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Estimating the effect of land use regulation on land price: At the kink point of building height limits in Fukuoka*

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Abstract
This study estimates the effect of land use regulation on land price by exploiting the feature of building height limits of the aviation law in Fukuoka, Japan. The law limits the height of a building that is within 4000 meters of an airport to 54.1 m, but when the distance exceeds 4000 meters, the limits are relaxed. Exploiting this regulation feature, we estimate the effect of the regulation on land price using the regression kink design. We find that building height restriction has a significantly negative effect on land price and the magnitude of the effects depends on the stringency of regulation.

Keywords: Land use regulation, Land price, Building height limits
JEL Codes: R28, R58

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1 Introduction

Land use regulations are widely adopted in many cities. These regulations aim to avoid congestion and protect the landscape. However, they prevent the land from being developed, and the land's value becomes lower than that in a laissez-faire economy (e.g., Brueckner et al., 2017; Brueckner and Singh, 2020). This is especially true in city centers, where demand for floor area is strong for both commercial and residential usage. As highlighted by (e.g., Brueckner and Sridhar, 2012), the reduced degree of development of the city centers causes spatial expansion of the city, which increases commuting costs.

However, in general, estimating the effect of land use regulation on land price is difficult in the causal sense, as reviewed by Quigley and Rosenthal (2005). First, land use regulation is not independently determined from the factors that affect land price. For instance, strong demand for land because of its attractive features increases land price, which simultaneously pushes the government to deregulate land use. Thus, to estimate the causal effect of land use regulation on land price, exogenous variation in land use regulation is necessary. Second, measures of land use regulation are difficult to quantify. In general, the local land use regulatory environment is complex, and only a few measures can be considered as strong quantitative measures of land use regulations, as reviewed by Quigley and Rosenthal (2005). An exception is the Wharton Residential Land Use Regulation Index (Gyourko et al., 2008). However, this type of index is not available outside the United States. Furthermore, it is difficult to construct finer geographic boundaries than city-level ones with this type of index. Different cities have different characteristics other than their land use regulations, and it is difficult to completely control for the confounding factors that affect both land use regulations and land prices using cross-city design analysis.

Against this background, this study estimates the effect of land use regulation on land price in the causal sense. To estimate the causal effect of land use regulations by overcoming the problem of endogeneity, we exploit the exogenous variation of the land use regulation in terms of the building height restrictions imposed by the aviation law in Fukuoka, Japan. Fukuoka, the fifth largest city in Japan, has a unique feature in building height restrictions under aviation law. In general, aviation law restricts the height of buildings in the areas surrounding an airport, but this law is not absolutely imposing because airports are usually built away from the central business districts (CBDs). However, in Fukuoka's case, the closest airport is located only 3000 m from the CBD; thus, the regulation strictly restricts the height of buildings in the city. Furthermore, the absolute level of the restriction on buildings' height differs according to their distance from the airport. Further, the absolute level of the restriction has a kink point. That is, the aviation law uniformly limits the height of buildings within 4000 m of an airport to 45 m above the elevation of the airport's representative point. However, when the distance exceeds this, the restrictions are relaxed linearly by 2% based on the distance from the airport. This implies that a building located 4,500 m from the airport can be 10 m higher than the one at the kink point. We exploit this kink point of the regulation and estimate the effect of land use regulation on land price using the regression kink design (RKD), which is widely used in policy evaluation exercises (e.g., Card et al., 2017; Simonsen et al., 2016).

The advantage of our identification strategy can be summarized as follows. First, the research design can adequately estimate the causal effect of land use regulation on land price. The characteristics and regulatory environments of the areas around the kink point of the building height limit can be considered similar because the absolute level of the building height restriction differs only by the distance from the airport. Second, our focus on land use regulation, that is, the building height limit under the aviation law, is precisely and quantitatively measurable, unlike the weak measures that have been used in previous studies (reviewed by Quigley and Rosenthal (2005)). Third, our study can estimate the effect of land use regulation on land price in the central areas of the city. Recently, there have been a substantial number of studies that estimated the effect of land use regulation on land price in the causal sense by focusing on the boundary of the regulations (e.g., Grout et al., 2011; Turner et al., 2014; Severen and Plantinga, 2018). However, most of these regulations are established at the administrative boundary level by, for example, municipalities. Therefore, these regulations' boundaries are also administrative boundaries. Thus, policies other than the land use policy would differ between municipalities, which may affect the land price. Further, a municipality's borders are generally located far from the city's center. In comparison to these studies, our study uses a boundary that is independent of the administrative boundary, and focuses on the effect of land use regulation in the central areas of the city. Fourth, (e.g., Brueckner et al., 2017) suggested that the elasticity of land price with respect to land use regulation depends on the strength of regulation relative to the level of land development under a free-market economy. In our setting, the kink point covers both the CBD and relatively rural residential areas. Thus, we can examine the effect of the strength of regulation relative to the level of land development under a free-market economy on land price elasticity by comparing the elasticity in CBD and rural residential areas under the same level of regulations.

Our study reveals the following results. First, the building height restriction is binding in the CBD in Fukuoka. Second, at 4000 m from the airport, the land price is positively and significantly kinked. The estimation result implies that the elasticity of the land price with respect to building height limits is 0.93, which is a reasonable estimate compared with former estimates (e.g., Brueckner et al., 2017). The results are robust for standard sensitivity tests for RKD and considering potential confounding factors. We also find that the elasticity of the land price with respect to building height limits depends on the strength of regulation relative to the level of land development under a free-market economy.

This study empirically demonstrates that the extent of land use regulation decreases land value within a city, in the causal sense. Brueckner et al. (2017) and Brueckner and Singh (2020) estimated the stringency of land use regulation using a cross- and within-city analysis. These studies addressed the problem of endogeneity by controlling for the zip-code fixed effects (or smaller circular-parcel fixed effects). By controlling for these detailed-area fixed effects, neighborhood characteristics were well controlled for. However, the variation of the strength of regulation within a parcel would be endogenously determined. In fact, relaxation of land use regulations, such as floor-area ratios (FAR), are often adopted at the building level. By exploiting a quasi-experimental situation, our study provides a more credible estimate of the effect of land use regulation on land price in the causal sense. Another group of studies focused on the boundary of regulation, such as boundaries of municipalities, where a different level of land use regulations (Turner et al., 2014) or spatially delineated regulations (e.g., Grout et al., 2011; Severen and Plantinga, 2018) are analyzed using a regression discontinuity design (RDD). Although these studies focus on non-central areas of the city, our study measures the effect of land use regulation in the central areas of the city, which has a larger demand for floor area. Our study is also related to the literature on the strength of regulations and housing affordability (e.g., Glaeser et al., 2005; Saiz, 2010; Albouy and Ehrlich, 2018). These studies used city-level data and documented that citywide strength of land use regulation increases housing prices in the city. However, our research estimates the local effect of the regulation, not the citywide effect. Recently, a growing number of studies have focused on the neighborhood-level regulatory differences within cities and examined their impact on the housing market (e.g., Kulka, 2019; Song, 2021; Kulka et al., 2023). Under this research trend, this study estimates the effect of land use regulations on land prices, focusing on differences in local regulations within a city.

The remainder of this paper is organized as follows. In the next section, we introduce the institutional setting of the building height restrictions under the aviation law in Fukuoka. Section 3 presents the theoretical background. Section 4 describes our empirical strategy, and section 5 presents our data. The results are reported in section 6, along with additional results and results on sensitivity tests. Finally, 7 presents the concluding remarks.

