distance based on the speed limit of each route rather than the shortest route distance, as with the travel time to the nearest station from the survey points.

A timetable for the LCS does not exist. Table A2 reports the average time distances based on the published information. For example, the average time distance from Shinagawa station to Nagoya station is the sum of travel time, 40 minutes, using the LCS and average waiting time, seven minutes. The average time distance to transfer from Shinagawa station to Tokyo station is 16 minutes. The average time distance from the intermediate station to city stations assumes the direct train overtakes the local train.

In sum, the treatment effect of the LCS can be classified into two types: (i) those that reduce the time distance to Tokyo and Nagoya (the intermediate stations correspond to this type) and (ii) those that reduce the time distance to Tokyo or Nagoya. The treatment group for which the nearest station is Shinagawa station in Tokyo aims to shorten the time distance to Nagoya station. Conversely, the treatment group for which the nearest station is Nagoya station aims to shorten the time distance to Tokyo station. Focusing on the second type allows us to compare the benefits of the shortening of the time distance to Tokyo station and Nagoya station.

Propensity score estimation

This study adopts a propensity score estimation to control for selection bias. Propensity scores are estimated by using information on the year immediately before the receiving treatment. To estimate a propensity score, information on official land prices in 2011 is combined with the Population Census 2010 and Economic Census for Business Frame 2006.[23] These Censuses report an aggregate value for each municipality. By using propensity score matching and the attributes of the neighboring environment, we select a control group that has a land market condition similar to that of the treatment group. In addition, estimating the propensity score uses land price history from 2008 to 2011 in order to select a control group that considers the situation that a market reacts before the treatment such as an Ashenfelter dip (Heckman and Smith, 1999) and the effect of adventitious urban development before the treatment.

Descriptive statistics

Table 1 reports the descriptive statistics. In columns (1) to (6) are the statistics of the treatment group for the LCS stations. Column (7) shows the statistics of the control group/participants. This table shows that the average land price from 2012 to 2015 is lower than that from 2008 to 2011 in Japan. The rate of change of the average land price of Shinagawa station in Tokyo is -10.0%. The land price of the treatment group by intermediate

[23] Both Censuses are reported every five years.

stations in Kanagawa, Yamanashi, Nagano, and Gifu prefectures falls by -6.6, -11.3, -13.1, and -12.2 percentage points, respectively. Moreover, the land price of the treatment group of Nagoya station in Aichi prefecture falls by -8.5 percentage points and that of the control group falls by -10.7 percentage points. According to a simple comparison of these statistics, the declines in the average land prices of the treatment group of the station in Tokyo, Kanagawa prefecture and Nagoya station are smaller than that of the control group.

Table 1 also shows that the opening of the LCS reduces the time distance to Tokyo station for the treatment group except Shinagawa station, and vice versa. Interestingly, the standard deviations of the treatment groups of Tokyo, Kanagawa, Gifu, and Nagoya stations are smaller than the standard deviations of time distance to Tokyo/Nagoya station. This finding implies that time distance shortening does not vary by treatment group. It is rather caused by the fact that the public transport around the linear station to each terminal station has already been developed. For example, when people have traveled to Tokyo station from the Nagoya treated group, they used the TS from Nagoya station before the LCS opened, while after the LCS opened, they used only this mode of transport. On the contrary, treatment groups whose standard deviation of time distance shortening was bigger distributed over the area of the public transport to each terminal station are insufficiently developed.

There is no clear difference between the control group and treatment groups for distance to the nearest station, acreage, building coverage, and floor area ratio, while the values of population, population trend, and office number and number of employees in the treatment group belonging to the station in Tokyo, Kanagawa, and Nagoya are higher than those in the control group. On the contrary, the population density of the treatment groups of the stations in Yamanashi, Nagano, and Gifu is lower than that of the other groups. Propensity score matching thus mitigates the differences in the covariates between the treatment group and control group.

Insert Table 1

4. EMPIRICAL STRATEGY

This study measures the change in residential land prices before and after the opening of the LCS by adopting a hedonic model. When the time distance to a large city reduces because of transport innovation, the land attributes also change when the market is exposed to such information. For example, land prices will rise with the discounted present value of the benefit of the transport innovation.

Discount rate

In the analysis, we estimate the discounted present value of the LCS. This describes the simplest case of the relationship between the estimation result and the discount rate. We assume that the LCS will open *j* years after the construction information disclosure. As a result, the change in land prices because of the transport innovation is $\delta LP = LP_j - LP_0$, where LP_j is the land price in the *j*-th year, which is immediately after the opening, and LP_0 is the land price in period 0, which is immediately before the announcement.[24] We also assume that discount rate *d* is constant over time. Thus, the change in land prices in the first year immediately after the announcement is expressed as $LP_1 - LP_0 = \delta LP / (1+d)^{j-1}$. The interest of this study is the average change rate of land prices from just before the announcement to four years after the announcement.

In our estimation, it is difficult to remove the influence of a specific urban development that is determined after the announcement. The influence of such a specific development may be included in the change in land prices. For example, the decision to stage the Tokyo Olympic Games in 2020 was agreed in September 2013. Our analysis cannot sufficiently remove the influence of infrastructure construction for the Olympic Games on land prices. For this reason, the results must be interpreted carefully.

Baseline model

The baseline model measuring the reduction in the time distance to Tokyo and Nagoya because of the LCS is

[24] In other words, this research assumes that the land rent will rise immediately after service start since the land rent reflects the land service.

$$\ln\left(LP_{it}\right) = \alpha + \beta\left(Treat\right)_{it} + \mathbf{X}'_{it}\gamma + YF_t + FE_i + \varepsilon_{it}, \tag{1}$$

where LP_{it} is the official land price at survey point *i* in year *t*, $\left(Treat\right)_{it}$ is a dummy indicating whether the survey point belongs to a treatment group in the post-announcement period, $\mathbf{X}'_{it}$ represents the control variables of *i* in *t*, TF_t is the year fixed effects, and FE_i is the individual fixed effects. That is, $\left(Treat\right)_{it}$ is a DID estimator and thus the coefficient β of variable $\left(Treat\right)_{it}$ represents the average increasing land price. In other words, β is the discounted present value, which is based on future benefit, immediately after the information disclosure to the land market. YF_t controls for the factors of each year such as the inflation rate. In this study, equation (1) is called a fixed effects DID (FEDID). For previous impact evaluations of railways, Gibbons and Machin (2005) and Billings (2011) adopt fixed effects DID models by exploiting the quasi-experimental situation.[25]

Identification

As described in Section 2, three estimation problems exist when evaluating infrastructure construction in the hedonic model: omitted variable bias, location selection bias, and the timing of the treatment. To control for the time-invariant omitted variables, some studies construct (quasi-) panel data and adopt a fixed effects model (e.g., Gibbons and Machin, 2005). The present study also constructs a balanced panel dataset and adopts individual fixed

[25] Camagni and Capello (2006) and Tsutsumi and Seya (2008) also measure the capitalization to the land price before the start of service.

effects. That is, the first problem is solved substantially in the estimation of equation (1).

Location selection bias is the second problem from which all impact evaluation studies of infrastructure construction suffer. On the one hand, since a railway is built to maximize revenue, the location of the railway station is less likely to be considered to be a natural experiment.[26] The effect of the construction of a terminal LCS station should also be affected by location selection bias. This study mitigates the location selection bias of terminal stations by using propensity score matching.

On the other hand, since the purpose of the LCS is to shorten the time distance between metropolitan areas, the route is straight. Hence, it can be regarded as a natural experiment with respect to the location of intermediate stations. However, the selection bias problem for the treatment effects of such an intermediate station must be noted. In general, if the control group covariates differ from the treatment group covariates, the year trends of the outcome in each group would be different. As a result, the DID estimator is biased. Therefore, balancing the covariates is essential in the DID estimation. However, solving this balancing problem is not easy for the impact evaluation of large-scale transportation infrastructure. The hedonic model obtains an estimate by regressing the price on the characteristics of interest of each good. Hence, the model assumes that demand-side preferences are homogeneous. However, as shown in Table 1, the range affected by the large-scale transportation infrastructure

[26] In the case of local railways, the endogeneity of location selection is more serious since engineering constraints such curvature radius and social problems (e.g., the trade-off between train speed and noise) are weaker than for high-speed railways.

construction might extend beyond a radius of 50 km. In this case, defining a control group for which demand-side preferences can be regarded as equal to those of the treatment group is difficult owing to the spatial sample selection problem. To address this problem, control groups for the intermediate stations are also selected by using propensity score matching.

