Who Gives a Dam? Capitalization of Flood Protection in Fukuoka, Japan

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Abstract

Large-scale flooding is becoming increasingly common due to prolonged and intensive rainfall caused by climate change. Communities have mitigated this risk by building flood protection, though it is unclear whether residents are aware of these public works or the protection they confer. We provide insight on this matter by examining whether apartment rental prices (2015 – 2019) responded to the completion of the Gokayama Dam in Fukuoka Prefecture, Japan. We find apartments protected by the Gokayama Dam experienced a 1.8% price increase relative to apartments in other floodplains after Typhoon Prapiroon hit western Japan and tested the dam. Renters used the natural disaster as a learning experience to update their perceptions of flood risk as opposed to the completion of the dam, suggesting a possible disconnect between perceptions of flood risk and objective risk. In addition, we find the benefits from flood protection were unevenly distributed with higher premiums observed in first floor units, units closer to rivers, and in areas where floodwaters are expected to exceed two meters, while rental units designed as temporary housing received no premium. Homeowners and commercial renters also benefited from the added flood protection but to an even greater extent than apartment renters. In aggregate, the Gokayama Dam provides $11.3 million in benefits to downstream apartment renters each year which offsets more than one-third the annualized cost of the dam.

Keywords: hedonic analysis; flood protection; difference in difference; natural disasters; Japan

JEL Codes: R30, Q51, Q54, Q25

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1. Introduction

Despite 41% of its population living in flood-prone areas, Japan manages flood risk well thanks in part to its extensive network of flood defense (Kundzewicz et al. 2014). At the center of this defense are more than 2,500 dams nationwide which control water levels across thousands of streams, rivers, and lakes. Many of these dams need to be repaired soon due to their age. Approximately 24% of Japanese flood control dams are more than 50 years old, which is considered a critical threshold of when stress begins to show and action needs to be taken (Perera et al. 2021). The decision to rebuild or reinvest in dams is difficult as policymakers need to weigh the benefits of flood control with the cost of replacement and potentially adding to the $11 trillion national debt (Ministry of Finance, 2021).[1]

To complicate matters, public opinion on dams is divided, and recent controversies surrounding dam construction have sprouted anti-dam movements. One particularly controversial project is the Yamba Dam, which is located 130 kilometers northwest of Tokyo. Construction of the dam started in 1967 despite fierce opposition from locals who wanted to save the area from being submerged. The project was once cancelled in 2009 to curb public spending (Fackler, 2009) but was later restarted in 2012 due to a change in the national ruling party. Finally, in 2019 the dam was completed billions of dollars over budget and decades beyond the original timeline. The mismanagement of the Yamba Dam led to a public opinion that dams are a product of wasteful government spending and caused many politicians to run on dam-free platforms in the 2000s (Mishima, 2015).

[1] Estimates referenced in the text that are originally measured in Japanese Yen (JPY) are converted into U.S. Dollars (USD) using a ratio of 110 JPY to 1 USD.

Climate change may tip the scales towards greater investment in water infrastructure, despite these concerns, as extreme weather events are expected to become more common in Japan (Mizuta et al., 2017; Hoshino et al., 2020). In Tokyo, for instance, the probability of having a 250+ mm rainfall day is predicted to at least double by the end of the 21st century (Mizuta et al., 2017). With greater rainfall comes greater flood risk. The national, prefectural, and local governments have responded by updating floodplain maps (MLIT, 2015), raising river banks (Ikeuchi, 2012), improving emergency warning systems (Japan Meteorological Agency, 2021), and building upstream flood protection. The extent to which residents value these precautionary measures, however, is not well understood.

In this study we investigate how apartment rental prices in Fukuoka Prefecture, Japan responded to the completion of the Gokayama Dam and its subsequent testing four months later caused by the arrival of Typhoon Prapiroon. We argue the latter event induced floodplain renters to update their perceptions of flood risk and use this as a natural experiment to causally identify the relationship between flood protection and downstream apartment rents. We use the former event, on the other hand, to test whether objective changes in flood risk are also capitalized in rental prices.

From this analysis we make three contributions to the flood risk literature. We are the first study to examine how improvements in flood protection, specifically the completion of an upstream dam, influence real estate markets. Although capitalization of coastal defense is a well-studied topic (McNamara et al., 2015; Qiu and Gopalakrishnan, 2018), little is known in regards to the benefits conferred by upstream dams. This may be due to lack of awareness as dams are often built several kilometers away from the area it protects. Second, we focus on how apartment renters respond to changes in flood risk. Renters are an important stakeholder group in Japan but are typically unaccounted for in hedonic applications due to data limitations. They are also likely to value flood protection differently than homeowners due to their more transitory nature and their lower level of risk. Finally, we contextualize these results by examining how flood protection is capitalized within the commercial rental and housing market. Business owners are another important stakeholder group concerned with mitigating flood risk but are often excluded from hedonic applications, while several studies have priced flood risk using housing transactions (Hallstrom and Smith, 2005; Kousky, 2010; Bin and Landry, 2013; Ortega and Taspinar, 2018; Georgic and Klaiber, 2021). The valuations we recover from all three real estate markets provide a more holistic understanding of the benefits conferred from flood protection.

Using a difference-in-difference estimator and a rich dataset of rental transactions from Fukuoka Prefecture, Japan (2015 – 2019), we find apartment rental prices increased by 1.8% if they were protected by the recently constructed Gokayama Dam relative to rental units in other floodplains. Capitalization also occurred in commercial rentals and housing values, but to an even greater extent, increasing by 9.1% and 11.6% respectively. This price increase is only observed after Typhoon Prapiroon hit western Japan and tested the dam, suggesting that nearby flooding altered renters' perception of flood risk while the completion of the dam did not. Higher flood protection premiums are also observed in first floor apartments, apartments closer to rivers, and in areas where floodwaters are expected to exceed two meters, while no premium is observed in apartments designed as temporary housing. Overall, the aggregate benefits from the residential rental market ($11.3 million per year) cover more than one-third the annualized cost of the Gokayama Dam ($27.9 million per year), which suggests the dam is cost-effective given the number of other stakeholder groups that benefit from flood protection.

2. Background

Typhoons are a regular occurrence in Japan and typically occur between the months of May and October. The timing of Typhoon Prapiroon in late June and early July of 2018 was a little unusual though as it coincided with a stronger than average rainy season[2], which was fueled by warm air from the Pacific Ocean (Japanese Meteorological Agency, 2018). The synergy between the typhoon, the seasonal rain front, and the warm air brought record-breaking rainfall to western Japan between June 28th and July 5th and resulted in widespread flooding, destruction of over 17,000 homes, and water outages for over 260,000 families. The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) estimate the floods caused over $10 billion in damages, the costliest in Japanese history. Fukuoka City, the 6th largest metropolitan in Japan and home to over 1.6 million residents (Figure 1), was especially hard hit receiving over 85 cm (33 inches) of rain over a 10-day period (Appendix Figure 1). Although much of the city is built on a floodplain, only 59 properties were damaged thanks in part to the city's extensive flood defense network (Fukuoka Prefecture, 2019).