2 Aviation Law and Land Use Regulations in Fukuoka City

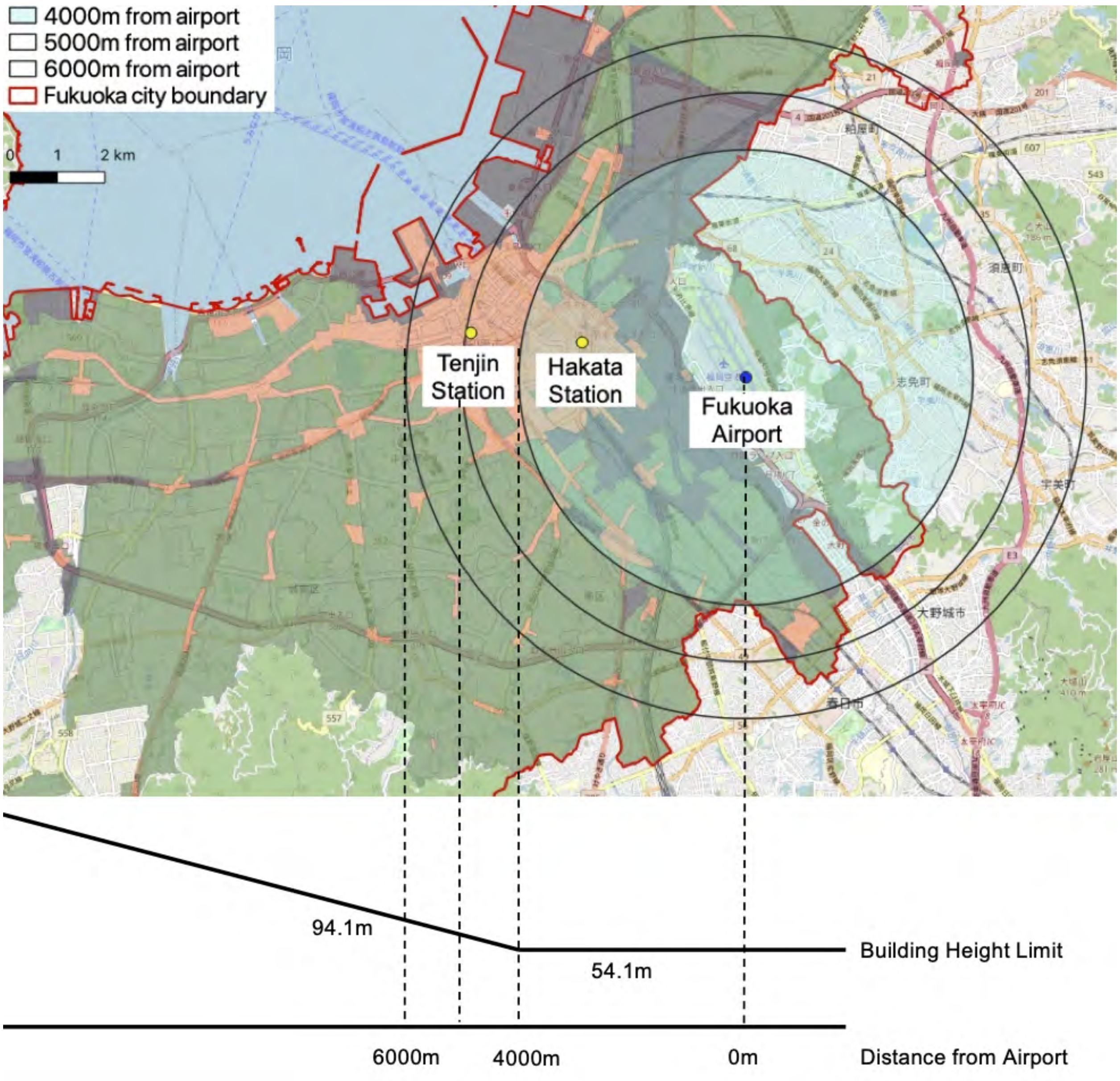
With a population of 1.5 million, Fukuoka is the fifth largest city in Japan. In 2018, the nominal gross production was 770 billion yen ($\approx$ 7.2 billion US dollars). Fukuoka's industrial composition is concentrated in the tertiary sector; more than 90% of the city's gross output comes from this sector.

Figure 1 shows a map of Fukuoka's city center. The red line is Fukuoka's city boundary. The figure is demarcated with three different colors according to the zoning. Red marks the commercial zone, green marks the residential zone, and purple marks the other zones (e.g., manufacturing). The red-colored cluster in the center of the map represents the CBD of the city, which has two main central railway stations, namely, *Tenjin* station and *Hakata* station—represented by the yellow-colored dots. Fukuoka Airport is located east of the city's center, and its representative point is indicated by the blue dot. The airport is in close proximity to the city center, and the distance between Hakata station and the airport is only 3000 m.

In general, aviation law regulates the height of buildings around airports to ensure safe takeoff and landing. It uniformly limits the height of buildings within 4000 m of an airport to 45 m above the elevation above sea level of the airport's reference point.[1] When the distance from the airport exceeds 4000 m, restrictions are relaxed linearly by 2 %. That is, the building height restriction has a kink point at 4000 m from the airport. The aviation law is applicable to all Japanese airports in the same way. In most cities in Japan, the closest airports are located at a distance that is sufficiently away from the CBD; consequently, the regulation is not usually restrictive. For example, if the CBD is located 10 km from the closest airport, the building height restriction is 165 m relative to the elevation of the airport reference point. However, the closest airport to Fukuoka is located only 3000 m from Hakata station in the center of the CBD. Thus, the CBD is subject to uniform restriction ranges (within 4000 m), the kink point of the regulation (4000 m from the airport), and the relaxing regulation range. The bottom part of Figure 1 shows the regulation situation in Fukuoka. The light blue colored part of the map highlights the area that lies within the 4000 m range from the representative point of Fukuoka airport. The bottom chart of the figure represents the building height restriction according to the elevation base. The elevation of the reference point of Fukuoka airport is 9.1 m. Thus, as the bottom chart of the figure shows, the height of buildings is restricted to 54.1 m. The figure also shows that beyond this range, the building height restriction is relaxed linearly by 2%. In other words, the circumference of this circle is the kink point of the regulation. Areas at 5000 m and 6000 m from the airport

[1] Aviation law Article 49, Clause 2 and Article 56 limit the height of the building in areas surrounding an airport. The airport reference point is usually set in the center of the runway, which is also the case for Fukuoka Airport.

Figure 1: Map and building height restriction in Fukuoka city



Note: The map is based on the Open Street Map (https://www.openstreetmap.org). Zoning information, station, and airport location information was obtained from Digital National Land Information. The elevation is measured above sea level.

are depicted outside the light blue circle. As shown in the map, almost the entire central area of Fukuoka city—which is colored in red—is within the range of 6000 m from the airport and is restricted by strong building height regulations.

It is expected that this building height regulation has a substantial effect on the construction of high-rise buildings in Fukuoka. Within the uniform restriction range, the building height is restricted to 45 m relative to the elevation of the reference point of the Fukuoka airport. In general, a single-story office building is 4 m in height. Under the building height restriction, the number of stories is restricted to approximately 11, which is sufficiently restrictive for a CBD in a large city. Compared to similarly populated cities in Japan, Fukuoka has fewer high-rise buildings. For example, Kobe, which has a similar population size as Fukuoka (1.5 million), has six skyscrapers over 150 m in height, most of which are located in the CBD, whereas Fukuoka has only one skyscraper over 150 m height, which is located more than 8 km from the CBD. Moreover, Kobe has 87 buildings higher than 60 m, whereas Fukuoka has only 27. The deregulation of the building height restriction has been discussed numerous times in Fukuoka. In fact, deregulation was realized in 2011 for the reconstruction of Hakata Station building. This deregulation led to a discussion of the deregulation of the Tenjin area in 2014. Finally, areas around Tenjin station were deregulated from 2015. Following this, areas surrounding Hakata station were also deregulated in 2019. These episodes indicate that the building height restriction is binding in Fukuoka.

Figure 2 is a picture of the front area of Hakata Station. The building at the far end of the road is the station. This area is included within 4000 m from the airport; thus, the building height is uniformly limited to 54.1 m. We can see that the height of all the buildings in this area is exactly the same.

To examine if the building height restriction actually constrains the construction of tall buildings, we demonstrate the distribution of buildings according to their height based on the elevation using a wider scale. The AW3D data provided by NTT Data and RESTEC estimates the height of each building by analyzing satellite images. Using this data, we map the distribution of the buildings in Fukuoka's CBD. Unfortunately, this data are available only for 2022, and building

Figure 2: Buildings in front of Hakata station

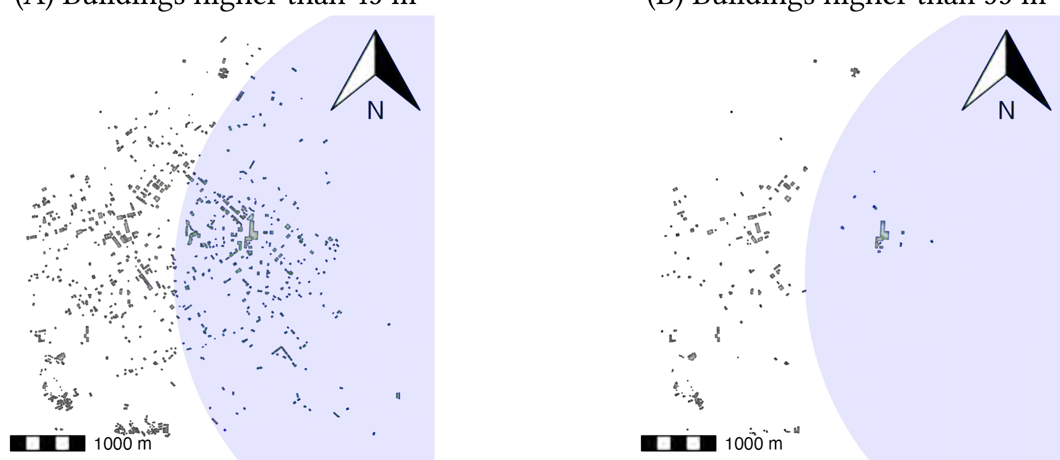
Data sources: Taken by authors. Areas within 4000 m from the airport. The building at the far end of the road is Hakata Station.

height data is not available before the deregulation. Figure 3 shows the map. The dark gray objects are buildings. The areas colored in purple are those within 4000 m of the airport, and those in white are farther than 4000 m from the airport. Figure 3 (A) shows buildings higher than 45 m, which is lower than the limit of the height of buildings within 4000 m of the airport. The density of buildings less than 45 m is similar in these areas. However, as shown in Figure 3 (B), the density of buildings higher than 55 m is different between these areas. Areas that are within 4000 m of the airport do not have buildings higher than 55 m—as the height restriction is that of 54.1 m—except surrounding areas of Hakata station, which has been deregulated in 2011 and after 2019. Meanwhile, there are many buildings over 55 m in areas that are more than 4000 m from the airport. These figures show that the building height restriction is binding in Fukuoka.

Figure 3: Building distributions in Fukuoka CBD

(A) Buildings higher than 45 m

(B) Buildings higher than 55 m



Note: The data source is AW3D, provided by NTT Data and RESTEC. Each gray rectangle represents a building that is higher than the threshold. The purple colored area represents areas less than 4000 m from Fukuoka airport. The data are from 2022, that is, after the deregulation of buildings surrounding the Hakata and Tenjin Station. The buildings higher than 55 m within 4000 m from the airport shown in Panel (B) were constructed after the deregulation in 2019.