The second problems are formulated on the basis of equation (1) as follows:

$$\ln\left(LP_{it}\right)=\alpha+\left(Treat\right)_{jt}\beta+\mathbf{X}'_{it}\boldsymbol{\gamma}+YF_{t}+FE_{i}+\eta_{jt}+\varepsilon_{it}, \tag{2}$$

where η_{jt} is the unobservable time-variant factors of group j in t that correlate with $\left(Treat\right)_{jt}$. Since the DID estimation assumes that the unobservable time-variant factor in the control and treatment groups is a common trend, the time-variant factors can be controlled for by using year fixed effects, YF_{t}. However, the η_{jt} of the control and treatment groups is unlikely to be a common trend because the treatment group in terminal stations is biased by location selection and that in intermediate stations is biased by spatial sample selection.

Therefore, we use propensity score matching to define the control group with a similar η_{jt} to the treatment group. This procedure can compare the treated land market to the untreated land market that is similar to the treated market. If both land markets were not treated, land prices would show the same trend. That is, the assumption of a common trend is met in the DID estimation by using propensity score matching.

This study adopts the inverse probability weighting (IPW) technique and nearest neighbor matching with caliper (NNMC) technique to eliminate the imbalance between the control group and treatment group covariates using propensity scores. IPW weights $\hat{P}_i \Big/ \left(1-\hat{P}_i\right)$, where $\hat{P}_i$ is the propensity score, for the control group to estimate the ATT. As apparent from the equation of weight, this is unsuitable for the estimation when the propensity score is too small or too large. Therefore, observations that have a propensity score of less than 0.1 or more than 0.9 are dropped from the analytical sample. NNM is a method to find out the observation whose propensity score is the nearest to the observation in the treated group from the control participants. This procedure defines the control group similar to the treatment group. However, NNM faces the risk of bad matches if the closest neighbor from the control participants is far away. Caliper is limitation not to match the observation that the degree of the estrangement of the propensity score has a big. NNM with Caliper relaxes the risk of bad matches under simple NNM. The caliper in this study is 0.01.[27]

5. ESTIMATION RESULTS AND DISCUSSION

Propensity score and common trend

Table 2 reports the propensity score of each treatment group and its estimates provided by using the logit model. In the estimation results of the terminal stations, Tokyo and Nagoya, population scale, population density, and population growth rate tend to raise the propensity score. On the contrary, in the estimation results of Yamanashi, Nagano, and Gifu, propensity

[27] The size of the caliper is typically set as less than 25% of the standard deviation of the propensity score (Guo and Fraser, 2015, Chap. 5). Table 2 shows that this value is appropriate.

score is high and thus population scale and population density are low. The estimation results of Kanagawa show in between tendencies. Indeed, the variables without a difference between the treatment group and control participants in Table 1 hardly affect the choice probability. Here, by checking the covariate balancing of the NNMC sample, its improvement is confirmed (see Table A3).

Insert Table 2

This study uses the propensity score to relax the problem that the common trend assumption of DID is not met because of sample selection and location selection. Figure 3 confirms whether this problem has been alleviated by using the propensity score. Figure 3 plots the coefficients when estimated by the following model. Each coefficient β means the land price difference based on 2008 prices between the treatment group and control group estimated by FEDID, IPW, and NNMC.

$$\ln\left(LP_{it}\right) = \alpha + \left(TreatG\right)_{jt} \times \mathrm{YF}_t\beta + YF_t + FE_i + \varepsilon_{it}, \qquad (3)$$

where *TreatG* is a dummy variable coded 1 if the observation is in the treatment group. The ideal state for the common trend is satisfied (i.e., there is no significant trend in land prices from 2008 to 2011) prior to the treatment. Overall, the estimation results show that except IPW in Nagano and IPW and NNMC in Gifu, the land price trends from 2008 to 2010 are small. For Tokyo in the treatment groups, the land price trend of IPW and NNMC has been greatly improved compared with FEDID. However, for example, in Nagoya, land prices confirm the upward trend from 2011. Although the propensity score estimate also includes information on land prices in 2011, it might not sufficiently control for the effect that a market reacted before the decision on the construction plan in the Nagoya estimation. In this case, ATT would be underestimated. In the Gifu and Nagano cases, the small sample size of the treatment groups affects the stability of the propensity score estimation. In addition, it can be confirmed that the land price trend from 2012 to 2015 is greatly changed by the improved covariate balancing by using the propensity score estimation. These results imply that the DID estimator is biased by imbalanced covariates even if the common trend is met.

Insert Figure 3

ATT for the whole treatment group

Table 3 reports the DID estimations using the whole treatment group. Column (1) shows the result estimated by using OLS. Column (2) shows the result estimated by (1) with individual fixed effects. Column (3) shows the result estimated by (2) with regulated samples that have a propensity score of more than 0.1 and less than 0.9. Column (4) shows the result estimated by (3) with IPW. Column (5) shows the result estimated by using the NNMC sample. Since we are using balanced panel data over eight years, the number of observations is eight times the number of individuals.

The interpretation of the estimation results of each column is as follows. Column (1) presents the results of the simplest model (i.e., not even control time-invariant omitted variable bias is included). Column (2) presents the results of the baseline model; here, there is a concern about sample selection bias and location selection bias. Column (3) presents the results analyzed by using a sample of relatively similar properties (i.e., limiting the sample based on the propensity scores). In the geographical experimental situation, this procedure is expected to control for much of the sample selection bias. Columns (4) and (5) present the results that control for sample selection bias and location selection bias by using the propensity score.

Although the land prices of the treatment groups belonging to each station tend to decrease in Table 1, every estimator is significantly positive in Table 3. These results imply that the benefits of the LCS are capitalized as the discounted present value immediately after the construction plan is revealed. The difference between columns (1) and (2) is caused by controlling for the time-invariant omitted variables. There is no significant difference between the results in columns (2) and (3) because there is almost no influence of the geographical experiment, since 94.5% of the sample is in the treatment group of terminal stations. Furthermore, the difference between columns (2)–(5) is caused by controlling for location selection bias. It can be seen that the estimation result is overestimated by about 2.4–2.7 percentage points because of location selection bias. That is, the ATT of the LCS on residential land prices is about 0.5% in the whole treatment group (see Figure 2).

Insert Table 3

ATT by station

According to Table 1, most of the treatment group belongs to the Shinagawa station area and the Nagoya station area. The ATT of the treatment group in each station could differ because of the difference in the socioeconomic backgrounds of these areas. Table 3 reports the estimation results for each station for the five estimation procedures reported in Table 2. Similar to Table 2, a reliable estimation result is provided by the fixed effects model with IPW in column (4) and NNMC in column (5). Although all the estimation results are reported, some results are not interpreted because IPW in Nagano and IPW and NNMC in Gifu do not meet the common trend assumption, as confirmed in Figure 2.

Insert Table 4

The effect of transport innovation on the residential land prices of the treatment group belonging to Shinagawa station is 3.26 percentage points (see column (2)). However, the rise in land prices is -0.44—0.55 percentage points after controlling for location selection bias (columns (4) and (5)). The benefit of the treatment group belonging to Shinagawa station is reducing the time distance to the Nagoya metropolitan area and further west. This result implies that the benefit does not capitalize in residential land prices, perhaps because Tokyo is overcrowded. The average treatment effect of the treatment group belonging to Nagoya station, the other terminal station, is 1.73–1.87 percentage points even after controlling for location selection bias. In other words, the benefit of shortening the time distance to the Tokyo metropolitan area is capitalized in the residential land prices in that area. These results are reasonable because the Tokyo metropolitan area has a population scale about four times that of the Nagoya metropolitan area. That is, the time distance shortening from a smaller economic scale area to a larger economic scale area increases land value in this case.

However, the average treatment effect on the treatment group belonging to each intermediate station is not large. The area showing rising land prices in the estimation results by both columns (4) and (5) is only the treatment group belonging to the station in Kanagawa prefecture. Residential land prices in that area have risen by about 1.00–1.43 percentage points. On the contrary, residential land prices do not tend to increase around the other stations. As shown in Table 1, the treatment groups belonging to stations other than the station in Kanagawa have low population density, a higher share of the elderly population, and decreasing population. Although the time distance to a major city has been greatly reduced, those areas could not be selected for residence because of the low utility related to the consumption of goods other than the time distance shortening. These nonpositive estimation results might also have been caused by the treatment groups including areas far from intermediate stations that do not receive the benefits of the LCS. This issue is examined in the following subsections. Nonetheless, the result in Table 3 is consistent with the Fogelian view (Fogel, 1962, 1964) as well as the conclusions of Banerjee, Duflo, and Qian (2012) that the construction of transportation infrastructure is worthwhile when in demand.