The Gokayama Dam

One of the largest flood control structures that protects Fukuoka City is the Gokayama Dam, which is located 10 km upstream from the city center (Figure 2). Construction of the dam finished four months before the arrival of Typhoon Prapiroon and is one of the largest public projects in Fukuoka Prefecture, costing $600 million and taking 6 years to complete. Based on a cost-benefit analysis conducted by the prefectural government, the dam provides $4.3 billion in

[2] Japan's rainy season, often referred to as tsuyu in Japanese, is a period of continuous rain brought by a stationary front that can last several weeks or even a few months.

benefits to the local community (Fukuoka Prefecture, 2011). The concrete embankment is over 100 meters tall, 550 meters wide, and is designed to reduce waterflow by as much as 33%, or 450 m^3/s (Fukuoka Prefecture, 2011). The dam generates only enough electricity to power itself and is primarily used for drought prevention and flood control, redirecting water from the Naka River which flows through Fukuoka and Nakagawa City. Prior to the completion of the Gokayama Dam, minor flooding events were reported along the Naka River in 1999, 2001, 2003, and 2009.

The prolonged rainfall brought by Typhoon Prapiroon was undoubtedly the first real-world test for the Gokayama Dam. There was no major flooding reported along the Naka River, and it fared well when compared with other nearby rivers. This is evident when looking at Google Trends data where search volume for the Naka River within Fukuoka Prefecture was relatively flat during July of 2018 (Appendix Figure 2) while Google searches for other Fukuoka City rivers, like the Muromi, Tatara, Hii, Umi, and Mikasa (Figure 2), reached a four-year high. In contrast to the Naka River, most of these rivers are either undammed or are protected by smaller and older dams built several decades before the study period.

Flood Insurance in Japan

Flood insurance in Japan is typically packaged with fire insurance and is only provided by private insurers as there is no national flood insurance program like the National Flood Insurance Program (NFIP) in the United States. According to the General Insurance Rating Organization of Japan (GIROJ), about 70% of residential fire insurance policies also cover flood damage.[3] Insurance prices do not reflect locational differences in flood risks, although major insurance

[3] Fire insurance is compulsory in most apartment rental contracts (GIROJ, 2022).

companies are considering to differentiate it in response to the increasing damages caused by climate disasters. Typically, flood damage is compensated when damages exceed 30% of the property's value or when inundation levels are greater than 45cm (GIROJ, 2022).

3. Literature Review

Capitalization of flood risk is a well-studied topic and is typically derived from housing price differentials between properties sold inside and outside of a floodplain (Bin and Kruse, 2006; Kousky, 2010) or from price changes inside a floodplain (Hallstorm and Smith, 2005; Bin and Landry, 2013; Georgic and Klaiber, 2021). Homeowners are expected to be compensated for living in riskier areas by paying less for a house (Kousky, 2010), though floodplain price discounts are typically not observed unless a flood recently occurred (Bin and Polasky, 2004; Bin and Landry, 2013). This suggests floodplain homeowners are not fully aware of the risk they face and use recent experiences to update their perceptions of risk (Kousky, 2010; Atreya et al., 2013; Bin and Landry, 2013; Beltrán et al., 2019).

Heightened awareness of flood risk may not be permanent even if it is induced by a natural disaster. Housing prices have been observed to revert back to pre-flood levels 5 to 10 years following a natural disaster (Atreya et al., 2013; Bin and Landry, 2013; Beltrán et al., 2019). Flood insurance follows a similar pattern as households are more likely to purchase insurance immediately after a storm. The number of households with insurance then reverts back to its mean level 5 to 10 years out (Gallagher, 2014; Atreya et al., 2015). This short-sightedness may be due to bounded rationality (Simon, 1957) where individuals are unable to evaluate all of the risk they face but instead rely on recent or dramatic events (Tversky and Kahneman, 1973) to help them prioritize which risk to mitigate. Alternatively, the temporal nature of the price discount may depend on the severity of the natural disaster, with more extreme events having longer-lasting effects (Ortega and Taspinar, 2018).

An additional concern is whether floodplain price discounts are caused by inundation and/or an updating of flood risk perceptions. In most instances it is difficult to separate the two as spatial data detailing where inundation occurs is sparse (Hallstrom and Smith, 2005; Atreya et al., 2013). Only a few studies have linked housing values with inundation damage (Oretega and Taspinar 2018; Beltrán et al., 2019; Gibson and Mullins, 2020), finding inundated homes lose up to 48% of their value following a flood. Losses from inundation are not permanent as price recuperation can take as little as 5 years, though the recovery time will depend on the type of flooding and the initial price of the home (Beltrán et al., 2019).

Houses that are not directly damaged by a flood also lose value due to a change in perceptions, inconveniences caused by the flood, and damage to the community. Non-floodplain homes in St. Louis, for instance, experienced a 4.5% price decrease following the flooding of the Mississippi and Missouri River in 1993 (Kousky, 2010). The flooding of the Mississippi and Missouri River indirectly affected many homeowners by forcing highways to close, damaging municipal water and sewer treatment plants, and shuttering hundreds of businesses. “Near miss” floodplain properties in Lee County, Florida, where Hurricane Andrew was expected to hit in 1992 but did not, also experienced a price reduction as home buyers and sellers used the information conveyed by the storm to update their perceptions of flood risk (Hallstrom and Smith, 2005).

We make three contributions to this literature using real estate data from Fukuoka Prefecture, Japan. Unlike previous studies which are concerned with measuring homeowner willingness to pay, we focus on how apartment renters responded to flood risk. Apartment renters likely respond differently to hazards as they are more transitory and have fewer financial investments tied to their home. There are also additional benefits from using rental data. The rental market in Japan is generally more active than the housing market as renters are more mobile, making it easier to identify small price effects due to the higher volume of transactions.[4] Second, renters constitute a large fraction of the population in Japan. Homeownership rates are 5% to 15% lower in Japan than in the United States and European Union (OECD Social Policy Division, 2021; U.S. Department of Commerce, 2021), which highlights the importance of this group and the need to recover reliable valuation estimates for non-homeowners. Third, apartments tend to be more uniform in quality and price than single-family residences (Naoi et al., 2009), lessening the chances of omitted variable bias and other confounding factors that could hamstring causal identification. Finally, hedonic price differentials will not reflect the future stream of benefits and costs tied to a property if amenity conditions included within the hedonic price schedule deviate from expectations (Bishop and Murphy, 2019). This is less likely to occur when rent is used in place of sale price, as renter expectations extend over a shorter time horizon.

As a second contribution we examine how improvements in flood protection, specifically construction of an upstream dam, influence rental values. Large scale investments in flood protection are common along coastal communities and confer significant benefits to nearby homeowners (McNamara et al., 2015). The extent of these benefits will depend on whether the infrastructure obscures oceans views, if neighboring communities have flood protection, and if the property is oceanfront or inland (Gopalakrishnan et al., 2011; Qiu and Gopalakrishnan,

[4] 30% of renters reported moving within the past 5 years as compare to only 8.6% of homeowners (Statistical Bureau of Japan, 2019).

2018). Capitalization of inland flood protection is less understood as only a handful of studies have linked housing prices to dam removal or other inland defenses (Lewis et al., 2008; Provencher et al., 2008), while no academic study to our knowledge has estimated the capitalized value from the completion of a dam. The relative scarcity of inland flood protection studies may be due to a lack of awareness of the protection provided by upstream infrastructure, which can be several kilometers away from the area it protects. Our study provides a unique opportunity to test this hypothesis by examining how rental prices responded to the completion of the Gokayama Dam in March of 2018 and the arrival of Typhoon Prapiroon four months later.

Finally, we estimate the value flood protection provides to homeowners and renters of office and retail space to help contextualize our primary contribution within the broader real estate market. Commercial property applications of the hedonic method are scarce as it is difficult to obtain attribute data for these property types. The commercial property market is also less active as there are fewer listings at any given time and properties are generally more expensive. Despite these challenges, commercial property prices have been found to increase with population density (Nagai et al., 2000), energy efficiency (Eicholtz et al., 2013), and proximity to the nearest rail station or highway (Cohen and Brown, 2017), while decreasing with crime rates (Lens and Meltzer, 2016).