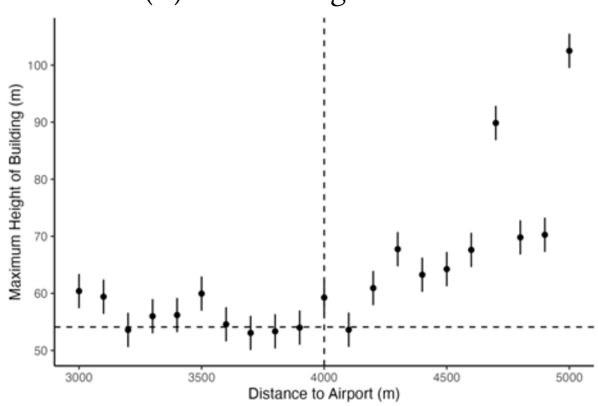
We also plot the relationship between a building's height and its distance from the airport. We make bins every 100 meters, starting from the airport. Then, we plot the relationship between the height of the tallest building in the bin and its distance from the airport. The plot is shown in Figure 4. As the available data are for the year 2022, they include buildings that were constructed after the deregulation of the building height limit after 2015. Panel A shows the plots using data for all buildings in 2022. As building height information is estimated from satellite imagery, there is a measurement error of 2-3 m. Thus, we include the 3-meter error bar in each plot. The horizontal dashed line represents the 54.1 m height, and the vertical dashed line represents 4000 m distance from the airport.

The height of buildings in most of the bins—that are within 4000 m from the airport—is almost equal to 54.1 m. Buildings taller than 54.1 m are found around 3000-3500 m point. These are buildings that were constructed after the deregulation of buildings around Hakata station in 2019. Furthermore, the height of buildings gradually increases as the distance from the airport increases beyond 4000 m. Buildings above 90 m were also constructed after 2015 as a result of deregulation in areas surrounding Tenjin station. This suggests that the building height limit is binding.

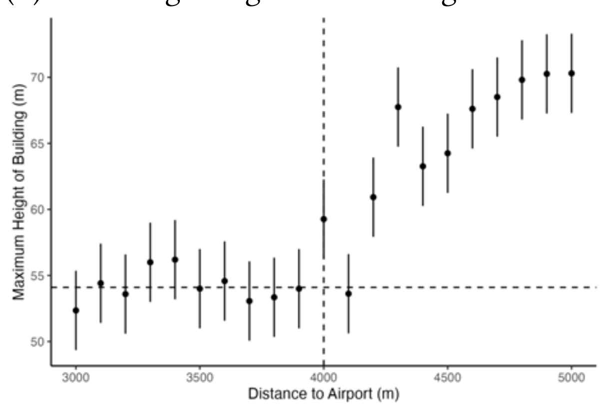
Panel B is plotted in the same manner, excluding buildings that were built after the deregulation in 2014.[2] It can be seen that within the 4000 m zone, a building's height is limited to 54.1 m, and the height gradually increases as we move beyond the 4000 m zone.

Figure 4: Building heights and distance to the airport

(A) All buildings in 2022



(B) Excluding deregulated buildings after 2014



Note: The data source is AW3D, provided by NTT Data and RESTEC. Each dot represents the height of the highest building in each 100 m bin. The bar represents 3 m, that is, the possible measurement error of building height. The horizontal dashed line represents the 54.1 m height, and the vertical dashed line represents 4000 m from the airport. Panel (A) includes all buildings in 2022. Panel (B) excludes buildings that were built after deregulation after 2014.

[2]As this data do not include the information on the construction year, we did not uniformly exclude buildings built after 2014. Based on the list of buildings constructed under the deregulation policy, we exclude buildings.

3 Theoretical Background

This section describes the theoretical background of how building height restriction affects land prices based on the standard urban land use model following Brueckner et al. (2017).

Consider land used for office or residential buildings. Let r denote the land price and p denote the price per square meter for office floors. The floor price p depends on the location attributes Z; thus, $p = p(Z)$. The supply of office floors per square meter is—as a function of investment of capital per square meter—denoted as $h(S)$, where S is capital investment per square meter, and h is a concave function satisfying $h' > 0$ and $h'' < 0$. Under this assumption, the developer's profit is described as

$$\pi = ph(S) - iS - r, \tag{1}$$

where i is the cost per unit of capital.[3] If there is no building height restriction, the developer can freely choose the optimal capital investment. We denote the optimal investment under no building height restriction as S^*. Under the assumption of the perfect competition of developers, the land price under the zero-profit condition is as follows:

$$r = ph(S^*) - iS^*. \tag{2}$$

Under the building height restriction, the height of the building and floor space supply are limited. The maximum value of $h(S)$ is denoted as $\bar{h}$, which also restricts S to $\bar{h} = h(\bar{S})$. Under the building height restriction, especially if the restriction is binding, developers set the invest-

[3]One may be concerned that a fixed cost for land development may exist, for example, the cost of assembling of land (Brooks and Lutz, 2016; Yamasaki et al., 2021). If fixed costs are present, it is possible to observe a discontinuous pattern of building construction in areas where regulations are excessively stringent and building construction is not economically viable. This is because in such areas, the marginal relaxation of the regulation can suddenly make building construction viable and lead to a discontinuous change in building height. While our data show that the building height restriction is mostly binding, it does not necessarily bind everywhere. This fixed cost issue would be one of the reasons why some buildings exist at lower heights than what the regulations stipulate. In this sense, our estimates would be a lower bound on the effect of regulation. Later in the paper, we address this issue, that is, when regulations are not necessarily restrictive everywhere, by calculating elasticity using the fuzzy RKD approach.

ment of capital as $\bar{S}$. Then, the land price is determined as follows:

$$r = ph(\bar{S}) - i\bar{S}. \tag{3}$$

The land price under the building height restriction is lower than optimal. Furthermore, we can take the derivative of the land price with respect to $\bar{S}$ as

$$\frac{\partial r}{\partial \bar{S}} = ph'(\bar{S}) - i > 0. \tag{4}$$

This implies that land prices decrease more in areas where the absolute level of building height restriction is more restrictive.

This study primarily examines the elasticity of land price with respect to the absolute value of building height limit, $\bar{h}$ denoted as $E_{r,\bar{h}}$. The elasticity of land price with respect to $\bar{h}$ differs depending on the stringency of the regulation. That is, it depends on the ratio of the optimal capital investment per square meter, S^*, and the level of the limits, $\bar{S}$, represented as follows:[4]

$$\frac{\partial E_{r,\bar{h}}}{\partial (S^*/\bar{S})} > 0. \tag{5}$$

This inequality implies that the more stringent the level of regulation than the laissez-faire level, the greater the elasticity. This predicts greater elasticity in urban central areas where higher levels of development are required to fulfill the large demand for floor areas.

In summary, building height restriction has a negative effect on land prices. The more restrictive the absolute level of building height, the more the land price decreases. Thus, it is expected that the relaxation of the building height restriction increases the land price. Furthermore, the elasticity of land price with respect to the building height restriction is greater when the level of regulation is more stringent than the laissez-faire level. In the next section, we present the empirical strategy to estimate the $E_{r,\bar{h}}$.

[4]For the derivation of the inequality, see Brueckner et al. (2017).

4 Empirical Strategy

As the theory predicts, the building height restriction negatively affects the land value by restricting the possibility of development to provide large floor spaces. However, because of the problem of endogeneity, it is difficult to empirically estimate the effect in the causal sense. The floor price depends on other location attributes, such as the distance to the CBD, and such attributes also affect the building height restriction. For example, areas close to the CBD have greater demand for land use, and the local government may deregulate the building height restrictions. In fact, a location close to the CBD tends to have a larger FAR (e.g., Brueckner and Singh, 2020). In this case, simply regressing land price on regulation cannot estimate the causal effect of the regulation.

To address this endogeneity problem, we exploit the unique features of regulation in Fukuoka. Specifically, we estimate the effect of the building height restriction using an RKD. As previously mentioned, the building height restriction in Fukuoka is constant up to 4000 m from the airport and is gradually relaxed once the distance from the airport exceeds 4000 m. As the theory suggests, if the building height limit is binding, then the height of the buildings will coincide with the maximum height of the regulation. If the regulations reduce the price of land by depreciating the possibility of development, it is likely that as the regulations are relaxed beyond the 4000 m limit, the price of land will increase. Of course, the price of land is affected by non-regulatory factors, and it is impossible to control for all price determinants, including unobservable factors, such as neighborhood environments. However, there should be no significant difference in attributes surrounding the 4000 m boundary. In fact, the attributes in the neighborhood environment should change continuously with the straddling of the 4000 m boundary. Therefore, the effect of the regulation can be precisely estimated in the causal sense using RKD.

Based on Nielsen et al. (2010) and Card et al. (2015), our empirical model can be described as a constant-effect and additive model:

$$\ln r = \tau B + g(V) + \varepsilon \tag{6}$$

where r is the land price, B is the building height restriction, V is the distance to Fukuoka airport, which directly affects the land price through continuous function $g(\cdot)$, and ε is an error term. As building height limit is determined by the distance from the airport, we assumed $B = b(V)$ as a deterministic and continuous function that has a kink at $V = 4,000$.

Under the assumption that $g(\cdot)$ and $E[\varepsilon|V = v]$ have derivatives that are continuous in v at $v = 0$, the treatment effect τ can be described as follows:

$$\tau = \frac{\lim_{v_0 \to 4000^+} \frac{dE[\ln r|V=v]}{dv}\Big|_{v=v_0} - \lim_{v_0 \to 4000^-} \frac{dE[\ln r|V=v]}{dv}\Big|_{v=v_0}}{\lim_{v_0 \to 0^+} b'(v_0) - \lim_{v_0 \to 0^-} b'(v_0)}. \tag{7}$$

The treatment effect is defined as the slope change of the conditional expectation function at the kink point over the slope change of the deterministic assignment function (i.e., relaxing the building height restriction).