The result for Kanagawa station, which is the only meaningful statistically significant one, allows us to consider the natural experiment for location selection. The location selection bias of the intermediate stations is small because of the geographical structure of the LCS. The results for the intermediate stations in column (2) exploit the experimental situation for location selection. However, the result for the station in Kanagawa in column (2) is significantly different from those in columns (3)–(5). This difference appears to be due to sample selection bias based on the spatial concentration of the sample. Further, the estimation results in column (3) are those when using the sample that dropped significantly different residential land markets based on the propensity score. Spatial sample selection bias is mitigated by this procedure. Interestingly, the results in columns (3)–(5) do not so differ since the location selection bias of intermediate stations is small because of the geographical experiment.

To confirm the robustness of the analysis using propensity scores in Table 4, we estimate using two types of samples that are limited to the control group participants. The first sample omits Hokkaido and the second sample omits Kyusyu (see Figure 2). The results are reported in Tables A4 and A5, which confirm no large differences, although the sample size in the control groups in Tables A4 and A5 is less than that in Table 3.

Heterogeneity of the ATT in each station

Each treatment group is distributed geographically widely as shown in Figure 2. A uniform treatment effect is unlikely considering the accessibility of the LCS. Therefore, we estimate the heterogeneity of the ATT in each station. However, the magnitude of the time distance shortening of the LCS does not vary in the treatment groups belonging to terminal stations because, for travel to Tokyo station from Nagoya station, the time distance difference occurs only by using the LCS or the TS, as already shown in Table 1. Moreover, as revealed in the estimation results in Table 4, land prices rise in the only area that shows demand for time distance shortening. Therefore, time distance shortening is not a good measure of the intensity of the LCS treatment. On the contrary, the terminal stations of the LCS, Tokyo and Nagoya, are located central to large-scale economies. Although the correlation between the distance from the nearest linear station and the magnitude of time distance shortening is not high,[28] the ATT closer to the station would be large. Residential land demand in the area close to the station would be large since the quality of attributes is high in such areas. In brief, the variable indicative of an explicitly continuous treatment does not exist. In this section, we examine whether rises in land prices depend on the distance from each station to facilitate our interpretation.[29]

Table 6 reports the estimation results using samples redefined depending on the distance from the station adopting IPW and NNMC. First, we explain the results for the terminal stations. The treatment group belonging to Shinagawa station is widely distributed and the ATT is significantly negative, while the ATT within 50 km of Shinagawa station is not significant for IPW and NNMC. On the contrary, the ATT for over 50 km is significantly negative. The average time distance to Tokyo station for the treatment group over 50 km of Shinagawa station is 131 minutes (one standard deviation is 67.9 minutes). This time distance is longer than the shortest time distance to Shinagawa station from Nagoya station using the LCS (40 minutes). Further, the shortest time distance to Shinagawa station from Nagoya station using the TS is about 100 minutes. Land demand in this area may have moved to the Nagoya area. Moreover, this area includes the city, where land prices decreased because

[28] See Table 5.

[29] We also analyzed the subgroup in the quartile of the value of time distance shortening and time distance shortening ratio (see Tables A6 and A7). The interpretation of the estimated results of all the regions except Tokyo is almost the same as the classification by distance. The interpretation of the estimation results of Tokyo is difficult because it is hard to divide the effect on land prices into the ATT of the LCS and the impact of the scattering of radioactive material from the Fukushima Daiichi nuclear power plant. As already mentioned, the impact of the Fukushima Daiichi nuclear power plant is strong farther from Tokyo and the correlation of the distance to the TDS and the station is not high.

radioactive material was scattered from the Fukushima nuclear power plant (Kawaguchi and Yukutake, 2014).[30]

By contrast, land prices for the treatment group within 100 km of Nagoya station rise, while such land price rises in the treatment group within 20 km are greater. These results imply that the expectation of public urban development and the integration of the private sector as an indirect effect of the LCS are higher in Nagoya station and its periphery. The ATT of the area within 50 km to 100 km is greater than that within 20 km to 50 km since that area includes the city, which would develop further owing to the time distance shortening. The area within 100 km to 200 km includes the Osaka area, but land prices have not yet increased because the extension of the LCS from Nagoya to Osaka is set for 2045.

Next, we explain the results for the intermediate stations. Land prices rise significantly only in the treatment group within 50 km from the station in Kanagawa prefecture. This finding could explain why only one Shinkansen stops at intermediate stations every hour. In sum, the results in Table 6 are consistent with those in Table 4.

Insert Table 6

6. CONCLUSION

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[30] As shown in Figure 1 of Kawaguchi and Yukutake (2014), cesium-134 and cesium-137 scattered from Fukushima Daiichi Nuclear Power Station have formed hot spots in areas of 20 to 50 km and 100 km to 200 km from Shinagawa Station and reduced nearby residential price.

This study investigated whether the benefits of the LCS, a high-speed railway in Japan scheduled to open in 2027, were capitalized in land prices immediately after the announcement of the construction decision. We found that residential land prices in the area that reduced the time distance to the Tokyo metropolitan area rose, except in the area where the population is decreasing. This result implies that benefits are capitalized in land prices when there is demand for time distance shortening immediately after the information disclosure.

This study confirmed that estimation problems such as location selection bias and the timing of the treatment must be addressed in impact evaluations. Because the construction of infrastructure is always accompanied by location selection bias, the estimation results in many cases can be overestimated if not carefully controlled for. The findings of this study indicated that sample selection bias may occur when samples are concentrated spatially, even when exploiting a geographical experiment for location selection. Furthermore, the presented findings also indicated the difficulty interpreting the estimation results without considering the starting timing of the treatment. In particular, this problem is serious when the outcome is a stock price and the theoretical background of the analysis is consumer utility maximization. Although infrastructure construction takes a long time, rational consumers take action when construction information is disclosed if its effect is obvious. If the analysis had focused only on the timing after the construction information was disclosed (i.e., a comparative analysis of before and after starting the railway service), it could not have measured the direct effect of the railway.

Two future works are proposed from the findings of this study. The first is to examine changes in the land prices from the disclosure of the construction information to the opening of the LCS. If the time-shortening effect of the LCS is all capitalized immediately after the disclosure, land price changes thereafter would be dependent on the discount rate and additional urban development. At the very least, land prices in Nagoya and Kanagawa have not tended to keep rising since 2013 (Figure 3). The second is to examine how much demand rising land prices need. This is an important issue in determining the burden of construction costs. If there is no demand or demand cannot be created, it would be preferable not to build a station, or the entire infrastructure.

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Table 1. Descriptive Statistics

	Treatment Group						
Station / (City)*[1]	Shinagawa	(Hashimoto)	(Kofu)	(Iida)	(Nakatsugawa)	Nagoya	Control group/participants
Prefecture	Tokyo	Kanagawa	Yamanashi	Nagano	Gifu	Aichi	
Land Price (yen/m2)							
Land Price (before)	428780	104433	49724	49783	56110	150651	100579
	(1419431)	(54384)	(29519)	(45182)	(25857)	(361691)	(505557)
Land Price (after)	385811	97537	44102	43255	49242	137822	89865
	(1240708)	(52616)	(26023)	(37511)	(21010)	(297479)	(443542)
Characteristics							
Time distance to Tokyo Station		102	173	242	243	219	255
(minutes)		(31)	(25)	(40)	(45)	(66)	(90)
Time distance to Tokyo Station		92	114	155	180	185	341
using Linear motor car (minutes)		(32)	(30)	(25)	(47)	(67)	(219)
Shortened time distance to Tokyo Station		10	59	87	63	34	-87
by Linear motor car (minutes)		(8.4)	(37)	(57)	(28)	(6)	(204)
Time distance to Nagoya Station	191	188	239	213	133		260
(minutes)	(64)	(47)	(43)	(35)	(45)		(97)
Time distance to Nagoya Station	155	119	110	117	112		312
using Linear motor car (minutes)	(62)	(32)	(30)	(25)	(47)		(190)
Shortend time distance to Nagoya Station	36	69	129	97	21		-52
by Linear motor car (minutes)	(10)	(20)	(61)	(51)	(22)		(178)
Distance to	1.7	2.7	2.7	1.6	2.8	1.8	2.8
the nearest station (km)	(2.0)	(2.6)	(3.6)	(1.5)	(2.7)	(3.2)	(6.1)
Distance to the nearest	80.5	28.2	36.7	77.2	72.5	147.8	449.6
Linear Station (km)	(109.2)	(34.2)	(39.0)	(34.9)	(51.9)	(104.3)	(332.5)
Acreage	359	443	372	300	296	457	391
	(1599)	(1979)	(300)	(163)	(242)	(3696)	(983)
Building coverage ratio	62	55	61	64	64	63	63
	(12)	(12)	(13)	(10)	(9)	(10)	(11)
Floor-area ratio	237	159	198	221	222	224	220
	(152)	(81)	(93)	(105)	(94)	(119)	(120)
Maching							
Population	251983	235919	107630	112347	64165	174065	191186
	(204635)	(178032)	(84292)	(93787)	(42810)	(135663)	(153685)
Population density_per_km2	6639	2926	541	257	322	3611	1614
	(5992)	(2327)	(404)	(115)	(912)	(3806)	(2346)
Population ratio of over 65	21.24	20.89	24.33	25.84	28.41	22.82	24.25
	(3.47)	(2.56)	(4.40)	(2.66)	(3.48)	(3.93)	(4.80)
Population trends	2.82	1.36	-1.50	-1.25	-4.00	0.45	-0.93
from 2005 to 2010	(4.79)	(2.40)	(2.84)	(2.34)	(2.46)	(3.94)	(3.93)
office number	11575	12804	5924	5968	3907	8073	9205
	(10058)	(9187)	(5134)	(5413)	(2665)	(6907)	(7653)
number of the employees	145669	143660	54535	55433	31784	86764	95992
	(183551)	(100408)	(49008)	(51378)	(24313)	(83546)	(85437)
Observations	35160	2224	1255	928	272	45920	47984