Flood risk is likely capitalized in commercial properties as floodwaters have caused significant damage to businesses in the past. Over $14 billion in insurance payouts have been distributed to businesses through the National Flood Insurance Program in the United States as of 2021 (NFIP, 2021). Many businesses also experience uninsurable losses. Hundreds of small to medium enterprises across Japan reported production delays, destroyed inventory, and logistical issues following the 2018 floods, which totaled over $4.3 billion in damages (Nikkei Newspaper, 2018). Insurance payments only covered some of these losses, as business owners were not compensated for things like foregone revenue and preparations made to protect their business prior to the flood.

Indaco et al. (2021) also find that a business' income generating potential can be negatively impacted by flooding. Following Hurricane Sandy, flooded businesses in New York City experienced a reduction in average wages, employment, wage income, and were more likely to exit or relocate. Taken altogether, Hurricane Sandy likely reduced the income-generating potential of the area, which in turn lowered commercial property values. This hypothesis was never formally tested, however (Indaco et al. 2021). We provide clarity on this matter by examining how commercial rents respond to nearby flooding and flood protection provided by the Gokayama Dam.

4. Data

We collect real estate listing data from the National Institute of Informatics (NII) to test if flood protection from the Gokayama Dam is capitalized in downstream rents (At Home Co. Ltd., 2020). The NII's database includes a vector of structural characteristics, locational features, and rent for apartments listed on the market. The total monthly payment for each unit is calculated by dividing the deposit by the number of months on the lease and adding that to the monthly rental payment.[5] Rentals with extreme or incorrectly measured characteristics (below the 1st percentile

[5] Deposit and rental prices come from the last month the unit is listed on the market. In most cases, there is no difference between the final listed rental price and transacted rental price in Japan as renters have little to no negotiating power when determining the final rental price. Sadayuki (2020) estimates the ratio between the two to be 0.99937 using transactions of apartment units between 1995 and 2016. Despite this limitation, renters indirectly alter equilibrium rental prices through their decision of where to live. Hedonic applications of listed rental price in Japan are also common (see for example Nakagawa et al. (2007), Shimizu et al. (2010), and Sadayuki (2018)).

or above the 99th percentile) are removed from the analysis to limit the impact of outliers. We follow a similar process when collecting rental information on commercial properties, which include office and retail locations, and housing transactions. Appendix B provides additional information on these secondary datasets. Summary statistics for apartment rentals are provided in Table 1, while a description of the variables is provided in Appendix Table A1.

The NII dataset also includes the latitude and longitude of the rental unit building. Four proximity measures are created with this information – distance to the nearest river, public park, school, and *shinkansen* (bullet train) station – using GIS and shapefiles collected from the MLIT. An indicator of whether the rental is located in a 100-year floodplain is also created using GIS. 100-year floodplains are areas where there is a 1% chance of a major flood occurring within a given year. For the Naka River floodplain, a major flood is defined as an instance where over 328mm of rainfall occurs over a 24-hour period. The expected flood depth from such a storm is also known and is discretized by the MLIT into three categories: greater than two meters, between one to two meters, or between zero and one meter. We create dummies for the former two categories and include them as controls within our hedonic price regression.

City, ward, and neighborhood identification numbers are also identified using GIS and MLIT shapefiles. We define neighborhoods in Fukuoka Prefecture at the *chocho* level. *Chocho* are geographical regions used by the postal service to indicate the city and neighborhood of each address. There are over 3,500 *chocho* across Fukuoka Prefecture, with the average *chocho* comprised of 355 households (Statistical Bureau of Japan, 2015). We use the terms *chocho* and neighborhood interchangeably throughout the text and tables given their similar definitions. Walking distance to the nearest local train station is also provided by the NII and therefore does not need to be computed using GIS.

Finally, we create two variables of interest: a dummy if the unit was leased after June, 2018 and a dummy if the rental is located within the Naka River floodplain. Rentals inside the Naka River floodplain receive additional protection from the Gokayama Dam, while rentals outside do not.[6] In our analysis we limit our sample to floodplain rentals, though our results are robust to the inclusion of non-floodplain units.

5. Identifying the impact of flood protection on rental values

Transactions between heterogenous buyers and sellers define a hedonic price equilibrium (Rosen, 1974) that maps underlying attributes of a good to its market value. By estimating the hedonic price function from price and attribute data, practitioners are able to indirectly value attributes of goods that are not sold in a conventional market. We apply the hedonic pricing method to estimate the value flood protection provides to renters living in Fukuoka Prefecture, Japan in equation (1).

$$(1)\ \mathrm{Ln\ Rent}_{ijt} = \gamma S_{it} + \pi \mathrm{NakaRiver}_i + \delta(\mathrm{NakaRiver}_i * \mathrm{Post}_t) + F_i + \zeta_t + \eta_j + \varepsilon_{ijt}$$

The natural log of rent for apartment i, leased in location j during month t is given by $\mathrm{Ln\ Rent}_{ijt}$. S_{it} is a vector of structural and locational features that define the unit, $\mathrm{NakaRiver}_i$ indicates whether the apartment is located within the Naka River's 100-year floodplain, Post_t is a dummy equaling one if the apartment was leased after June, 2018 and 0 otherwise, F_i, ζ_t, and η_j are vectors of floor, time, and spatial fixed effects respectively, while ε_{ijt} is an idiosyncratic error term. We define ζ_t at the year by month level to control for any seasonal and annual shifts

[6] In addition to indicating which areas are flood-prone, the MLIT links each floodplain to a specific river. This allows us to identify which properties are protected by the Gokayama Dam and which are not. It is also important to note that we use the most recent prefectural-wide floodplain map, which was published in 2012.

in the rental market. Finally, the shape of the hedonic price equilibrium is defined by the coefficients γ, π, and δ. Taking the derivative of the rental price function with respect to any of the observable attributes will reveal the capitalized value of that attribute (Rosen, 1974; Kuminoff and Pope, 2014).

The hedonic specification outlined in equation (1) follows a traditional difference-in-difference (DD) approach and relies on the occurrence of a flood as a source of exogeneous variation. Focusing on the first difference, $\text{NakaRiver}_{\text{i}}$ classifies apartments into a treated or control group where group assignment is dependent on whether the apartment is located in the Naka River floodplain. The parameter π is referred to as the group effect (Athey and Imbens, 2006; De Chaisemartin and d'Haultfoeuille, 2020) and captures any price difference associated with living within the Naka River floodplain prior to the 2018 floods. The second difference classifies apartments as being leased before $(\text{Post}_{\text{t}} = 0)$ or after the 2018 floods $(\text{Post}_{\text{t}} = 1)$ and controls for any price differential common to all floodplain apartments. Post_{t} is not directly included in equation (1) as the year by month fixed effects (ζ_{t}) already control for this difference. Finally, the coefficient on the interaction term δ reveals the average treatment effect on the treated, or put more simply: the effect of having flood protection from the Gokayama Dam on apartment rental values in the Naka River floodplain.

It is worth mentioning an implicit assumption made in equation (1). We define treatment based on when the dam was first tested by severe rainfall (July, 2018) rather than when it was completed (March, 2018). This is intentional as the added flood protection needs to be salient in order for it to be capitalized (Bradley, 2017). This decision aligns with prior findings which indicate differences in flood risk are only capitalized in periods following a flood (Bin and Polasky, 2004; Kousky, 2010; Atreya et al., 2013; Bin and Landry, 2013) and is consistent with the availability heuristic (Tversky and Kahneman, 1973) which suggests decision makers are unable to recognize all of the risk they face but instead rely on recent or dramatic events to teach them which risk to respond to. We test the validity of this assumption in section 6.