As the running variable V is level, but not its logarithm form, τ is the semi-elasticity of the land price with respect to the building height limits, $\bar{h}$. To obtain the elasticity $E_{r,\bar{h}}$, we need to use the percent change of the building height restriction at the kink point as the denominator. Specifically, at the kink point, the building height is restricted to 45 m from the elevation of the reference point of the Fukuoka airport; 1 m away from the kink point, the building height limit is relaxed by 0.02 m, which is 0.044 % of the regulation height. We take the logarithm of land price as equation (6) and show that the numerator of equation (7) times 100 can be interpreted as the percent change of the land price with response to the 0.02 m relaxation of the building height limit. As the 0.02 m relaxation corresponds to a 0.044 % relaxation at the kink point, we calculated the elasticity by dividing the numerator of equation (7) times 100 by 0.044.

We estimate the treatment effect using local polynomial regressions as used in RDD. We estimate the RKD coefficient by following the standard method proposed by Cattaneo et al. (2019). Specifically, we employ local polynomial regressions with order one as the benchmark estimation. We use the optimal bandwidth by minimizing the mean squared error, and a triangular kernel for the kernel function. For statistical inference, we use robust bias-corrected standard errors. To allow for the possibility of spatial autocorrelation, we used the cluster robust standard errors by a 100 m grid cell, including the observational unit, which is defined as a 50 m $\times$ 50 m grid cell.[5]

The key assumption for the identification of RKD as satisfied, is that $B = b(V)$ is a deterministic and continuous function. As discussed in section 2, the building height restriction is determined by the distance from the airport, and the relationship between distance and the regulation is continuous and has a kink at 4000 m from the airport. Thus, the key assumption for the identification of RKD can be considered satisfied.

Another key assumption is that the building height restriction is binding. As the theory suggests, if the building height limit is binding, then the height of the building will coincide with the maximum height of the regulation. As shown in Figure 3, buildings are certainly not built according to the full regulatory limit applicable to all the locations near the kink point. Possible reasons for this include other land use regulations and differences in demand for floor space. For example, FAR regulation determines the possibility of land development. Amenity is also an important determinant of land price. Distance to the CBD also determines the demand for floor space. To control for these factors, we include the following variables as covariates in the estimation process (Calonico et al., 2019). First, to control for the land use regulations other than the building height limit imposed by the aviation law, we include the maximum permissible FAR in a grid cell. The maximum permissible FAR is designated by the Land Use Zones and common in areas in the same zoning. To capture a more geographically granular regulation situation, we also include the average road width in the grid cell as an additional covariate. The road in front of a land parcel is called the front road, and the front road width constrains permissible FAR. That is, land with a narrow front road width regulates the upper limit of FAR below the maximum permissible FAR designated by the Land Use Zones. Second, to control for the environmental amenity of the area, we include the distance to the nearest park from a grid cell. We also include the average elevation. As the building height restriction is based on the elevation of the reference

[5]For the estimation, we use the R package, `rdrobust`, developed by Calonico et al. (2015).

point of the airport, it is appropriate to control for it as a covariate. Last, to control for the distance to the CBD, we include the linear distance to the central stations of the CBD (Hakata and Tenjin stations). For identification, the additional key assumption is that the observed and unobserved covariates vary smoothly across the kink point.

Finally, building height restrictions may not necessarily bind in all areas under the restriction; as we see in Figure 3, there are locations where only buildings below the height restrictions are built, and the reasons may not necessarily be explained by observable covariates. In this case, the relationship $B = b(V)$ could deviate from the function of $b(\cdot)$. Therefore, to obtain the elasticity $E_{r,\bar{h}}$, we need to use the fuzzy RKD approach. Specifically, equation 7 must be divided by the change in actual building height at the kink point, not the change in regulation at that point (Card et al., 2017). We also calculate the elasticity $E_{r,\bar{h}}$ using the fuzzy RKD approach.

5 Data

The study area is Fukuoka city, and the 50 m $\times$ 50 m grid cell in the city is the unit of observation. In total, there are 35,617 grid cells in the study area. For land price data, we use the *rosenka* land value, which is the assessed value of land fronting roads as fixed assets published by the National Tax Administration Agency. The rosenka land value is provided by street level, which has a length of 63 m on average. To aggregate to the grid-cell level, we calculate the average price of all roads, even those partially included in each grid cell.[6] Land appraisal is conducted by prefectural governments and updated every three years. The rosenka land value is appraised by certified real estate appraisers based on the market prices of the neighborhood's comparable

[6]As the street-level data have different lengths and areas, it would be better to aggregate them to the grid-cell level than to use raw data.

land parcels.[7][8] As mentioned in Section 2, the building height restriction around Hakata station was deregulated in 2011, which was followed by a discussion on the deregulation of Tenjin area in 2015. To avoid the announcement effect of the deregulation of Tenjin area, we use street-level land price data in 2012.[9] At this period, deregulation was allowed only at the Hakata Station building. The Hakata Station building is 1000 m away from the kink point and does not play a significant role in the identification strategy. We use the price per square meter and aggregate the street-level data by taking the average in a grid cell.

We also use the maximum permissible FAR information from the urban planning map in Fukuoka city, which is obtained from Digital National Land Information provided by the Ministry of Land, Infrastructure, Transportation, and Tourism. The locations of public parks are included in the Digital National Land Information. We calculate the distance from the centroid of the grid cell to that of the park that is located closest to the grid cell. The location of the railway stations and the reference point of Fukuoka Airport are also obtained from the Digital National Land Information. We calculate the distance from the airport and other railway stations for each grid cell. We also calculate the average elevation of a grid cell, which is obtained from Digital Map (Basic Geospatial Information) provided by The Geospatial Information Authority of Japan. Further, we calculate the average road width using Digital Map (Basic Geospatial Information).

[7] There are few studies that have discussed the potential bias of the rosenka value's appraisal. Instead, there is literature on the bias of another official appraisal land value, namely, the kojichika, which is the national comprehensive land price survey and widely used in the literature (e.g., Tabuchi, 1996; Nakagawa et al., 2009; Kanasugi and Ushijima, 2018). The kojichika valuation is undertaken by the National Land Agency and is the most comprehensive land value data covering the entire area of Japan. Kojichika is also assessed by certified real estate appraisers, and there are fewer subjective land values than those in the rosenka. It is known that kojichika reflects 70-80 % of the market value, and that there is a time lag before the market value is reflected in the kojichika (e.g., Shimizu and Nishimura, 2006). The rosenka that we use in this study is set to be appraised based on the level of the kojichika of the nearest place, so they may have a similar bias as that of the kojichika. However, all the known problems associated with kojichika are caused by variations through time-series (Shimizu and Nishimura, 2006), and no significant problem has been highlighted in utilizing cross-sectional variations of the data. Note that as the appraisal of the land value is conducted by the prefectural government, the appraised value may contain biases among prefectures (Barthold and Ito, 1992; Homma and Atoda, 1991); however, because all the areas under examination in this study are included in the same prefecture, such problems can be ignored.

[8] There is a database of transaction-level land prices in Japan. However, as the number of points where actual transaction data can be observed is limited, it is not possible to secure a sufficient sample size for RKD.

[9] The deregulation in Tenjin was discussed for the first time at the Fukuoka City National Strategic Special Zone Conference held on September 25, 2014. Therefore, although the building height limit was recognized as an issue, most of the people did not expect the deregulation to be implemented in 2012, that is, in our analysis period.

The descriptive statistics are reported in Table 1. The average distance from Fukuoka Airport

Table 1: Summary statistics

Statistic	N	Mean	St. Dev.	Min	Max
Land price per square meter (JPY)	34,306	78,862.650	113,168.700	8,552.000	4,023,000.000
Distance from airport (m)	34,306	7,945.546	3,917.689	395.382	21,297.270
Distance from Hakata station (m)	34,306	6,642.485	3,375.287	67.616	18,388.160
Distance from Tenjin station (m)	34,306	6,341.421	2,984.635	29.417	16,301.810
Maximum permissible floor area ratio	34,306	1.743	1.086	0.600	8.000
Distance from the nearest park (m)	34,306	159.828	109.141	0.966	1,592.871
Elevation (m)	30,218	15.083	14.741	0.557	137.970
Average road width (m)	33,928	5.242	3.550	1.500	19.500

is 7946 m, which implies that the airport is located near the city.

6 Result

6.1 Baseline results

Table 2 reports the baseline estimation results. Column (1) shows the result, which does not include covariates. The kink point estimate at 4000 m from the airport is 0.00073 and is significant at the 5% level. This implies that the land price gradient with respect to the distance from the airport is positively kinked at the distance where the regulation is relaxed. Specifically, land price increases by 0.073% for every meter above the kink point. Column (2) includes the covariates. Here, we include the distance to Tenjin and Hakata stations, distance to the nearest park, elevation, average road width, and maximum permissible FAR. The estimated coefficients are smaller than the results without covariates, but the coefficient is significantly positive.