Notes: Standard deviation in parentheses. *1; This line reports the station name. If the station name is undecided, the cell reports the name of the city that the station will be built in.

Table 2. Propensity Score Estimation using logit model

	Tokyo		Kanagawa		Yamanashi		Nagano		Gifu		Nagoya	
Acreage	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)	-0.001	(0.000)	-0.001	(0.001)	0.000	(0.000) *
Buildingtolandratio	-0.004	(0.003)	-0.041	(0.008) ***	0.007	(0.012)	-0.008	(0.015)	-0.006	(0.027)	0.006	(0.003) **
Floorarearatio	-0.001	(0.000) *	-0.003	(0.001) **	-0.001	(0.002)	0.000	(0.002)	0.000	(0.003)	-0.001	(0.000) *
Water works Dummy	0.136	(0.239)									0.616	(0.247) **
Sewage works Dummy	-0.115	(0.065) *	-0.066	(0.171)	0.180	(0.199)	2.909	(0.721) ***	2.022	(0.742) ***	-0.450	(0.052) ***
City Gas Dummy	-0.169	(0.052) ***	-1.381	(0.139) ***	-0.902	(0.200) **	-0.569	(0.235) **	-2.272	(0.758) ***	0.404	(0.045) ***
LandPrice / 10000 in 2008	0.033	(0.014) **	-0.466	(0.165) ***	-0.311	(0.944)	1.747	(0.883) **	-0.813	(1.050)	-0.041	(0.014) ***
LandPrice / 10000 in 2009	-0.041	(0.013) ***	0.231	(0.178)	-0.417	(1.778)	-7.020	(2.613) ***	0.288	(1.757)	0.054	(0.023) **
LandPrice / 10000 in 2010	-0.009	(0.016)	-0.196	(0.198)	-0.328	(1.816)	9.069	(3.304) ***	-1.068	(2.248)	-0.010	(0.025)
LandPrice / 10000 in 2011	0.020	(0.013)	0.499	(0.182) ***	1.098	(0.966)	-3.823	(1.466) ***	1.733	(1.365)	-0.002	(0.013)
Population / 1000000	0.568	(0.035) ***	-0.304	(0.066) ***	-4.777	(0.402) ***	-2.689	(0.718) ***	-5.826	(1.077) ***	0.075	(0.031) **
Population density_per_km2 / 1000000	25.21	(0.875) ***	3.299	(2.890)	-74.46	(15.65) ***	-482.20	(60.43) ***	-55.04	(41.11)	20.12	(0.822) ***
Population ratio of over 65	0.041	(0.008) ***	-0.215	(0.028) ***	-0.326	(0.032) ***	0.017	(0.044)	-0.103	(0.064)	-0.009	(0.008)
Population trends from 2005 to 2010	0.106	(0.009) ***	-0.109	(0.030) ***	-0.049	(0.033)	0.367	(0.046) ***	-0.074	(0.088)	0.045	(0.009) ***
Office number / 1000000	-28.03	(1.375) ***	-11.49	(4.327) ***	228.54	(16.87) ***	148.82	(20.10) ***	269.28	(38.06) ***	-5.525	(1.406) ***
Number of employees / 1000000	1.077	(0.079) ***	1.968	(0.355) ***	-15.05	(1.476) ***	-9.693	(2.002) ***	-18.43	(3.454) ***	-0.103	(0.104)
Time Distance to the Nearest local railway station (minuts)	-0.006	(0.004)	0.005	(0.010)	-0.034	(0.015) *	-0.077	(0.029) ***	-0.023	(0.023)	-0.030	(0.004) ***
Propensity Score												
Treatment group	0.633	(0.281)	0.155	(0.145)	0.172	(0.171)	0.165	(0.136)	0.153	(0.241)	0.576	(0.185)
Control Group/Participants	0.302	(0.184)	0.042	(0.062)	0.024	(0.046)	0.017	(0.043)	0.005	(0.014)	0.431	(0.161)
Number of obs.	12940		7378		7231		7168		7068		14321	
Treated obs.	5842		349		202		139		39		7223	
Pseudo R2	0.2697		0.187		0.271		0.328		0.325		0.1095	

Notes : Standard error in parentheses. The Number of observations in square brackets. *, **, *** denote significance at the 10, 5 and 1% levels, respectively.

Table 3. ATT of transportation innovation on residential land price: estimates on whole sample

	DID	Fixed Effect DID	Fixed Effect DID (0.1<=PS<=0.9)	DID (IPW: 0.1<=PS<=0.9)	NNM with Caliper(.01)
	(1)	(2)	(3)	(4)	(5)
treatD	0.0229 **	0.0381 ***	0.0355 ***	0.0118 ***	0.0087 ***
	(0.0073)	(0.0012)	(0.0013)	(0.0014)	(0.0016)
Other Controls	✓	✓	✓	✓	✓
Individual fixed effect		✓	✓	✓	✓
Year fixed effect	✓	✓	✓	✓	✓
Number of obs.	133951	133951	115495	115495	76392
Number of individuals		16745	14438	14438	9549
R-sq (within)	0.635	0.645	0.656	0.630	0.630

Notes : In the all column, estimation results without other controls are almost the same since the individual fixed effect mostly control the time-invariant factors. Robust standard error in parentheses. *, **, *** denote significance at the 10, 5 and 1% levels, respectively.

Table 4. ATT of transportation innovation on residential land price by station

	DID	Fixed Effect DID	Fixed Effect DID (0.1<=PS<=0.9)	Fixed Effect DID (IPW: 0.1<=PS<=0.9)	NNM with Caliper(.01)
	(1)	(2)	(3)	(4)	(5)
Tokyo	0.0251 **	0.0326 ***	0.0258 ***	-0.0055 ***	-0.0044 **
	(0.0099)	(0.0015)	(0.0017)	(0.0020)	(0.0022)
	[83144]	[83144]	[70728]	[70728]	[38344]
Kanagawa	0.0252	0.0414 ***	0.0180 ***	0.0143 ***	0.0100 *
	(0.0184)	(0.0031)	(0.0044)	(0.0049)	(0.0057)
	[50208]	[50208]	[5648]	[5648]	[4200]
Yamanashi	0.0015	0.0038	-0.0022	-0.0069	-0.0035
	(0.0223)	(0.0044)	(0.0070)	(0.0072)	(0.0077)
	[49239]	[49239]	[3520]	[3520]	[2271]
Nagano	0.0022	-0.0086 *	-0.0133	-0.0200 **	-0.0041
	(0.0277)	(0.0048)	(0.0084)	(0.0083)	(0.0096)
	[48912]	[48912]	[2432]	[2432]	[1704]
Gifu	0.0129	0.0091	-0.0733 ***	-0.0866 ***	0.0495 **
	(0.0625)	(0.0130)	(0.0246)	(0.0273)	(0.0200)
	[48256]	[48256]	[240]	[240]	[448]
Nagoya	0.0300 ***	0.0445 ***	0.0443 ***	0.0173 ***	0.0187 ***
	(0.0074)	(0.0014)	(0.0014)	(0.0016)	(0.0017)
	[93904]	[93904]	[91456]	[91456]	[62264]

Notes : Robust standard error in parentheses. The Number of observations in square brackets. *, **, *** denote significance at the 10, 5 and 1% levels, respectively.