The capitalization of flood protection is likely heterogeneous across property types. We provide three alternatives to equation (1) which allow for additional heterogeneity. First, we implement a triple-difference estimator.

$$(2)\quad \text{Ln Rent}_{ijt} = \gamma S_{it} + \pi \text{NakaRiver}_i + \alpha I_i + \delta(\text{NakaRiver}_i * \text{Post}_t) + \theta(I_i * \text{Post}_t) + \rho(\text{NakaRiver}_i * I_i) + \varphi(\text{NakaRiver}_i * I_i * \text{Post}_t) + F_i + \zeta_t + \eta_j + \varepsilon_{ijt}$$

Equation (2) differs from equation (1) due to the inclusion of the third-difference I_i and its interactions with Post_t, NakaRiver_i, and $\text{NakaRiver}_i * \text{Post}_t$. We describe I_i only in generic terms as several sources of heterogeneity are tested, including whether the apartment unit is on the first floor or if the apartment building is located near a river. I_i takes a different form in each case. The coefficient of interest in equation (2) is φ as it indicates whether the average treatment effect of the treated varies across apartment types identified by the indicator I_i.

As an alternative to equation (1), we also estimate a hedonic equilibrium for commercial properties and housing transactions in equations (3) and (4) respectively. A separate hedonic equilibrium needs to be estimated for each property type as apartments, commercial real estate, and homes are transacted in separate markets.

$$(3)\quad \text{Ln ComRent}_{ijt} = \gamma_C \tilde{S}_{it} + \pi_C \text{NakaRiver}_i + \delta_C(\text{NakaRiver}_i * \text{Post}_t) + \zeta_t + \eta_j + \upsilon_{ijt}$$

$$(4)\quad \text{Ln HousePrice}_{ijt} = \gamma_H \check{S}_{it} + \pi_H \text{NakaRiver}_i + \delta_H(\text{NakaRiver}_i * \text{Post}_t) + \zeta_t + \eta_j + \sigma_{ijt}$$

The natural log of rent for commercial rental unit i, leased in location j during time t is given by Ln ComRent_{ijt}, while the natural log of housing price is given by $\text{Ln HousePrice}_{ijt}$. The covariates in equations (3) and (4) are defined as before, though accents are added to S_{it} to indicate that different characteristics are available for each property type (see Appendix B for more details). Subscripts C and H are also added to indicate differences in capitalization rates, while υ_{ijt} and σ_{ijt} are idiosyncratic error terms. We expect $\delta_C > \delta$ and $\delta_H > \delta$ as commercial renters and homeowners have more to lose monetarily than residential renters and therefore place a higher value on flood protection.

6. Results

Hedonic estimates from four variants of equation (1) are reported in Table 2, with the coefficients associated with the group effect and DD term listed at the top. Starting with the group effect in model 1, we find renters are willing to pay 9.1% more to live near the Naka River compared to living in another floodplain prior to July of 2018.[7] This aligns with expectations as the Naka River flows through some of the most densely populated areas in Fukuoka Prefecture where rental and housing prices are higher. This premium increased to 10% following the July 2018 floods, indicating the added flood protection provided by the Gokayama Dam increased downstream rental values by 0.9%. Model 1 is unlikely to provide a causal relationship though as unobserved amenities (distance to the nearest convenience store, average crime rates, access to open space, etc.) are spatially correlated, likely biasing the DD coefficient.

One solution is to add more stringent spatial fixed effects which forces identification to come from within a tighter spatial grouping (Kuminoff et al., 2010). We explore different transformations of the spatial fixed effect in models 2 - 4 and discuss their role on identification.

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[7] Dummy variable coefficients referenced in the text have been corrected using the technique suggested by Halvorsen and Palmquist (1980) due to the use of a semi-log functional form.

We begin by adding ward and neighborhood fixed effects to models 2 and 3 respectively. Neighborhood characteristics like access to open space, average school quality, and distance to the nearest shopping center are likely correlated with rent and the Naka River indicator, biasing the DD coefficient. Models 2 and 3 are better suited to mitigate this bias by controlling for time-invariant features specific to the apartment's ward and neighborhood respectively.

In both models, the DD coefficient is positive and statistically significant indicating the premium associated with living in the Naka River floodplain increased following the 2018 floods.[8] Renters likely updated their perceptions of how often a flood could happen and the damage it could inflict after seeing reports of widespread destruction across western Japan. These updated preferences manifested themselves in higher rental rates within the Naka River floodplain where a newly constructed dam prevented downstream flooding. Relative to rental prices in other floodplains, rental prices along the Naka River increased between 1.8% and 2.1%. This suggests a yearly benefit between $120 (model 3) and $140 (model 2) when evaluated at the average monthly rent within the Naka River floodplain ($556). We attribute this premium to the added flood protection provided by the Gokayama Dam.

The DD specification in models 2 and 3 causally identifies the relationship between rental values and flood protection so long as unobserved apartment characteristics are independent of the treatment and group status. Inclusion of apartment unit fixed effects are one of the strongest controls to ensure this independence as they control for characteristics that are difficult to measure, such as the view from the apartment unit, whether there is a noisy neighbor, and the overall flow and design. Similar to a repeat-sales or property fixed effect model, we limit

[8] The Naka River indicator is removed from model (3) due to perfect collinearity with the neighborhood fixed effects.

the sample to rentals leased multiple times (16,904) while also including a fixed effect for each rental unit.

Flood protection provided by the Gokayama Dam continues to be positively capitalized in model 4 with rental prices increasing by 1.4% after July 2018. This point estimate is similar to the previous measures as it is within model 3's 95% confidence interval (0.012 to 0.024). One concern is that more frequently transacted apartments may not be representative of the entire rental market (Palmquist, 2005). We find evidence of this when comparing attributes of apartments sold once vs multiple times in Appendix Table A2. The difference across samples is often meaningful and statistically significant, with one-time rentals 12% less likely to have an AC unit. Large differences are also observed in relation to whether the apartment comes with a stove, is near the Naka River, has an elevator within the building and whether there are security cameras nearby. Given these differences, we use model 3 as our baseline model as it retains the full sample, includes stringent spatial fixed effects, and produces estimates similar to model 4.

First Floor Units

The extent to which flood protection is reflected in rent is likely heterogeneous across apartment units. We explore four sources of heterogeneity using a triple-difference estimator (equation (2)). For each triple-difference model, we include an indicator for the third difference directly in the model as well as its interaction with $\mathrm{NakaRiver_i}$, $\mathrm{Post_t}$, and $\mathrm{NakaRiver_i} * \mathrm{Post_t}$. For brevity, we only report the coefficients from $\mathrm{NakaRiver_i} * \mathrm{Post_t}$ and the triple-difference term.

We begin with an examination of whether flood protection is capitalized differently between first and higher floor units. First floor units in general are sold at a discount[9] as they lack the privacy, view, and security that is afforded to units higher up (Nakagawa et al., 2007) but are also likely to receive the most flood damage. We capture this difference by transforming our DD model into a triple-difference model using a first-floor indicator ($\mathrm{I_i} = \mathrm{First_i}$) and report the coefficients under model 5 in Table 3.

First floor units within Naka River floodplain received an additional premium following the 2018 floods, increasing in value by approximately 3.3% while higher-floored units experienced a 1.6% price increase. Interestingly, model 5 indicates that flood protection is capitalized in all apartment units, even those above the water inundation level. This conforms with findings observed in other markets (Kousky, 2010). Residents living on higher floors are still inconvenienced by floodwaters as flooding can make local roads and railways impassable, cause power outages, shutter nearby businesses, cut off water and sewage services, and damage local amenities. In addition, any vehicles parked nearby may be damaged or completely lost during a flood.