One may be concerned that the maximum permissible FAR may be determined by considering the building height limit mandated under the aviation law. Even the maximum permissible FAR is designated by the Land Use Zones and common in areas that are in the same zoning. The local government may consider building height regulations established by the aviation law while making zoning decisions. In this case, the maximum permissible FAR will be a bad control. To address this concern, Column (3) presents the results that exclude the maximum permissible FAR from the covariates. These results are mostly similar to those included in Column (2). This suggests that irrespective of whether the maximum permissible FAR is used as a covariate, the results are not significantly affected.[10]

Table 2: Baseline results

Dependent variable:	(1) log(price)	(2) log(price)	(3) log(price)	(4) Average building height
Coefficient	0.00073	0.00041	0.00045	0.01433
Robust SE	0.00023	0.00005	0.00016	0,00366
Robust CI	[0.00027, 0.00119]	[0.00023, 0.00059]	[0.00014, 0.00076]	[0.00715, 0.02152]
Bandwidth	437.371	799.462	491.382	799.462
Number of efficient observations	[1334, 1548]	[2264, 2709]	[1459, 1706]	[972, 984]
Number of observations	[5654, 28652]	[5597, 24291]	[5597, 24291]	[2450, 1926]
Coefficients of covariates:				
log(distance to Tenjin)		0.219	0.667	4.123
log(distance to Hakata)		-0.587	-1.137	-0.160
log(distance to park)		0.009	0.031	-0.002
Elevation		0.016	0.016	0.991
Road width		0.039	0.048	0.344
Maximum permissible FAR		0.149		3.803

Notes: The log of land price is the dependent variable in Columns 1-3, and average building height is the dependent variable in Column 4. The coefficient is the bias-corrected RKD estimate, which represents the land price kink at 4000 m from the airport. The robust standard error (SE) and the robust confidence intervals (CIs) are clustered by a 100 m grid-cell level. The bandwidth is the optimal bandwidth obtained by minimizing the mean squared error. The number of efficient observations is the observations within the bandwidth, which are used to estimate the treatment effect. The number of observations is the total observations used to estimate the optimal bandwidth. On the number of efficient observations and number of observations, each number in brackets shows the number of observations located to the left or right of the cutoff, respectively. Covariates are maximum permissible FAR, distance to the nearest park, and linear distance to the central stations of the CBDs, average elevation, and average road width.

The difference in the estimated coefficients without and with controlling for covariates may come from the difference in the estimated optimal bandwidth across specifications. To address this issue, we also estimate the kink without and with covariates by fixing the bandwidth to the baseline specification, 437.371 m. The results are shown in Table 3. Column 1 shows the results excluding covariates, and Column 2 shows the results including covariates. The results

[10] One may be concerned by the positive coefficient for elevation. Under the building height regulation based on the sea level, low, elevated areas can develop more. If this is true, the estimated coefficient should be negative. In general, elevation and land price have a positive correlation because elevated areas have a relatively low risk of disasters, such as earthquakes and floods (e.g., Kok et al., 2014). The 4000 m threshold covers a wide area with a circular form, and the latter's margin would be more important than the former's margin.

are almost similar to the baseline results. By including covariates, the estimated kink becomes smaller. Another possible reason is bias-correction owing to the observations that are away from the threshold. To check this possibility, we estimate with a shorter bandwidth, 300m. The results are shown in Columns 3 and 4. With the shorter bandwidth, the estimated points are similar for the two cases, that is, without and with controlling for covariates. The difference in the estimated kink between the two cases partly comes from the bias corrections due to the observations relatively far away from the kink point.

Table 3: Baseline results fixing bandwidth

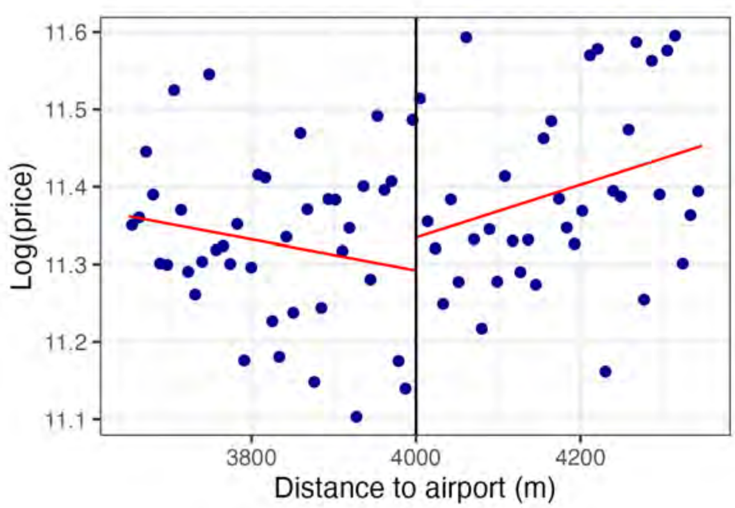
	(1)	(2)	(3)	(4)
Coefficient	0.00073	0.00046	0.00032	0.00032
Robust SE	0.00023	0.00018	0.00035	0.00025
Robust CI	[0.00027, 0.00119]	[0.00011, 0.00081]	[-0.00036, 0.001]	[-0.00017, 0.00082]
Bandwidth	437.371	437.371	300	300
Number of efficient observations	[1334, 1548]	[1318, 1536]	[956, 1066]	[942, 1056]
Number of observations	[5654, 28652]	[5597, 24291]	[5654, 28652]	[5597, 24291]
Covariates	No	All	No	All

Notes: The log of land price is the dependent variable. The coefficient is the bias-corrected RKD estimate, which represents the land price kink at 4000 m from the airport. The robust standard error (SE) and the robust confidence intervals (CIs) are clustered by a 100 m grid-cell level. The bandwidth is 437.371 m in Columns 1 and 2, and 300 m in Columns 3 and 4. The number of efficient observations is the observations within the bandwidth, which are used to estimate the treatment effect. The number of observations is the total observations used to estimate the optimal bandwidth. On the number of efficient observations and number of observations, each number in brackets shows the number of observations located to the left or right of the cutoff, respectively. Covariates are maximum permissible FAR, distance to the nearest park, and linear distance to the central stations of the CBDs, average elevation, and average road width.

Figure 5 represents the plot of the results. Dots represent the mean value of bins of the distance from the airport. It can be observed that the land price decreases with respect to the distance to the airport until 4000 m, at which point the negative slope becomes positive. The change of the slope is the effect of the relaxation of building height restriction on the land price. Note that there is a negative relationship between distance from the airport and land price in the areas within 4000 m of the airport. This would be due to the fact that Hakata Station is located 3,000 m from the airport and that land price declines as the distance from the station increases.

In summary, the building height restriction has a significant negative effect on the land price.

Figure 5: Plot of the baseline result



Notes: The plot is based on the estimation with the covariates. Covariates are maximum permissible FAR, distance to the nearest park, and linear distance to the central stations of the CBDs, average elevation, and average road width. The red line represents the linear fitting curve. The bin width of the plot is chosen by mimicking the variance method: 8.53 m up to 4000 m from the airport and 9.40 m beyond 4000 m from the airport.

The results suggest that land price increases by 0.041% for every meter above the kink point. The regulation relaxes the restriction by 2% as the distance increases from the airport, which implies that the building height restriction is relaxed by 2 cm for every meter outside the range of 4000 m from the airport. At the kink point, the level of the building height limit is 45 m, and relaxation of 2 cm of the restriction limit corresponds to a 0.044% relaxation of the restriction. By dividing 0.041 by 0.044, we obtain the elasticity of the land price with respect to building height limits: 0.93.

We also calculate the elasticity using the fuzzy RKD approach. At the first stage estimation, we obtain 0.014 as the RKD coefficient for the average building height as shown in Column (4) in Table 2. This implies that average building height increases by 1.4 cm for every meter outside the range of 4000 m from the airport, which corresponds to a 0.031% increase. By using this estimate, we obtain the elasticity of the land price with respect to building height limits: 1.32.

Therefore, the estimated elasticity ranges from 0.93 to 1.32, which is comparable to the elasticity estimated in Beijing by Brueckner et al. (2017), who used FAR as the measure of building height restriction and obtained 0.98 as the estimated elasticity.

6.2 Potential concerns

This section tests the robustness of our results by addressing potential concerns. The first concern is the validity of the continuity of the regression functions at the kink point in the absence of the treatment. For example, the result could be obtained from other factors, such as the distance to the main stations instead of the relaxation of the building height restriction. To address this concern, we conduct placebo kink point tests. We replace the actual kink point with another point, at which there is no kink in the policy, and conduct the regression under the artificial kink point. We move away up to 500 m for every 100 m away from the true kink point; these are used as the placebo kink points for the analysis. The results are presented in Table 4. Panel (A) includes the results with respect to the placebo kink points from 3900 to 3500 m from the airport. Panel (B) includes the results with respect to the placebo kink points from 4100 to 4500 m from the airport. For example, Column (1) in Panel (A) presents the result with respect to the placebo kink point as 3,900 m from the airport. The point estimate of the kink is positive and its magnitude is large, but not significant. Overall, we do not observe any significant result with respect to the placebo cutoff analyses. In some specifications, the estimated coefficient is larger than the baseline results, and the coefficients vary with the specifications. Relatively small sample size[11] and heterogeneity of the effect across locations on the kink points might explain the large variation in the estimates. In summary, we cannot observe any significant effect at the artificial kink points close to the actual kink point of the building height regulation. This supports the fact that our main results are, in fact, because of the relaxation of building height restrictions.

The second concern is that our main results could be driven by the kink of the predetermined covariates. The covariates could also kink at the kink point of the regulation, which might influ-

[11]In the placebo kink point exercise, it is recommended that the data do not include the actual kink point. For example, when we set 3900 m as the placebo kink point, we should omit the data beyond 4000 m, the actual kink point. This reduces the number of observations.