Table 5. Correlation coefficients between distance to Linear station and time distance shortening

	Tokyo	Kanagawa	Yamanashi	Nagano	Gifu	Nagoya
Time distance shortening to Tokyo		-0.122	-0.621	-0.822	-0.361	-0.564
Time distance shortening ratio to Tokyo		-0.336	-0.712	-0.846	-0.795	-0.849
Time distance shortening to Nagoya	0.392	0.643	-0.712	-0.852	-0.142	
Time distance shortening ratio to Nagoya	-0.594	-0.165	-0.594	-0.900	-0.548	

Notes : Time distance shortening ratio is calculate from (Time distance shortenin)/(Time distance)

Table 6. ATT of transportation innovation on residential land price by station & distatnce

	Tokyo		Kanagawa		Yamanashi		Nagano		Gifu		Nagoya	
IPW												
whitin 20km	-0.0064		0.0101	**	0.0125		0.0165		-		0.0382	***
	(0.0111)		(0.0051)		(0.0106)		(0.0222)		-		(0.0040)	
	[1912]		[3192]		[1344]		[208]		-		[11544]	
20km ~ 50km	-0.0248	***	0.0279	***	0.0386		0.0141		-0.0012		0.0206	***
	(0.0022)		(0.0097)		(0.0253)		(0.0165)		(0.0375)		(0.0032)	
	[15384]		[1168]		[408]		[104]		[48]		[19200]	
50km ~ 100km	-0.0135	***	-0.0404	*	0.0311		-0.0110		0.0436		0.0303	***
	(0.0028)		(0.0155)		(0.0218)		(0.0118)		(0.0376)		(0.0054)	
	[28640]		[272]		[344]		[896]		[64]		[11088]	
100km ~ 200km	-0.0245	***	0.0070		0.0283		-0.0538	**	-0.2004	***	0.0022	
	(0.0066)		(0.0272)		(0.0098)		(0.0167)		(0.0297)		(0.0019)	
	[12848]		[256]		[34]		[80]		[56]		[55960]	
NNM with Caliper(.01)												
whitin 20km	-0.0192	**	0.0076		-0.0075		0.0460		0.0415	*	0.0431	***
	(0.0089)		(0.0061)		(0.0133)		(0.0391)		(0.0209)		(0.0045)	
	[1304]		[2448]		[792]		[152]		[128]		[5816]	
20km ~ 50km	-0.0041		0.0235	***	-0.0104		0.0060		0.0849	*	0.0191	***
	(0.0030)		(0.0086)		(0.0245)		(0.0236)		(0.0402)		(0.0030)	
	[9024]		[1112]		[376]		[176]		[72]		[11624]	
50km ~ 100km	-0.0093	***	-0.0178		0.0111		-0.0067		0.0985		0.0368	***
	(0.0032)		(0.0159)		(0.0122)		(0.0131)		(0.0548)		(0.0043)	
	[13776]		[400]		[720]		[832]		[56]		[7016]	
100km ~ 200km	-0.0298	***	-0.0150		-0.0165		-0.0103		0.0002		0.0056	**
	(0.0046)		(0.0222)		(0.0378)		(0.0191)		(0.0470)		(0.0023)	
	[8416]		[272]		[79]		[320]		[112]		[26496]	

Notes : Robust standard error in parentheses. The Number of observations in square brackets. *, **, *** denote significance at the 10, 5 and 1% levels, respectively.