One Room Apartments

The rental market provides housing services for both short and long-term residents. We expect short-term renters have a lower capitalization rate as the probability of experiencing a flood reduces with shorter residency. Although we do not have information on how long renters stay, some units are designed specifically for renters searching for temporary housing. Approximately

[9] We observe a monotonic relationship in the floor fixed effects in model 3 where higher-floored units are 1% to 10% more expensive than first floors units.

8.4% of the rental units in our sample are designated as "one room" apartments. One room apartments are distinctive as they are similar in quality and layout to a college dorm, with the entire apartment consisting of one multi-purpose room and one bathroom. The average one room apartment is 20.0% cheaper and 30.3% smaller than the average unit in our sample.

To test whether one room apartment renters are responsive to flood protection, we convert the DD model into a triple-difference estimator using a third difference term $(\mathrm{I_i} = \mathrm{One\ Room_I})$ and report the results under model 6. The triple interaction term is similar in magnitude and significance as the baseline coefficient but has an opposing sign, indicating that flood protection is not capitalized into one room apartment rents. The lack of a relationship is intuitive as these units are often rented to a more transitory segment of the population (students and single-person households). According to a survey conducted by the Japanese Property Management Association, only 9.5% of students and 22.6% of single-person households have lived within their current residence for more than 4 years, while 73.4% of multi-person households meet this criteria (Japan Property Management Association, 2020). As flooding is an extreme but infrequent event, we do not expect short-term residents to prioritize or even consider flood protection when searching for their new apartment, which is what we observe in model 6.

Expected Flood Depth and Proximity to the Nearest River

Floodplain renters in low elevation areas are expected to incur greater damage from floodwaters relative to renters higher up. To capture this difference, we use expected flood depth data contained with the floodplain maps. In particular, the MLIT details not only the location of the 100-year floodplains but also the expected flood depth within these areas (see section 4 for more details). We define a triple-difference model using the deepest flood depth category (>2 meters) and report the results under model 7 of Table 3. Apartments within the Naka River floodplain where floodwaters are predicted to exceed two meters experienced an additional 4.6% price premium after the 2018 floods.

Similar to renters living in low elevation areas, renters living near rivers may be more sensitive to flood protection as they are the first to be impacted. We consider this possibility by creating a spatial indicator of whether an apartment is within 50 meters of a river ($\mathrm{Adjacent_i} = 1$) and use this dummy to form a triple-difference model, which we label as model 8 in Table 4. The positive and statistically significant coefficient on the triple interaction term indicates renters living near rivers benefit more from additional flood protection than those living farther away. Specifically, Naka River floodplain rents increased by 4.6% if the property was river adjacent, while non-adjacent properties experienced a 1.7% price increase. This triple interaction term attenuates to zero as more distant properties are defined as river adjacent in models 9 – 11, where adjacency is defined using a 75-meter, 100-meter, and 125-meter cutoff respectively.

Commercial Rentals and Housing Sales

Residential renters are not the only beneficiaries of flood protection; business and home owners are also concerned about protecting their property from flood damage. According to a survey of 900 business establishments in Ozu City, which east of the study area, 6% of businesses had to close or relocate due to damage caused by Typhoon Prapiroon (Nikkei Newspaper, 2021). We examine how commercial rentals responded to Typhoon Prapiroon by re-estimating models 1 – 3 using listing data from office and retail locations (see Appendix B for more details) and present these results in Table 5. Focusing on the first two rows, we find commercial rents were more reactive, increasing in value between 8.3% and 9.5%. For the average commercial renter within the Naka River floodplain with a monthly rent of $3,010, this translates into an annual price premium between $3,088 and $3,431.

Homeowners are another stakeholder group that benefited from the Gokayama Dam. Their capitalized gains likely exceed the price premiums observed in apartment rental contracts as their chances of encountering a 100-year storm within their current residence are higher. In addition, they are at risk of losing more as homeowners need to replace not only their lost belongings but also pay for any structural repairs. We examine this issue by collecting housing transactions information from the MLIT and re-estimating models 1 – 3 once again (see Appendix B for the full set of results and additional information about the data). Overall, downstream housing prices increased by 9.6% to 11.6%. Assuming a 4% rate of interest over a 30-year timespan (MLIT, 2018), this suggests the average homeowner within the Naka River gained a yearly benefit between $2,299 and $2,783 from the Gokayama Dam.[10]

Threats to Identification and Robustness

Apartment rents within the Naka River floodplain may have increased over time for reasons outside of the completion and subsequent testing of the Gokayama Dam. We test this concern by modifying the baseline model (model 3) to allow the DD coefficient to vary across time (quarters) and present the updated coefficients and their 95% confidence intervals in Figure 3. All coefficients in Figure 3 should be interpreted in relation to the omitted category, which is the quarter of the flood. There does not appear to be any significant pre-trends in apartment rental

[10]We follow the guidelines provided in section 6 of National Center for Environmental Economics (2014) when converting total cost or benefit estimates into annual terms throughout the text. A 4% interest rate is also assumed when making these calculations (MLIT, 2018).

prices as most of the DD terms are statistically insignificant prior to the flooding event. Had several of the coefficients been statistically significant or if there was an increasing trend over time, this would suggest Naka River apartment rental prices would have increased regardless of whether the Gokayama Dam was built.

Instead, we observe a discrete increase immediately after the flood that is retained until at least the end of the study period. The temporal pattern observed in Figure 3 is consistent with the idea that renters updated their perceptions of flood risk after the July 2018 floods and acted on those new perceptions by paying more for apartments downstream from the recently constructed Gokayama Dam. Three other major milestone events occurred between 2015 and 2019 that should be noted. The main embankment of the Gokayama Dam was completed in January of 2016, test flooding began later that year in October, and finally the dam became operational in March of 2018. Each milestone could have been taken as a signal by downstream residents that the area was better protected against major flooding. Residents do not appear to have acted in this manner though as rental prices were relatively flat, suggesting a possible information gap between renters' perceptions of flood risk and actual flood risk.

A common robustness check within the quasi-experimental literature is to perform falsification tests by incorrectly defining the group assignment or treatment variable and seeing whether the relationship revealed in prior models holds. The expectation is that the DD coefficient should be statistically insignificant as there should be no treatment effect on observations that did not receive a treatment. We perform two falsification tests by changing the definition of the group assignment variable. In model 18 (model 19) we assume the treatment group is defined by whether the apartment is within the Hii (Tatara and Umi) River floodplain or not (see Figure 2 for locations of the Hii and Tatara and Umi River floodplain). If our estimates are causally identified, we should expect the DD coefficient to be statistically as no dam was recently built in either of these floodplains. We find this to be the case in Table 6 with both DD coefficients not statistically different from zero.

Rental properties along the Naka River could have been renovated following the floods, biasing the DD coefficient as the effect of improved rental unit quality would be confounded with an updating of risk perceptions (McCoy and Xiaoxi, 2018; Gibson and Mullins, 2020). We find little evidence this occurred, however. Only 59 properties in Fukuoka City[11] were damaged by the floods (Fukuoka Prefecture, 2019) making it unlikely that widespread renovation occurred. Reconstruction of public facilities along the Naka River (i.e., public access points, boardwalks, parks, etc.) could also confer secondary benefits that would confound identification. After discussing this matter with local river managers from Fukuoka Prefecture, we found no such projects occurred as there was minimal damage to the Naka River or its embankments.