Table 4: Placebo cutoff results

Panel (A): From 3900m to 3500m

	(1)	(2)	(3)	(4)	(5)
Coefficient	0.00212	-0.00078	0.00106	-0.00028	-0.00097
Robust SE	0.00297	0.00125	0.00103	0.00059	0.00074
Robust CI	[-0.00371, 0.00794]	[-0.00323, 0.00168]	[-0.00096, 0.00308]	[-0.00144, 0.00087]	[-0.00241, 0.00048]
Bandwidth	536.884	253.247	231.791	464.121	334.5
Number of efficient observations	[1492, 326]	[714, 649]	[623, 720]	[1190, 1230]	[868, 952]
Number of observations	[5271, 326]	[4948, 649]	[4655, 942]	[4367, 1230]	[4114, 1483]
Covariates	All	All	All	All	All
Placebo cutoff points	3900 m	3800 m	3700 m	3600 m	3500 m

Panel (B): From 4100m to 4500m

	(1)	(2)	(3)	(4)	(5)
Coefficient	0.00064	-0.00141	-0.00092	0.00025	0.00014
Robust SE	0.0018	0.00084	0.00054	0.00042	0.0003
Robust CI	[-0.00289, 0.00417]	[-0.00305, 0.00023]	[-0.00197, 0.00014]	[-0.00058, 0.00107]	[-0.00044, 0.00073]
Bandwidth	968.02	610.146	688.941	536.12	728.892
Number of efficient observations	[359, 3232]	[712, 2034]	[1056, 2292]	[1399, 1768]	[1734, 2389]
Number of observations	[359, 23932]	[712, 23579]	[1056, 23235]	[1399, 22892]	[1734, 22557]
Covariates	All	All	All	All	All
Placebo cutoff points	4100 m	4200 m	4300 m	4400 m	4500 m

Notes: The log of land price is the dependent variable. The coefficient is the bias-corrected RKD estimate, which shows the land price kink at the placebo cutoff point from the airport. The robust standard error (SE) and the robust confidence intervals (CIs) are clustered by a 100 m grid-cell level. The bandwidth is the optimal bandwidth derived by minimizing the mean squared error. The number of efficient observations is denoted by the observations within the bandwidth that are used to estimate the treatment effect. The number of observations is the total observations used to estimate the optimal bandwidth. On the number of efficient observations and number of observations, each number in the bracket represents the number of observations located to the left or right of the cutoff, respectively. The covariates are maximum permissible FAR, distance to the nearest park, and linear distance to the central stations of the CBDs, average elevation, and average road width.

ence our results. For example, the maximum permissible FAR could also be relaxed at the kink point, which could influence the increase in the land price. To address this issue, we test the kink of the predetermined covariates at the kink point of the building height regulation. We use the covariates, that is, maximum permissible FAR, distance from the nearest park, distance to Tenjin station, distance to Hakata station, elevation, and average road width as outcome variables, and conduct the RKD exercises with the kink point set at 4000 m from the airport. In each estimation, all covariates other than the variable used as the outcome are included as covariates. The results are reported in Table 5. Column (1) represents the result using the maximum permissible

Table 5: Predetermined covariates

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	FAR	Distance to Park	Distance to Tenjin St.	Distance to Hakata St.	Road width	Elevation
Coefficient	-0.00041	0.03917	-0.00012	0.00014	-0.00244	0.00081
Robust SE	0.00046	0.04992	0.00016	0.00011	0.00263	0.00225
Robust CI	[-0.00131, 0.00049]	[-0.05868, 0.13702]	[-0.00042, 0.00019]	[-8e-05, 0.00036]	[-0.00759, 0.00271]	[-0.00359, 0.00521]
Bandwidth	558.985	602.577	1021.545	699.796	559.07	1770.864
Number of efficient observations	[1631, 1920]	[1731, 2054]	[2775, 3452]	[1988, 2379]	[1631, 1921]	[4169, 5817]
Number of observations	[5597, 24291]	[5597, 24291]	[5597, 24291]	[5597, 24291]	[5597, 24291]	[5597, 24291]
Covariates	Yes	Yes	Yes	Yes	Yes	Yes

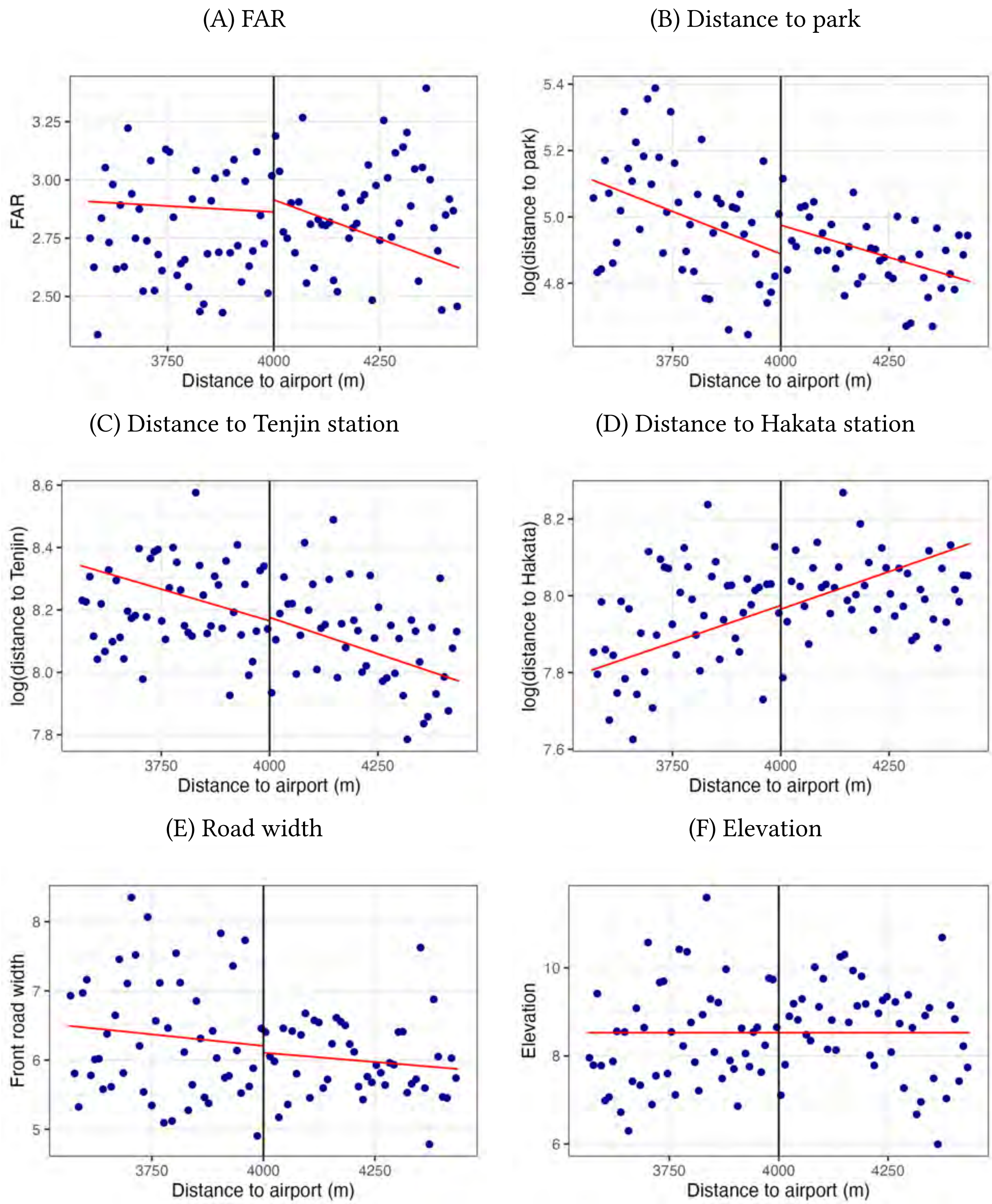
Notes: Maximum permissible FAR (column 1), distance from nearest park (column 2), log of distance from Tenjin Station (column 3), log of distance from Hakata Station (column 4), road width (column 5), and elevation (column 6) are dependent variables. The coefficient is the bias-corrected RKD estimate, which shows the land price kink at 4000 m from the airport. The robust standard error (SE) and the robust confidence intervals (CIs) are clustered by a 100 m grid-cell level. The bandwidth is the optimal bandwidth obtained by minimizing the mean squared error. The number of efficient observations is the observations included within the bandwidth that are used for estimating the treatment effect. The number of observations is the total observations used to estimate the optimal bandwidth. On the number of efficient observations and number of observations, each number in the bracket represents the number of observations located to the left or right of the cutoff, respectively. The covariates are FAR, distance to the nearest park, linear distance to the central stations of the CBDs, average elevation, and average road width. All covariates other than the variable used as the outcome are included in each estimation

FAR as the outcome variable. The point estimate is positive, but not significant at the 10% level. Column (2) presents the result using the distance from the nearest park as the outcome variable. The estimates are positive, but not significant at the 10% level. Column (3) presents the result using the log of distance to Tenjin station. The estimates are not statistically significant. Column (4) includes the result obtained from using the log of distance to Hakata station. The estimates are not statistically significant. Column (5) presents the result of using the average road width. The estimates are not statistically significant. Column (6) includes the result of using the average elevation. The estimates are not statistically significant. In summary, we do not find any kink on the covariates at the kink point of the building height regulation. This suggests that our main results are not driven by a kink caused by the covariates. To see the pattern of predetermined covariates through the distance from the airport, we plot the RKD results shown in Table 5 as Figure 6. We do not observe a kink at 4000 m from the airport with respect to any covariate. One may highlight that there is a slight kink at 4000 m from the airport with respect to maximum permissible FAR as shown in Panels A. As Hakata Station is located within 3000 m, it is possible that land use demand in this area decreases with the distance from the airport. This can lead to a decline in the maximum permissible FAR. As shown in Table 4, this kink is not significant in the formal RKD estimation, but it suggests that FAR could correlate with the relaxation of the building height limit.[12] However, there is no such kink pattern for road width, so it may be desirable to use it as a covariate for the regulation other than the building height limit.