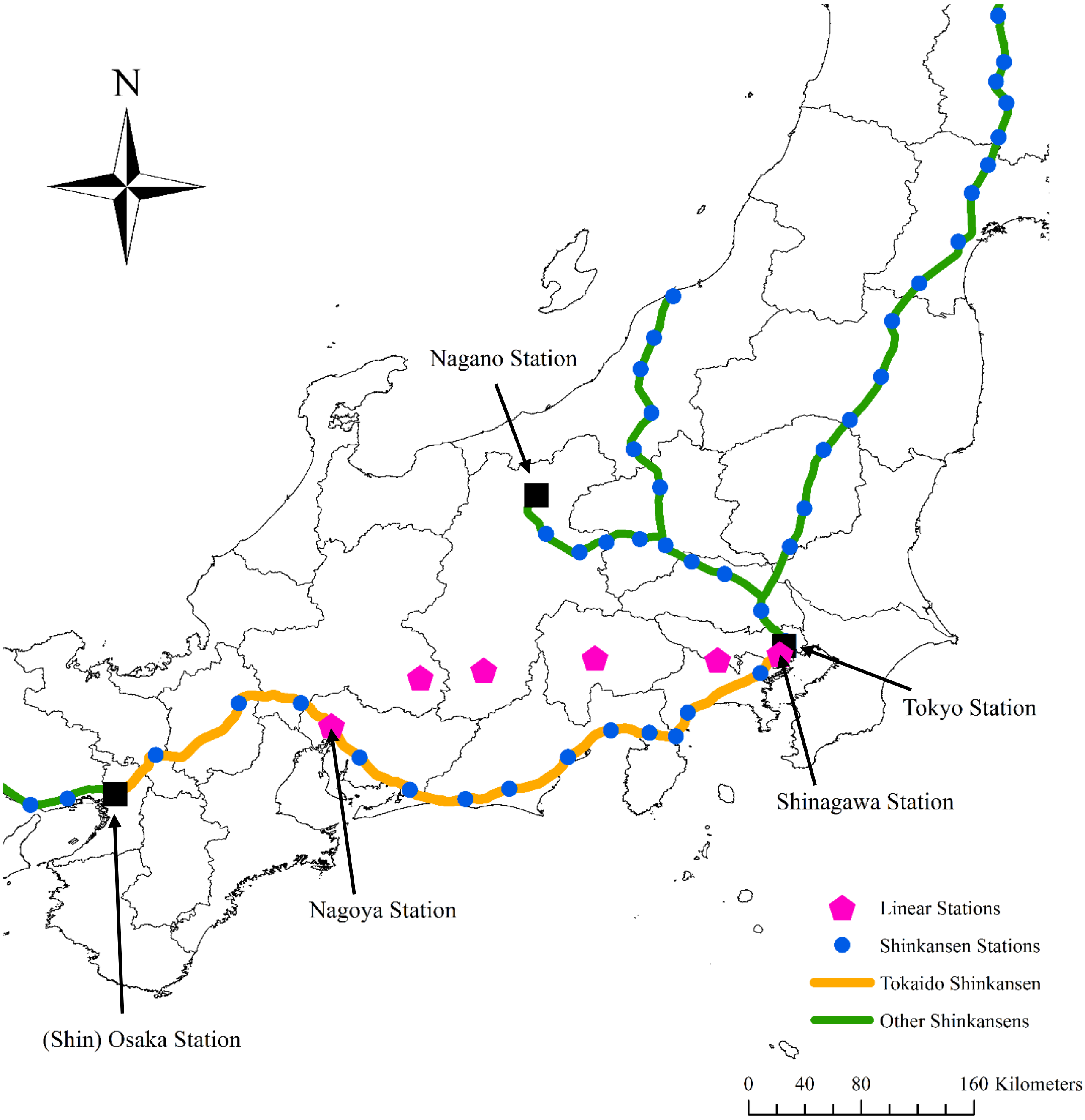

Fig. 1. Shinkansen stations in Japan

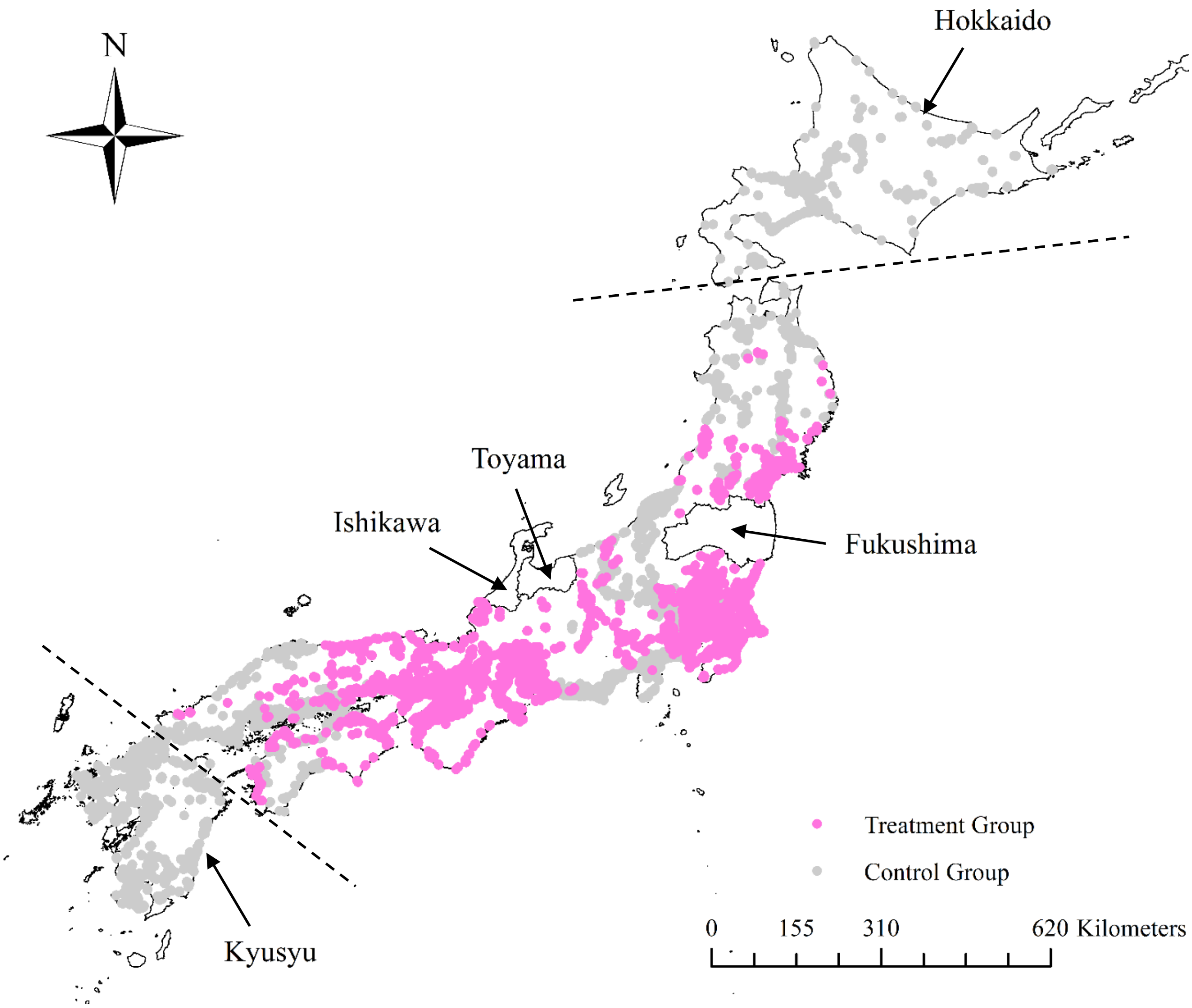

Fig. 2. Treatment Group and Control Group/Participants

Note: Fukushima, Toyama, Ishikawa, and Okinawa prefectures are dropped in all analyses. Hokkaido prefecture and the Kyusyu area are dropped in the analysis of the robustness checks.