Policy Implications

Our capitalization estimates suggest apartment renters are less responsive to flood risk than homeowners or commercial renters, with apartment rents increasing by 1.8% (model 3) after the completion and subsequent real-world testing of an upstream dam. This premium is small in comparison to the price effects observed in the commercial rental (9.1%) and housing (11.6%) market. This difference is magnified even further when evaluated in dollar terms as apartment renters gained a yearly benefit of $120, while homeowners and commercial renters gained $2,783 and $3,280 respectively.

[11] Similar to other studies, spatially-fine data detailing where flooding occurred is unavailable. Damage estimates are only reported at the city level (Fukuoka Prefecture, 2019).

There are at least two reasons why we see smaller capitalization estimates within the apartment rental market. First, apartment renters tend to be more mobile than other demographic groups. According to a survey conducted by the Statistical Bureau of Japan, 30.8% of renters moved within the past 5 years as compared to only 8.6% of homeowners (Statistical Bureau of Japan, 2019). Renters therefore face systematically lower levels of risk due to their shorter residency. Second, apartment renters have less at stake financially as they are only responsible for covering the cost of their lost or damaged possessions. Homeowners need to replace their lost belongings as well as pay for structural repairs, while businesses may suffer financial losses from production delays and damage to commercial equipment (Nikkei Newspaper, 2018).

To better understand the cost-effectiveness of the Gokayama Dam, we calculate an aggregate benefit measure using information from the downstream apartment rental market and compare to the total cost of the dam. We do not include benefits from the housing or commercial rental market as there is a lower likelihood, in either case, the identifying sample is representative of the larger market. Both datasets are also less detailed in terms of the available structural and locational attributes that define each property (see Appendix B for more details). Turning our attention to the average floodplain apartment renter, their yearly benefit from living downstream from the Gokayama Dam is $120. If we aggregate this measure across *all* rental apartments within the Naka River floodplain (94,532)[12], we find a yearly benefit of $11.3 million associated with the completion of the Gokayama Dam.

[12] We use the following equation to estimate the total number of rental apartments within the Naka River floodplain: $\sum_{j=1}^{J}(FloodLand_j * TotalApt_j * 0.788)$. j indexes across neighborhoods, $FloodLand_j$ is the percentage of neighborhood j's land area within the Naka River floodplain, and $TotalApt_j$ is the total number of apartment units in neighborhood j (Statistical Bureau of Japan, 2016). We multiply the product of $FloodLand_j$ and $TotalApt_j$ by 0.788 as 21.2% of households in Fukuoka Prefecture own rather than rent their apartment (Statistical Bureau of Japan, 2016).

The cost of the Gokayama Dam – $600 million – overshadows these benefits by more than 50 to 1. In annual terms this is equivalent to $27.9 million per year, which is a more reasonable comparison.[13] Taken together, the benefits from the apartment rental market cover more than one-third the yearly cost of the dam. This suggests the Gokayama Dam would likely pass a cost-benefit analysis as there are many other stakeholder groups unaccounted for within this analysis, including: homeowners, commercial renters, owners of rental properties, non-renter commercial entities, and the local government. The dam provides benefits to non-floodplain properties as well through irrigation management and drought prevention.

Nevertheless, it should be noted that the benefits within apartment rental market may be temporary. Capitalization of flood risk within housing prices is found to dissipate 5 to 10 years following a natural disaster (Atreya et al., 2013; Bin and Landry, 2013). Persistent price effects, on the other hand, were observed in both damaged and undamaged units in areas flooded by Hurricane Sandy (Ortega and Taspinar, 2018). The temporal nature of the price discount depends on the severity of the natural disaster. Only extreme events, relative to what's normal in each area, impact beliefs and give rise to persistent effects (Ortega and Taspinar, 2018). We are unable to test which scenario is more likely though as our rental data is limited to listings posted between 2015 and 2019.

7. Conclusion

Japan has one of the world's most extensive inland flood-protection networks. At the forefront of this network are more than 2,500 dams that generate electricity, store irrigation water, and

[13]We assume a 50-year timespan when annualizing the cost of the Gokayama Dam as this is the average length of time until a dam shows sign of stress (Perera et al., 2021).

provide protection to millions of downstream residents. Many of these dams need to be repaired or replaced in the near future to maintain current levels of flood protection, though the cost of replacement can be in the hundreds of millions of dollars. To complicate matters, there is growing discontent and an opinion that public money should be spent elsewhere. Climate change may tip the scales towards greater flood protection in the future, however, due to the increased likelihood of flooding events caused by heavy rainfall and damaging typhoons.

We provide key information for one of the largest stakeholder groups impacted by flood protection, downstream renters. Following the large-scale flooding in July of 2018 that caused billions of dollars in damage across western Japan, we find apartment rental prices within the Naka River floodplain increased by 1.8% relative to apartments in other floodplains within Fukuoka Prefecture, Japan. We attribute this price premium to the flood protection provided by the newly constructed Gokayama Dam as downstream residents were likely unaware of the protection it provided until it was put to the test in July of 2018. Rental prices for commercial properties and housing values also appreciated, increasing in value by 9.1% and 11.6% respectively. Translated into annual terms, our capitalization estimate suggests an annual benefit of $120 to apartment renters each year from the added flood protection provided by the Gokayama Dam, while homeowners and commercial renters experienced benefits of more than $2,500 each year.

The capitalized gains from flood protection within the apartment rental market are small in comparison to the premiums paid by homeowners and commercial renters. Apartment renters may be more tolerant of flood risk as they have fewer financial liabilities and can walk away from the disaster more easily. Flood protection is also observed to be heterogeneously capitalized in downstream rents with first floor apartments receiving a larger price premium from flood protection compared to higher units. Apartments designed as more temporary housing did not change in value, while units closer to rivers and in areas where floodwaters are expected to reach two meters benefited more.

Our capitalization measures provide key insights as to who benefits from flood protection and the extent of these benefits. Going forward, policymakers may find these measures useful when determining where and to what extent additional flood protection should be constructed. Additional research examining the relationship between flood protection and land, housing, and commercial property sales would complement our research and provide a more holistic understanding of how communities benefit from reduced flood risk. We expect this line of research will grow in importance as communities worldwide continue to be impacted by floods and search for cost-effective mitigation strategies.

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Table 1 – Floodplain Apartment Summary Statistics