The third concern is the difference in the number of observations surrounding the kink points. The unit of observation is a grid cell, and there is no room for manipulation with respect to choosing inside or outside the kink point, which is typically concerning in RKD and RDD exercises. However, the number of units of observation may differ across areas because of the availability of land price information. The data for land prices are from *rosenka*, which reflects the assessed value of the land fronting to each street. As a result, the unit of observation for the raw data is the street itself, that is, there is no data available for areas without streets. For example, if the neighborhoods at kink points have large public spaces (e.g., parks) or large plants, and there is no street in that area, land price data are not available. The non-uniform distribution of the unit of observation may produce the results. To address this issue, we check the density of the unit of observations through distance from the airport. Figure 7 shows a histogram of the observations in each bin of the distance from the airport. The density of observations surrounding the kink point is similar, and there is no spike and notch in the distribution. Thus, the non-uniform

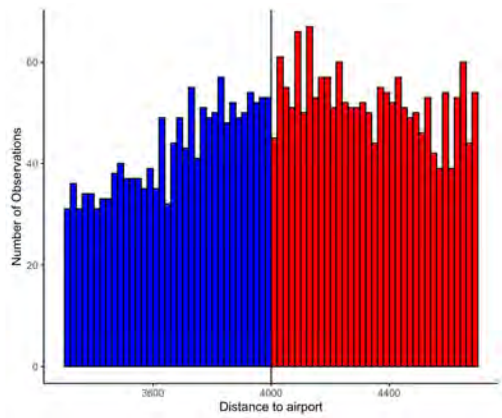
[12] However, if building height limit and the maximum permissible FAR are correlated, it is rather natural to assume that the maximum permissible FAR will relax along with the relaxation of building height limits. Thus, this possible correlation is the opposite of what is expected.

Figure 6: Plots in predetermined covariates



Note: The plot is based on the estimation shown in Table 5. Maximum permissible FAR (Panel A), distance from nearest park (Panel B), log of distance from Tenjin Station (Panel C), log of distance from Hakata Station (Panel D) average road width (Panel E), and average elevation (Panel F) are the dependent variables. Maximum permissible FAR, distance to the nearest park, linear distance to the central stations of the CBDs, average elevation, and average road width are the covariates. All covariates other than the variables used as the outcome are included in each estimation. The bin width in each figure is chosen by mimicking the variance method, and ranged from 8.7 m to 9.9 m.

Figure 7: Observation unit distributions in Fukuoka CBD



Notes: The figure shows the histogram of the observations by the distance from the airport. The blue-colored bars show the density of observations within 4000 m from the airport. The red-colored bars show the density of observations beyond 4000 m from the airport. The bin width is 20 m.

distribution of the unit of observation does not explain the main results.

Finally, we check the robustness of the bandwidth choice. In the main specification, we choose the bandwidth by minimizing the mean squared error, which is the most standard way to choose bandwidth. Here, we conduct the analysis with the bandwidth chosen through optimizing the coverage error rate, which is the alternative method to choose the bandwidth. We also use the bandwidths which are twice as long as the respective optimal bandwidths. The results are reported in Table 6. Column (1) includes the benchmark result of using the optimal bandwidth by minimizing the mean squared error. Column (2) shows the results of using the bandwidth by minimizing the coverage error rate. The bandwidth becomes shorter than the baseline estimation, but the coefficient does not change. Columns 3 and 4 include the bandwidths twice as long as the respective optimal bandwidths. Mostly, the estimated coefficients do not change. This suggests that the main results are robust with respect to the choice of the bandwidth.

6.3 Concern regarding the two central stations

The final concern is that of the location of the central railway stations. As Figure 1 shows, Fukuoka has two central railway stations, Hakata and Tenjin. The land price is highest in areas surrounding

Table 6: Bandwidth choice robustness

	(1)	(2)	(3)	(4)
Coefficient	0.00041	0.00041	0.00041	0.00047
Robust SE	0.00005	0.00013	0.0001	0.00017
Robust CI	[0.00023, 0.00059]	[0.00016, 0.00066]	[0.00022, 0.0006]	[0.00013, 0.00081]
Bandwidth	799.462	499.814	1598.924	999.627
Number of efficient observations	[2264, 2709]	[1483, 1732]	[3918, 5278]	[2727, 3381]
Number of observations	[5597, 24291]	[5597, 24291]	[5597, 24291]	[5597, 24291]
Covariates	All	All	All	All
Bandwidth choice	MSE optimal	CER-optimal	MSE-optimal × 2	CER-optimal × 2

Notes: The log of land price is the dependent variable. The coefficient is the bias-corrected RKD estimate, which represents the land price kink at 4000 m from the airport. The robust standard error (SE) and the robust confidence intervals (CIs) are clustered by a 100 m grid-cell level. The bandwidth is the optimal bandwidth obtained by minimizing the mean squared error in Column (1) and minimizing the coverage error rate in Column (2). Further, twice the optimal bandwidth is obtained by minimizing the mean squared error in Column (3) and minimizing the coverage error rate in Column (4). The number of efficient observations is the observations within the bandwidth, which are used to estimate the treatment effect. The number of observations is the total observations used to estimate the optimal bandwidth. On the number of efficient observations and number of observations, each number in the bracket represents the number of observations located to the left or right of the cutoff, respectively. Covariates are maximum permissible FAR, distance to the nearest park, linear distance to the central stations of the CBDs, average elevation, and average road width.

these central railway stations and is expected to decline as the distance increases from these stations. This may generate a kink in land prices. This is likely to occur in the middle of the two central railway stations. As shown in Figure 1, a part of the kink point is located between these central railway stations. Thus, the kink in land prices may not be caused by the building height limit mandated by the aviation law, but by the location of these central railway stations. We demonstrate that controlling with distance from those stations does not change the results. Furthermore, the placebo cutoff results presented in Table 4 show that significant results are obtained only at the 4000 m boundary. Note that the kink point is not exactly in the middle of Tenjin and Hakata stations. The midpoint of the straight line from Hakata to Tenjin is within the 4000 m boundary. If the location of the two central railway stations influences the results, then we may observe a kink at the placebo cutoff points. These results suggest that our main results are not driven by the location of the two stations. However, as a further robustness check, we conduct an analysis excluding area where the kink point is located between Tenjin and Hakata stations.

By connecting Tenjin and Hakata stations in a straight line, generating a buffer of about 1 km in width between them, and removing it and the area on that extension, we exclude the effect of the decreasing land price as distance from the two central stations increases. In the estimation, we still control for distance from Tenjin and Hakata stations by including them as covariates. The results are shown in Table 7. Column (1) presents the results of excluding covariates, Column (2)

Table 7: Estimation results excluding the buffer between two central stations

	(1)	(2)	(3)
Coefficient	0.00055	0.00035	0.00039
Robust SE	0.00022	0.00008	0.00018
Robust CI	[0.00011, 0.00099]	[0.0002, 0.0005]	[0.00003, 0.00075]
Bandwidth	465.626	957.174	487.42
Number of efficient observations	[1310, 1506]	[2409, 2972]	[1351, 1553]
Number of observations	[4945, 27416]	[4897, 23164]	[4897, 23164]
Covariates	No	All	Excluding FAR

Notes: In this estimation, we exclude a buffer of 1 km from the straight line connecting Tenjin and Hakata stations. The log of land price is the dependent variable. The coefficient is the bias-corrected RKD estimate, which represents the land price kink at 4000 m from the airport. The robust standard error (SE) and the robust confidence intervals (CIs) are clustered by a 100 m grid-cell level. The bandwidth is the optimal bandwidth derived by minimizing the mean squared error. The number of efficient observations is the observations within the bandwidth that are used to estimate the treatment effect. The number of observations is the total observations used to estimate the optimal bandwidth. On the number of efficient observations and number of observations, each number in the brackets represents the number of observations located to the left or right of the cutoff, respectively. Covariates are maximum permissible FAR, distance to the nearest park, linear distance to the central stations of the CBDs, average elevation, and average road width.

includes the results with covariates, and Column (3) includes the results of excluding FAR from the covariates. The results are similar to the baseline results shown in Table 2. Even if we exclude the area connecting Tenjin and Hakata Stations in a straight line, we observe a significant kink at 4000 m from the airport. This implies that our main results are not driven by the two peaks of land price areas close to the two central stations.

6.4 Difference in elasticity depending on the demand for floor area

As equation 5 shows, the estimated elasticity of land price with respect to regulation depends on the strength of the regulation relative to the laissez-faire level. In our setting, the level of regulation is common at the kink point, but the demand for land differs across areas. This unique regulation feature allows us to identify the effect of the gap between the strength of the regulation and the laissez-faire level on the elasticity of land price with respect to the regulation.