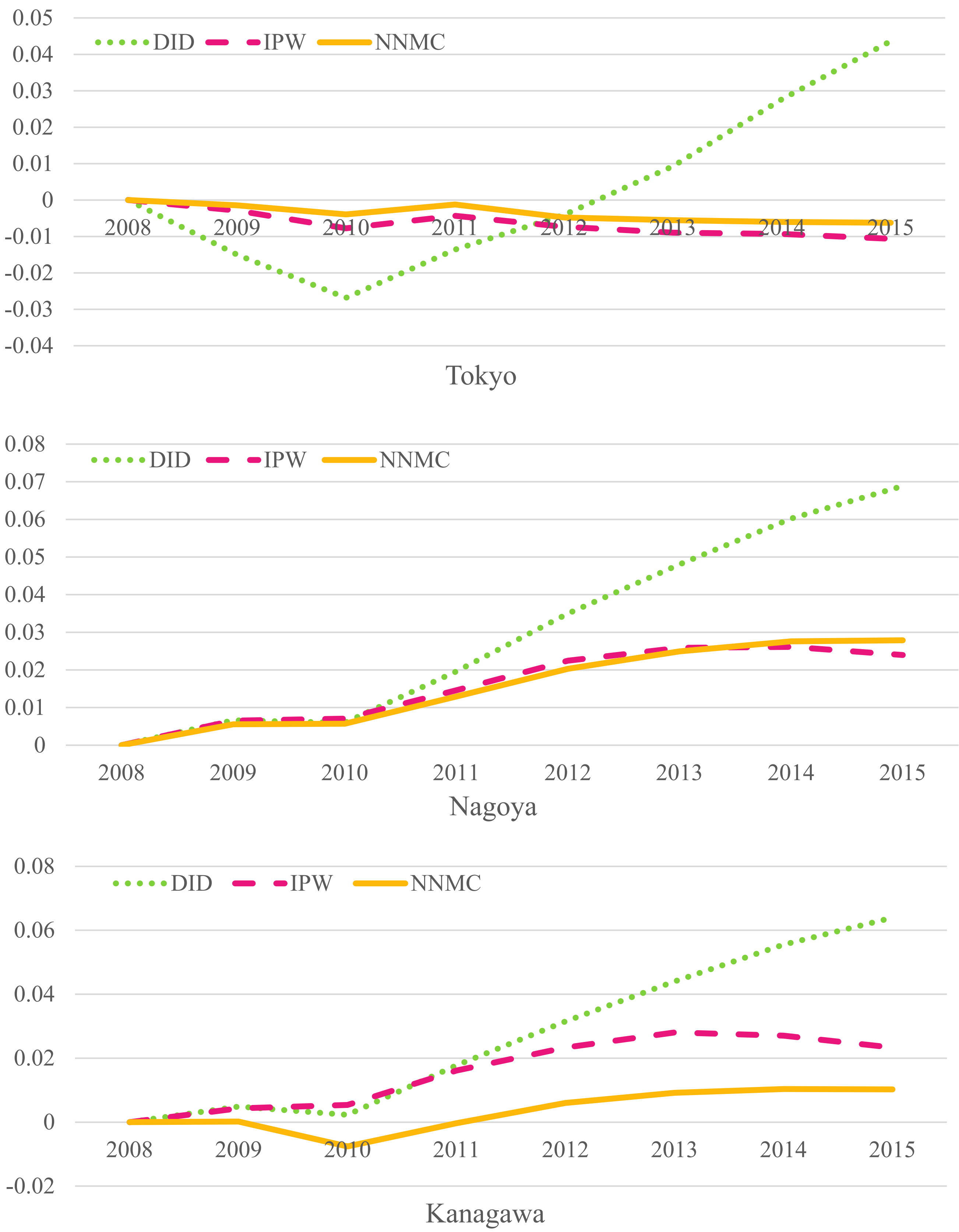

Fig. 3. Land Price Changes by Year based on 2008 Prices

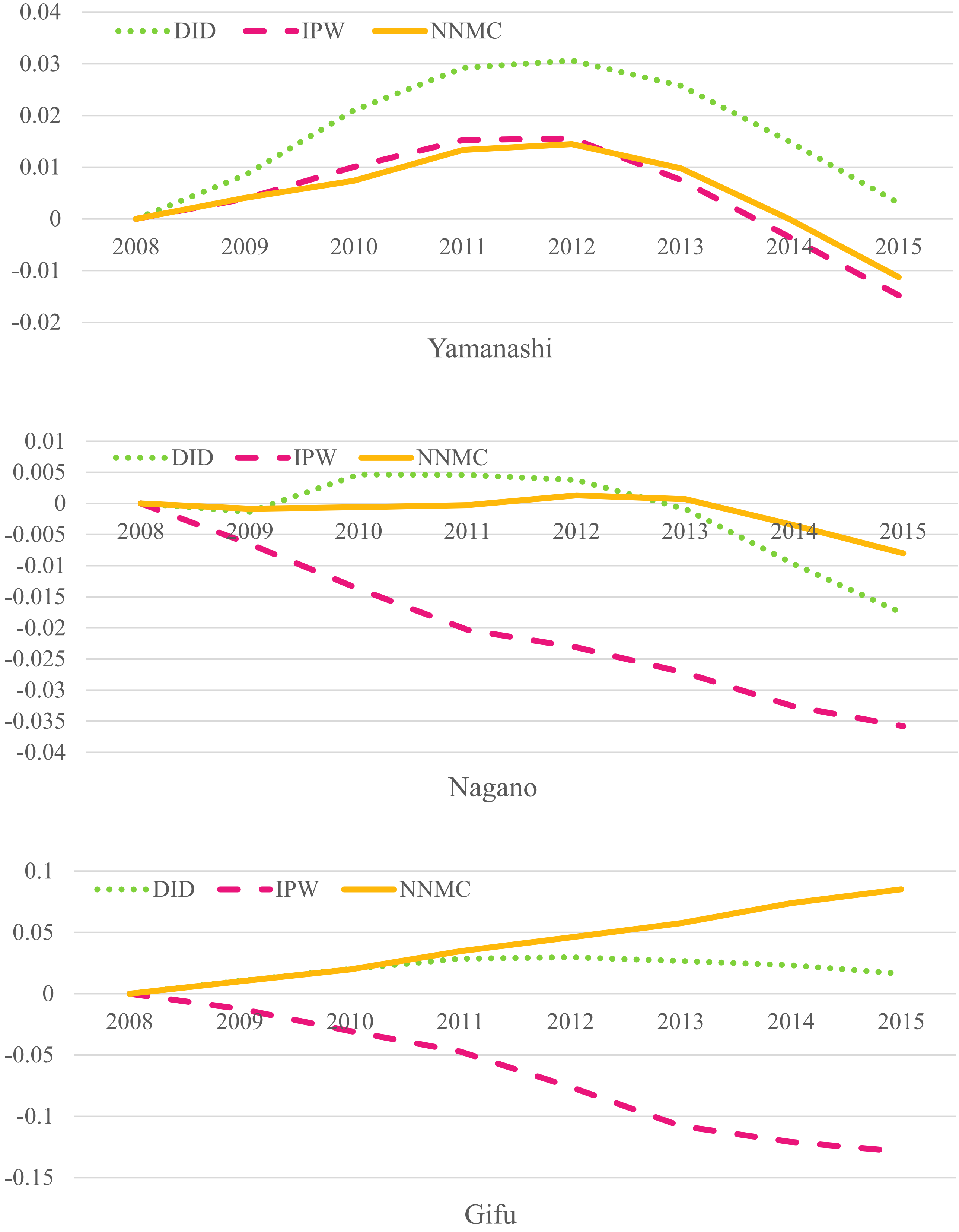

Fig. 3. (cont.) Land Price Changes by Year based on 2008 Prices

Table A1. Variable Definisitons

Variables	Description	Source
Dependent variable		
Land Price	Assested land price . The unit is "Yen"	Publication of Land Price Data
Land Characteristics		
Time distance to Tokyo Station (minutes)	Time distance to the nearest station(NS) + Time distance to Tokyo station from NS	Rail line time-series data, Digital Road Map, YAHOO! JAPAN route information
Time distance to Tokyo Station using Linear motor car (minutes)	Time distance to the nearest Linear station(NLS) + Time distance to Tokyo station from NLS	ditto
Time distance to Nagoya Station(minutes)	Time distance to the nearest station(NS) + Time distance to Nagoya station from NS	ditto
Time distance to Nagoya Station using Linear motor car (minutes)	Time distance to the nearest Linear station(NLS) + Time distance to Nagoya station from NLS	ditto
Distance to the nearest station (km)	Euclidean distance to NS	Rail line time-series data
Distance to the nearest Linear Station (km)	Euclidean distance to NLS	(Created from materials of JR Tokai)
Acreage	Area of the land with the survey point. The unit is "m 2".	Publication of Land Price Data
Building coverage ratio	Ratio of coverage area of building to lot area. Units in "%" (Land regulations)	ditto
Floor-area ratio	Units are "%" (Land regulations)	ditto
Region attributes		
Population	Population of municipality with survey point	Population Ceusus 2010
Population density_per_km2	Population density of municipality with survey point	ditto
Population ratio of over 65	Ratio of people aged 65 or over of the municipality with the survey point	ditto
Population trends from 2005 to 2010	Population growth rate of municipality from 2005 to 2010 with the survey point	ditto
Office number	Number of establishments of municipality with survey point	Economic Census for Business Frame 2006
Number of the employees	Number of the employees of municipality with survey point	ditto

Note: Publication of Land Price Data and Rail line time-series data can be downloaded in National Land Numerical Information download service. There are strong restrictions on the use of digital data sets of Digital Road Map and YAHOO! JAPAN route information. Population Census and Economic Census for Business Frame can be downloaded from Statistics Bureau web site.

Table A2. time distance to metropolitan Stations by Linear stations (minuts)

	to Tokyo Station	to Nagoya Station
Shinagawa	16	47
(Kanagawa)	57	88
(Yamanashi)	74	74
(Nagano)	91	57
(Gifu)	106	42
Ngoya	63	0

Notes : In parentheses of the intermediate stations, it is entered the name of the city that the station is buil.

Table A3. Covariate imbalance test using NNMC sample

	Tokyo		Kanagawa		Yamanashi		Nagano		Gifu		Nagoya	
	Unmatched	Matched	Unmatched	Matched	Unmatched	Matched	Unmatched	Matched	Unmatched	Matched	Unmatched	Matched
Acreage	-1.4	-0.1	-0.1	3.6	-3.7	2.1	-11.6	0.1	-11.1	1.0	1.7	1.6
Buildingtolandratio	-7.0 ***	-1.9	-68.7 ***	-4.8	-7.7	-9.0	0.0	-4.6	5.3	-2.4	1.8	2.6
Floorarearatio	8.6 ***	-1.8	-61.1 ***	-1.9	-19.7 **	-5.4	-4.2	2.2	-1.6	5.1	1.5	2.5
Water works Dummy	5.1 ***	0.0									8.2 ***	0.8
Sewage works Dummy	20.8 ***	-1.0	2.8	6.6	-7.3	-1.5	54.7 ***	-2.9	37.2 *	-10.2	4.0 **	2.2
City Gas Dummy	43.4 ***	-0.7	-29.1 ***	2.5	-58.9 ***	0.0	-53.9 ***	1.7	-116.8 ***	-7.8	38.7 ***	-2.1
LandPrice in 2008	30.6 ***	-0.3	0.0	-0.5	-14.7	0.1	-14.8	0.7	-13.4	1.0	11.3 ***	2.1
LandPrice in 2009	29.6 ***	-0.3	0.5	-0.5	-14.3	0.1	-14.5	0.7	-13.0	1.0	11.4 ***	2.0
LandPrice in 2010	31.8 ***	-0.3	1.3	-0.8	-15.7	0.1	-16.1	0.8	-14.2	1.3	12.7 ***	2.1
LandPrice in 2011	32.3 ***	-0.2	1.9	-0.7	-15.7	0.1	-16.1	0.8	-14.2	1.5	13.2 ***	2.1
Population	34.4 ***	0.9	23.8 ***	-0.2	-67.8 ***	6.2	-63.1 ***	-0.1	-115.3 ***	-0.2	-13.4 ***	6.0 ***
Population density_per_km2	112 ***	-2.0	51.3 ***	-10.1	-66.6 ***	1.5	-83.7 ***	-2.3	-76.4 ***	-3.2	64.4 ***	2.1
Population ratio of over 65	-69.3 ***	-0.4	-77.9 ***	0.8	6.0	8.6	42.5 ***	16.9	103.8 ***	-21.7	-33.7 ***	-2.0
Population trends from 2005 to 2010	85.5 ***	-0.2	66.2 ***	-2.2	-21.2 ***	-4.1	-11.7	-18.9	-97.5 ***	23.4	36.3 ***	0.1
Office number	27.1 ***	0.5	35.8 ***	-0.6	-50.0 ***	8.7	-48.1 ***	1.6	-95.6 ***	1.7	-17.3 ***	7.0 ***
Number of employees	34.9 ***	0.2	45.2 ***	-0.5	-59.6 ***	7.4	-57.3 ***	1.6	-105 ***	4.0	-12.3 ***	6.9 ***
Time Distance to the Nearest local railway station (minutes)	-25.5 ***	-2.0	0.9	1.6	-3.1	6.3	-14.8	-0.7	-4.7	-0.5	-24.5 ***	-2.1

Notes: Standard error in parentheses. The Number of observations in square brackets. *, **, *** denote significance at the 10, 5 and 1% levels, respectively.