	Naka River Floodplain (N=47,417)				Other Floodplains (N=44,222)			
	Mean	**Std. Dev.**	**Min**	**Max**	**Mean**	**Std. Dev.**	**Min**	**Max**
Monthly Rent (2015 USD)	555.798	168.550	209.091	1,325.758	514.778	167.977	207.976	1,325.758
Square Meters	33.008	12.808	20.000	86.100	41.275	16.090	20.000	86.040
Number of Bedrooms	1.262	0.548	1.000	4.000	1.588	0.744	1.000	4.000
Floor	5.558	3.241	1.000	15.000	3.546	2.593	1.000	15.000
Months Advertised	3.335	4.095	1.000	32.000	4.871	5.297	1.000	32.000
Living Room (0/1)	0.329	0.470	-	-	0.471	0.499	-	-
Dining Room (0/1)	0.451	0.498	-	-	0.655	0.475	-	-
WC (0/1)	0.598	0.490	-	-	0.522	0.500	-	-
Heated Toilet (0/1)	0.464	0.499	-	-	0.443	0.497	-	-
AC (0/1)	0.549	0.498	-	-	0.597	0.491	-	-
Stove (0/1)	0.664	0.472	-	-	0.424	0.494	-	-
Fridge (0/1)	0.036	0.187	-	-	0.018	0.133	-	-
Washer Hookups (0/1)	0.937	0.244	-	-	0.914	0.280	-	-
Storage (0/1)	0.812	0.391	-	-	0.611	0.488	-	-
Walk-in Closet (0/1)	0.108	0.310	-	-	0.087	0.282	-	-
One Room Apt (0/1)	0.108	0.310	-	-	0.059	0.235	-	-
Elevator (0/1)	0.884	0.320	-	-	0.541	0.498	-	-
Security Camera (0/1)	0.846	0.361	-	-	0.502	0.500	-	-
Bicycle Parking (0/1)	0.964	0.187	-	-	0.896	0.305	-	-
Fiber Internet (0/1)	0.932	0.251	-	-	0.636	0.481	-	-
CATV (0/1)	0.952	0.213	-	-	0.656	0.475	-	-
Steel (0/1)	0.060	0.237	-	-	0.194	0.395	-	-
Concrete (0/1)	0.909	0.287	-	-	0.656	0.475	-	-
Medium Water Depth (0/1)	0.180	0.384	-	-	0.216	0.411	-	-
High Water Depth (0/1)	0.003	0.052	-	-	0.051	0.221	-	-
Post (0/1)	0.330	0.470	-	-	0.294	0.456	-	-
Sale Month	6.312	3.375	1.000	12.000	6.125	3.428	1.000	12.000
Sale Year	2017	1.279	2015	2019	2017	1.282	2015	2019
Year Built	2000	10.317	1928	2019	2000	9.731	1933	2019
Distance to Station (minutes)	8.593	4.485	1.000	78.000	11.856	8.708	1.000	83.000
Distance to River (100s of meters)	4.890	3.329	0.067	16.280	3.353	2.548	0.048	23.471
Distance to Park (100s of meters)	1.853	0.898	0.091	5.453	3.605	8.562	0.027	114.702
Distance to School (100s of meters)	3.412	1.502	0.254	8.354	4.481	2.595	0.324	16.205
Distance to Bullet Train (100s of meters)	20.189	13.402	2.053	94.511	62.927	57.945	1.403	412.490

Table 2 – Baseline Model and Robustness to Spatial Fixed Effect Definition

VARIABLES	Model (1)	Model (2)	Model (3)	Model (4)	VARIABLES	Model (1)	Model (2)	Model (3)	Model (4)
Naka River*Post (0/1)	**0.009****	**0.021*****	**0.018*****	**0.014*****	Bicycle Parking (0/1)	0.008	0.011	0.013*	-
	(0.004)	**(0.003)**	**(0.003)**	**(0.002)**		(0.009)	(0.007)	(0.007)	-
Naka River (0/1)	**0.087*****	**0.004**	-	-	Fiber Internet (0/1)	0.008	-0.001	0.003	-
	(0.011)	**(0.010)**	-	-		(0.007)	(0.006)	(0.005)	-
Ln Floor Area	0.573***	0.609***	0.621***	-	CATV (0/1)	0.067***	-0.014*	-0.013*	-
	(0.019)	(0.016)	(0.016)	-		(0.009)	(0.007)	(0.007)	-
Number of Bedrooms	0.010	0.004	0.010*	-	Steel (0/1)	0.012	0.025***	0.011	-
	(0.007)	(0.006)	(0.006)	-		(0.009)	(0.008)	(0.007)	-
Living Room (0/1)	0.049***	0.040***	0.039***	-	Concrete (0/1)	0.014	0.012	0.009	-
	(0.006)	(0.005)	(0.005)	-		(0.010)	(0.008)	(0.007)	-
Ln Months Advertised	-0.007***	0.003**	0.002	-	Year Built 1970 (0/1)	-0.030	-0.049	-0.030	-
	(0.002)	(0.001)	(0.001)	-		(0.031)	(0.033)	(0.030)	-
Dining Room (0/1)	-0.009	-0.010*	-0.008	-	Year Built 1980 (0/1)	-0.003	-0.018	0.001	-
	(0.007)	(0.006)	(0.006)	-		(0.029)	(0.032)	(0.030)	-
WC (0/1)	0.016***	0.015***	0.015***	-	Year Built 1990 (0/1)	0.069**	0.068**	0.099***	-
	(0.004)	(0.003)	(0.003)	-		(0.029)	(0.032)	(0.029)	-
Heated Toilet (0/1)	0.037***	0.040***	0.033***	-	Year Built 2000 (0/1)	0.176***	0.170***	0.201***	-
	(0.004)	(0.003)	(0.003)	-		(0.029)	(0.032)	(0.030)	-
AC (0/1)	0.011***	0.011***	0.009***	-	Year Built 2010 (0/1)	0.239***	0.234***	0.264***	-
	(0.003)	(0.002)	(0.002)	-		(0.031)	(0.033)	(0.031)	-
Stove (0/1)	0.045***	0.037***	0.026***	-	Medium Water Depth (0/1)	0.035***	0.012**	-0.002	-
	(0.004)	(0.003)	(0.003)	-		(0.007)	(0.006)	(0.006)	-
Fridge (0/1)	0.031***	0.032***	0.030***	-	High Water Depth (0/1)	-0.055***	0.034***	0.001	-
	(0.012)	(0.011)	(0.010)	-		(0.011)	(0.012)	(0.021)	-
Washer Hookups (0/1)	0.020***	0.021***	0.018***	-	Ln Distance to Station	-0.047***	-0.044***	-0.008	-
	(0.006)	(0.005)	(0.005)	-		(0.006)	(0.006)	(0.006)	-
Storage (0/1)	-0.026***	-0.028***	-0.018***	-	Ln Distance to River	0.017***	0.012***	0.008**	-
	(0.003)	(0.003)	(0.002)	-		(0.004)	(0.003)	(0.004)	-
Walk-in Closet (0/1)	0.011*	0.016***	0.018***	-	Ln Distance to Park	-0.011**	0.001	-0.003	-
	(0.007)	(0.006)	(0.005)	-		(0.004)	(0.004)	(0.004)	-
One Room Apt (0/1)	-0.034***	-0.030***	-0.034***	-	Ln Distance to School	-0.008	0.001	0.006	-
	(0.006)	(0.005)	(0.005)	-		(0.006)	(0.005)	(0.006)	-
Elevator (0/1)	0.074***	0.070***	0.058***	-	Ln Distance to Bullet Train	-0.017***	-0.060***	-0.069***	-
	(0.007)	(0.006)	(0.005)	-		(0.005)	(0.007)	(0.019)	-
Security Camera (0/1)	0.016**	0.008*	0.006	-					
	(0.006)	(0.005)	(0.005)	-					
Floor FE	YES	YES	YES	NO					
Time FE	YEAR x MONTH	YEAR x MONTH	YEAR x MONTH	YEAR x MONTH					
Spatial FE	NO	WARD	NBHD	UNIT					
Observations	91,639	91,639	91,639	16,904					
Adjusted R^2	0.796	0.845	0.881	0.980					

Notes: *, **, *** denotes significance at the 10%, 5%, and 1% level respectively.
Robust standard errors are clustered at the neighborhood level.

Table 3 – Heterogeneity in Flood Protection Capitalization

VARIABLES	Model (5) First Floor	Model (6) One Room Units	Model (7) Floodwater Depth
Naka River*Post (0/1)	**0.016*** **	**0.019*** **	**0.016*** **
	(0.003)	**(0.003)**	**(0.003)**
Naka River*Post*First (0/1)	**0.017** **	**-**	**-**
	(0.007)	**-**	**-**
Naka River*Post*One Room (0/1)	**-**	**-0.020** **	**-**
	-	**(0.009)**	**-**
Naka River*Post*High Water Depth (0/1)	**-**	**-**	**0.045*** **
	-	**-**	**(0.012)**
Property-Level Controls	YES	YES	YES
Floor FE	YES	YES	YES
Time FE	YEAR x MONTH	YEAR x MONTH	YEAR x MONTH
Spatial FE	NBHD	NBHD	NBHD
Observations	91,639	91,639	91,639
Adjusted R^2	0.881	0.881	0.881

Notes: Secondary interaction and level terms are included within each model but not reported for brevity.
*, **, *** denotes significance at the 10%, 5%, and 1% level respectively.
Robust standard errors are clustered at the neigborhood level.