In our main estimation, we focus on the Fukuoka city area and almost all the areas at the kink point located in the CBD and its neighborhood—which has a large floor area demand. As Figure 1 shows, the eastern side of Fukuoka Airport also has a kink point located 4000 m from the airport. As these areas are not included in Fukuoka city and are relatively rural where land is mainly used for low rise housing, demand for land is lower than in Fukuoka city. In these areas, no building is taller than 54.1 m. Thus, while the demand for floor area differs greatly between the west and east sides of the airport, the absolute level of building height limits is common: building heights are 54.1 m or less. Therefore, the stringency of the regulation is different on the west and east sides; consequently, the impact of the regulation on land prices should be different. Equation 5 predicts that the effect of regulations is considered to be smaller in the east side, where regulations are less stringent than in the west side.

Based on the prediction above, we conduct the RKD analysis on the east side of the airport. We only use the data on the eastern side of the airport outside the Fukuoka city area. We use the same covariates as the main analysis. The results are shown in Table 8. Column (1) shows the results without covariates. The estimated elasticity is larger than that in the main analysis shown in Table 2. However, once we include covariates, the coefficient becomes smaller and not significant as presented in Column (2).[13] Similar to the baseline analysis, we exclude the maximum permissible FAR from the covariates. As shown in Column (3), the coefficient is also not significant at the conventional level. As the absolute level of the building height limit is common on both sides, the difference in the estimated elasticity comes from the demand for land. Fukuoka city has a larger demand for floor space, and has a larger gap between the regulation and level of development under a laissez faire economy than areas east of the airport.

[13]We also conduct an analysis wherein we include one covariate at a time, and found that all variables, except the maximum permissible FAR, make coefficients become not significant when introduced as covariates. Those differences in the estimated coefficients would be attributed to the large heterogeneity across the grid cells.

Table 8: Estimation results for the eastern side of the airport

	(1)	(2)	(3)
Coefficient	0.00096	-0.00005	-0.00004
Robust SE	0.00027	0.00011	0.00012
Robust CI	[0.00044, 0.00149]	[-0.00026, 0.00017]	[-0.00027, 0.00019]
Bandwidth	345.606	429.185	430.761
Number of efficient observations	[509, 563]	[330, 439]	[330, 442]
Number of observations	[2425, 9197]	[1888, 4238]	[1888, 4238]
Covariates	No	All	Excluding FAR

Notes: In this estimation, we use the areas located east of Fukuoka airport. The log of land price is the dependent variable. The coefficient is the bias-corrected RKD estimate, which represents the land price kink at 4000 m from the airport. The robust standard error (SE) and the robust confidence intervals (CIs) are clustered by a 100 m grid-cell level. The bandwidth is the optimal bandwidth derived by minimizing the mean squared error. The number of efficient observations are the observations within the bandwidth that are used to estimate the treatment effect. The number of observations is the total observations used to estimate the optimal bandwidth. On the number of efficient observations and number of observations, each number in the brackets presents the number of observations located to the left or right of the cutoff, respectively. Covariates are maximum permissible FAR, distance to the nearest park, linear distance to the central stations of the CBDs, average elevation, and average road width.

7 Conclusion

This study estimates the effect of land use regulation on the land price. To address the problem of endogeneity of the regulation, we exploit the unique feature of the building height limits mandated by the aviation law in Fukuoka, Japan. Buildings' heights are limited by their distance from the airport, and the regulation has a kink point at 4000 m from the airport. Exploiting RKD, we find that building height restriction has a negative and significant effect on land prices. The magnitude is substantial. The estimated elasticity of the land price with respect to building height limits ranges from 0.93 to 1.32. Our estimate is reasonable compared with those of the previous literature (e.g., Brueckner et al., 2017). The results are robust even if we control for the covariates and other possible regulations and characteristics that could affect the land price. We also find that the estimated elasticity is not significantly different from zero in areas east of the airport, which is relatively rural. This result suggests that the elasticity of the land use regulation depends on the stringency of the regulation relative to the level of land development under a free-market economy.

This study's results show that strong land-use regulations in city centers undermine the value of the land. As Brueckner and Sridhar (2012) highlighted, less development in a city center causes the spatial expansion of the city, which increases commuting costs. These results suggest that relaxing land use regulations is important to use land efficiently, at least in city centers.

References

Albouy, D. and G. Ehrlich (2018): "Housing Productivity and the Social Cost of Land-Use Restrictions," *Journal of Urban Economics*, 107, 101–120.

Barthold, T. A. and T. Ito (1992): "Bequest Taxes and Accumulation of Household Wealth: U.S.-Japan Comparison," in *The Political Economy of Tax Reform*, National Bureau of Economic Research, Inc, NBER Chapters, 235–292.

Brooks, L. and B. Lutz (2016): "From Today's City to Tomorrow's City: An Empirical Investigation of Urban Land Assembly," *American Economic Journal: Economic Policy*, 8, 69–105.

Brueckner, J. K., S. Fu, Y. Gu, and J. Zhang (2017): "Measuring the Stringency of Land Use Regulation: The Case of China's Building Height Limits," *The Review of Economics and Statistics*, 99, 663–677.

Brueckner, J. K. and R. Singh (2020): "Stringency of Land-Use Regulation: Building Heights in US Cities," *Journal of Urban Economics*, 116, 103239.

Brueckner, J. K. and K. S. Sridhar (2012): "Measuring Welfare Gains from Relaxation of Land-Use Restrictions: The Case of India's Building-Height Limits," *Regional Science and Urban Economics*, 42, 1061–1067.

Calonico, S., M. Cattaneo, D., and R. Titiunik (2015): "Rdrobust: An R Package for Robust Nonparametric Inference in Regression-Discontinuity Designs," *The R Journal*, 7, 38.

Calonico, S., M. D. Cattaneo, M. H. Farrell, and R. Titiunik (2019): "Regression Discontinuity Designs Using Covariates," *The Review of Economics and Statistics*, 101, 442–451.

Card, D., D. S. Lee, Z. Pei, and A. Weber (2015): "Inference on Causal Effects in a Generalized Regression Kink Design," *Econometrica*, 83, 2453–2483.

——— (2017): "Regression Kink Design: Theory and Practice," in *Regression Discontinuity Designs*, Emerald Publishing Limited, vol. 38 of *Advances in Econometrics*, 341–382.

Cattaneo, M. D., N. Idrobo, and R. Titiunik (2019): *A Practical Introduction to Regression Discontinuity Designs: Foundations*, Cambridge University Press, 1 ed.

Glaeser, E. L., J. Gyourko, and R. Saks (2005): "Why Is Manhattan So Expensive? Regulation and the Rise in Housing Prices," *The Journal of Law and Economics*, 48, 331–369.

Grout, C. A., W. K. Jaeger, and A. J. Plantinga (2011): "Land-Use Regulations and Property Values in Portland, Oregon: A Regression Discontinuity Design Approach," *Regional Science and Urban Economics*, 41, 98–107.

Gyourko, J., A. Saiz, and A. Summers (2008): "A New Measure of the Local Regulatory Environment for Housing Markets: The Wharton Residential Land Use Regulatory Index," *Urban Studies*, 45, 693–729.

Homma, M. and M. Atoda (1991): *Empirical Analysis of Tax Reform (In Japanese)*, Tokyo: Toyo Keizai Shinposha.

Kanasugi, H. and K. Ushijima (2018): "The Impact of a High-Speed Railway on Residential Land Prices," *Papers in Regional Science*, 97, 1305–1335.

Kok, N., P. Monkkonen, and J. M. Quigley (2014): "Land Use Regulations and the Value of Land and Housing: An Intra-Metropolitan Analysis," *Journal of Urban Economics*, 81, 136–148.

Kulka, A. (2019): "Sorting into Neighborhoods: The Role of Minimum Lot Sizes," *mimeograph.*

Kulka, A., A. Sood, and N. Chiumenti (2023): "How to Increase Housing Affordability? Understanding Local Deterrents to Building Multi-family Housing," *mimeograph.*

Nakagawa, M., M. Saito, and H. Yamaga (2009): "Earthquake Risks And Land Prices: Evidence From The Tokyo Metropolitan Area," *Japanese Economic Review*, 60, 208–222.

Nielsen, H. S., T. Sørensen, and C. Taber (2010): "Estimating the Effect of Student Aid on College Enrollment: Evidence from a Government Grant Policy Reform," *American Economic Journal: Economic Policy*, 2, 185–215.

Quigley, J. M. and L. A. Rosenthal (2005): "The Effects of Land Use Regulation on the Price of Housing: What Do We Know? What Can We Learn?" *Cityscape*, 1, 69–137.

Saiz, A. (2010): "The Geographic Determinants of Housing Supply *," *Quarterly Journal of Economics*, 125, 1253–1296.

Severen, C. and A. J. Plantinga (2018): "Land-Use Regulations, Property Values, and Rents: Decomposing the Effects of the California Coastal Act," *Journal of Urban Economics*, 107, 65–78.

Shimizu, C. and K. Nishimura (2006): "Biases in Appraisal Land Price Information: The Case of Japan," *Journal of Property Investment & Finance*, 24, 150–175.

Simonsen, M., L. Skipper, and N. Skipper (2016): "Price Sensitivity of Demand for Prescription Drugs: Exploiting a Regression Kink Design," *Journal of Applied Econometrics*, 31, 320–337.

Song, J. (2021): "The Effects of Residential Zoning in U.S. Housing Markets," *mimeograph*.

Tabuchi, T. (1996): "Quantity Premia in Real Property Markets," *Land Economics*, 72, 206–217.

Turner, M. A., A. Haughwout, and W. van der Klaauw (2014): "Land Use Regulation and Welfare," *Econometrica*, 82, 1341–1403.

Yamasaki, J., K. Nakajima, and K. Teshima (2021): "From Samurai to Skyscrapers: How Historical Lot Fragmentation Shapes Tokyo," *mimeograph*.