Table A4. ATT of transportation innovation on residential land price by station: estimates except Hokkaido

	DID	Fixed Effect DID	Fixed Effect DID (0.1<=PS<=0.9)	IPW (0.1<=PS<=0.9)	NNM with Caliper(.01)
Tokyo	0.0235 **	0.0287 ***	0.0225 ***	-0.0069 ***	-0.0096 ***
	(0.0097)	(0.0015)	(0.0018)	(0.0021)	(0.0024)
	[74096]	[74096]	[61520]	[61520]	[34664]
Kanagawa	0.0250	0.0375 ***	0.0151 ***	0.0139 ***	0.0023
	(0.0170)	(0.0031)	(0.0042)	(0.0053)	(0.0057)
	[41160]	[41160]	[5944]	[5944]	[4072]
Yamanashi	-0.0036	-0.0023	0.0071	0.0022	-0.0001
	(0.0241)	(0.0043)	(0.0060)	(0.0063)	(0.0073)
	[40399]	[40399]	[4287]	[4287]	[2743]
Nagano	0.0019	-0.0126 ***	0.0142 *	-0.0004	-0.0098
	(0.0276)	(0.0048)	(0.0076)	(0.0074)	(0.0091)
	[39864]	[55712]	[2896]	[2896]	[1648]
Gifu	0.0125	0.0051	-0.0495 *	-0.0550 *	0.0520 ***
	(0.0632)	(0.0130)	(0.0246)	(0.0242)	(0.0191)
	[39208]	[39208]	[360]	[360]	[440]
Nagoya	0.0264 ***	0.0407 ***	0.0410 ***	0.0132 ***	0.0170 ***
	(0.0071)	(0.0015)	(0.0015)	(0.0017)	(0.0019)
	[84856]	[84856]	[82272]	[82272]	[55608]

Notes : Robust standard error in parentheses. The Number of observations in square brackets. *, **, *** denote significance at the 10, 5 and 1% levels, respectively.

Table A5. ATT of transportation innovation on residential land price by station: estimates except Kyusyu

	DID	Fixed Effect DID	Fixed Effect DID (0.1<=PS<=0.9)	IPW (0.1<=PS<=0.9)	NNM with Caliper(.01)
Tokyo	0.0285 **	0.0364 ***	0.0314 ***	0.0047 **	-0.0052 **
	(0.0110)	(0.0017)	(0.0019)	(0.0021)	(0.0024)
	[68776]	[68776]	[56984]	[56984]	[33880]
Kanagawa	0.0292	0.0452 ***	0.0214 ***	0.0140 ***	0.0084
	(0.0196)	(0.0032)	(0.0043)	(0.0047)	(0.0058)
	[35840]	[35840]	[6504]	[6504]	[3960]
Yamanashi	0.0039	0.0054	0.0135 **	0.0037	-0.0056
	(0.0249)	(0.0044)	(0.0063)	(0.0068)	(0.0081)
	[35079]	[35079]	[4837]	[4837]	[2511]
Nagano	0.0033	-0.0050	-0.0021	-0.0159 *	-0.0117
	(0.0285)	(0.0048)	(0.0079)	(0.0085)	(0.0094)
	[34544]	[34544]	[2600]	[2600]	[1608]
Gifu	0.0138	0.0130	-0.0913 ***	-0.1023 ***	0.0542 **
	(0.0636)	(0.0130)	(0.0260)	(0.0298)	(0.0208)
	[33888]	[33888]	[280]	[280]	[432]
Nagoya	0.0327 ***	0.0483 ***	0.0496 ***	0.0263 ***	0.0183 ***
	(0.0088)	(0.0016)	(0.0017)	(0.0017)	(0.0020)
	[79536]	[79536]	[75792]	[75792]	[49704]

Notes: Robust standard error in parentheses. The Number of observations in square brackets. *, **, *** denote significance at the 10, 5 and 1% levels, respectively.

Table A6. ATT of transportation innovation on residential land price by station and time distance shortening

	Tokyo		Kanagawa		Yamanashi		Nagano		Gifu		Nagoya	
IPW (0.1<=PS<=0.9)												
4Q	-0.0279	***	0.0187	**	-0.0036		0.0083		-0.0227	*	0.0231	***
	(0.0032)		(0.0080)		(0.0141)		(0.0129)		(0.0125)		(0.0028)	
	[33168]		[768]		[592]		[536]		[96]		[30760]	
3Q	-0.0305	***	0.0163		0.0057		-0.0330		-0.0310		0.0306	***
	(0.0025)		(0.0105)		(0.0132)		(0.0217)		(0.0273)		(0.0030)	
	[12128]		[784]		[712]		[312]		[40]		[26832]	
2Q	-0.0285	***	-0.0266	***	0.0235		-0.0257	*	-0.0127		-0.0181	***
	(0.0028)		(0.0053)		(0.0177)		(0.0145)		(0.0627)		(0.0023)	
	[10152]		[752]		[536]		[376]		[32]		[24032]	
1Q	-0.0090	***	0.0012		0.0410		-0.0078		-		0.0032	
	(0.0030)		(0.0173)		(0.0375)		(0.0244)		-		(0.0028)	
	[10720]		[608]		[80]		[416]		-		[21312]	
NNM with Caliper(.01)												
4Q	-0.0239	***	-0.0068		-0.0030		0.0328		0.0406		0.0083	***
	(0.0035)		(0.0111)		(0.0187)		(0.0199)		(0.0279)		(0.0030)	
	[16672]		[832]		[472]		[376]		[96]		[16080]	
3Q	-0.0137	***	0.0179		0.0159		0.0071		0.0547	**	0.0352	***
	(0.0034)		(0.0117)		(0.0172)		(0.0176)		(0.0227)		(0.0032)	
	[7488]		[904]		[504]		[440]		[128]		[13720]	
2Q	-0.0145	***	-0.0060		-0.0174		0.0227		-0.0451		-0.0033	
	(0.0040)		(0.0091)		(0.0152)		(0.0198)		(0.0598)		(0.0024)	
	[7192]		[1184]		[538]		[288]		[32]		[15640]	
1Q	0.0014		-0.0023		0.0201		0.0054		0.0463	**	0.0213	***
	(0.0047)		(0.0126)		(0.0123)		(0.0202)		(0.0202)		(0.0033)	
	[7024]		[928]		[605]		[504]		[152]		[11800]	

Notes : The grouping of the intermediate stations is based on time distance shortening to Tokyo station. Robust standard error in parentheses. The Number of observations in square brackets. *, **, *** denote significance at the 10, 5 and 1% levels, respectively.

Table A7. ATT of transportation innovation on residential land price by station and time distance shortening ratio

	Tokyo		Kanagawa		Yamanashi		Nagano		Gifu		Nagoya	
IPW (0.1<=PS<=0.9)												
4Q	-0.0231	***	0.0333	***	-0.0003		0.0083		-0.0301	*	0.0362	***
	(0.0050)		(0.0082)		(0.0144)		(0.0129)		(0.0135)		(0.0024)	
	[4616]		[696]		[656]		[536]		[128]		[25232]	
3Q	-0.0222	***	-0.0128		-0.0043		-0.0366	*	-0.0454	*	0.0321	***
	(0.0023)		(0.0119)		(0.0144)		(0.0199)		(0.0209)		(0.0026)	
	[14624]		[688]		[584]		[400]		[56]		[35952]	
2Q	-0.0270	***	-0.0144	**	0.0164		-0.0284	*	-0.0530		-0.0196	***
	(0.0027)		(0.0063)		(0.0186)		(0.0142)		(0.0533)		(0.0025)	
	[22240]		[592]		[656]		[392]		[120]		[23904]	
1Q	-0.0153	***	0.0029		-		0.0035		-		0.0031	
	(0.0029)		(0.0203)		-		(0.0252)		-		(0.0028)	
	[33184]		[528]		-		[408]		-		[20456]	
NNM with Caliper(.01)												
4Q	-0.0019		0.0139		0.0011		0.0328		0.0153		0.0301	***
	(0.0074)		(0.0122)		(0.0206)		(0.0199)		(0.0143)		(0.0031)	
	[3104]		[632]		[384]		[376]		[128]		[13576]	
3Q	-0.0062		0.0126		-0.0185		-0.0136		0.0475		0.0338	***
	(0.0039)		(0.0094)		(0.0164)		(0.0238)		(0.0308)		(0.0032)	
	[9024]		[1096]		[560]		[328]		[96]		[17488]	
2Q	-0.0263	***	0.0036		0.0149		0.0328	*	0.0265		-0.0048	*
	(0.0036)		(0.0091)		(0.0182)		(0.0174)		(0.0485)		(0.0026)	
	[12592]		[1088]		[525]		[352]		[80]		[14104]	
1Q	-0.0098	***	0.0030		0.0246	*	0.0161		0.0258		0.0257	***
	(0.0032)		(0.0123)		(0.0131)		(0.0204)		(0.0396)		(0.0035)	
	[16272]		[992]		[674]		[472]		[104]		[11576]	

Notes : The grouping of the intermediate stations is based on time distance shotening to Tokyo station. Robust standard error in parentheses. The Number of observations in square brackets. *, **, *** denote significance at the 10, 5 and 1% levels, respectively.