Table 4 – Proximity to the Nearest River

VARIABLES	Model (8) 50 meters	Model (9) 75 meters	Model (10) 100 meters	Model (11) 125 meters
Naka River*Post (0/1)	**0.017*** **	**0.016*** **	**0.016*** **	**0.016*** **
	(0.003)	**(0.003)**	**(0.003)**	**(0.003)**
Naka River*Post*Adjacent (0/1)	**0.028** **	**0.018** **	**0.014* **	**0.010**
	(0.012)	**(0.009)**	**(0.008)**	**(0.007)**
Property-Level Controls	YES	YES	YES	YES
Floor FE	YES	YES	YES	YES
Time FE	YEAR x MONTH	YEAR x MONTH	YEAR x MONTH	YEAR x MONTH
Spatial FE	NBHD	NBHD	NBHD	NBHD
Observations	91,639	91,639	91,639	91,639
Adjusted R^2	0.881	0.881	0.881	0.881

Notes: Secondary interaction and level terms are included within each model but not reported for brevity.
*, **, *** denotes significance at the 10%, 5%, and 1% level respectively.
Robust standard errors are clustered at the neighborhood level.

Table 5 – Commercial Rentals and Housing Sales

	Commerical Rentals			Housing Sales		
VARIABLES	Model (12)	Model (13)	Model (14)	Model (15)	Model (16)	Model (17)
Naka River*Post (0/1)	**0.091***	**0.080****	**0.087*****	**0.092***	**0.095****	**0.110*****
	(0.046)	**(0.040)**	**(0.033)**	**(0.048)**	**(0.042)**	**(0.036)**
Naka River (0/1)	**0.410*****	**0.181*****	**-**	**0.445*****	**0.264*****	**-**
	(0.044)	**(0.061)**	**-**	**(0.038)**	**(0.068)**	**-**
Property-Level Controls	YES	YES	YES	YES	YES	YES
Time FE	YEAR x MONTH	YEAR x MONTH	YEAR x MONTH	YEAR x QUARTER[a]	YEAR x QUARTER[a]	YEAR x QUARTER[a]
Spatial FE	NO	WARD	NBHD	NO	WARD	NBHD
Observations	5,456	5,456	5,456	9,206	9,206	9,206
Adjusted R^2	0.779	0.784	0.827	0.596	0.747	0.807

Notes: [a]Sales of single-family homes are only identified during the quarter of the transaction. See Appendix B for more details.
*, **, *** denotes significance at the 10%, 5%, and 1% level respectively.
Robust standard errors are clustered at the neighborhood level.

Table 6 – Falsification Tests

VARIABLES	Model (18) Hii River	Model (19) Tatara/Umi River
Naka River*Post (0/1)	**0.002**	**0.005**
	(0.006)	**(0.004)**
Property-Level Controls	YES	YES
Floor FE	YES	YES
Time FE	YEAR x MONTH	YEAR x MONTH
Spatial FE	NBHD	NBHD
Observations	91,639	91,639
Adjusted R^2	0.881	0.881

Notes: *, **, *** denotes significance at the 10%, 5%, and 1% level respectively. Robust standard errors are clustered at the neighborhood level.

Figure 1 – Fukuoka Prefecture Floodplains

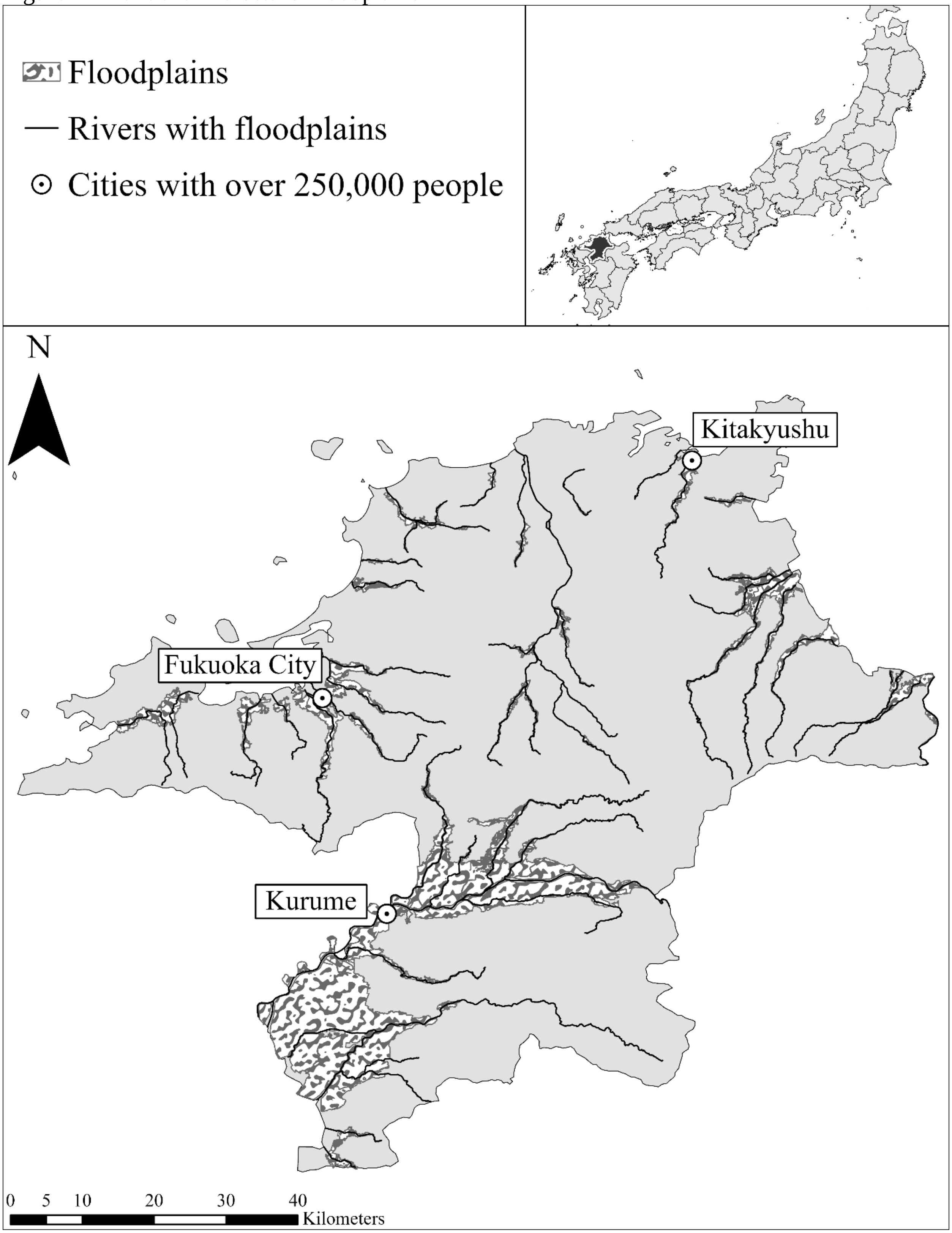


Figure 2 - Major Rivers and their Floodplains in Fukuoka and Nakagawa City

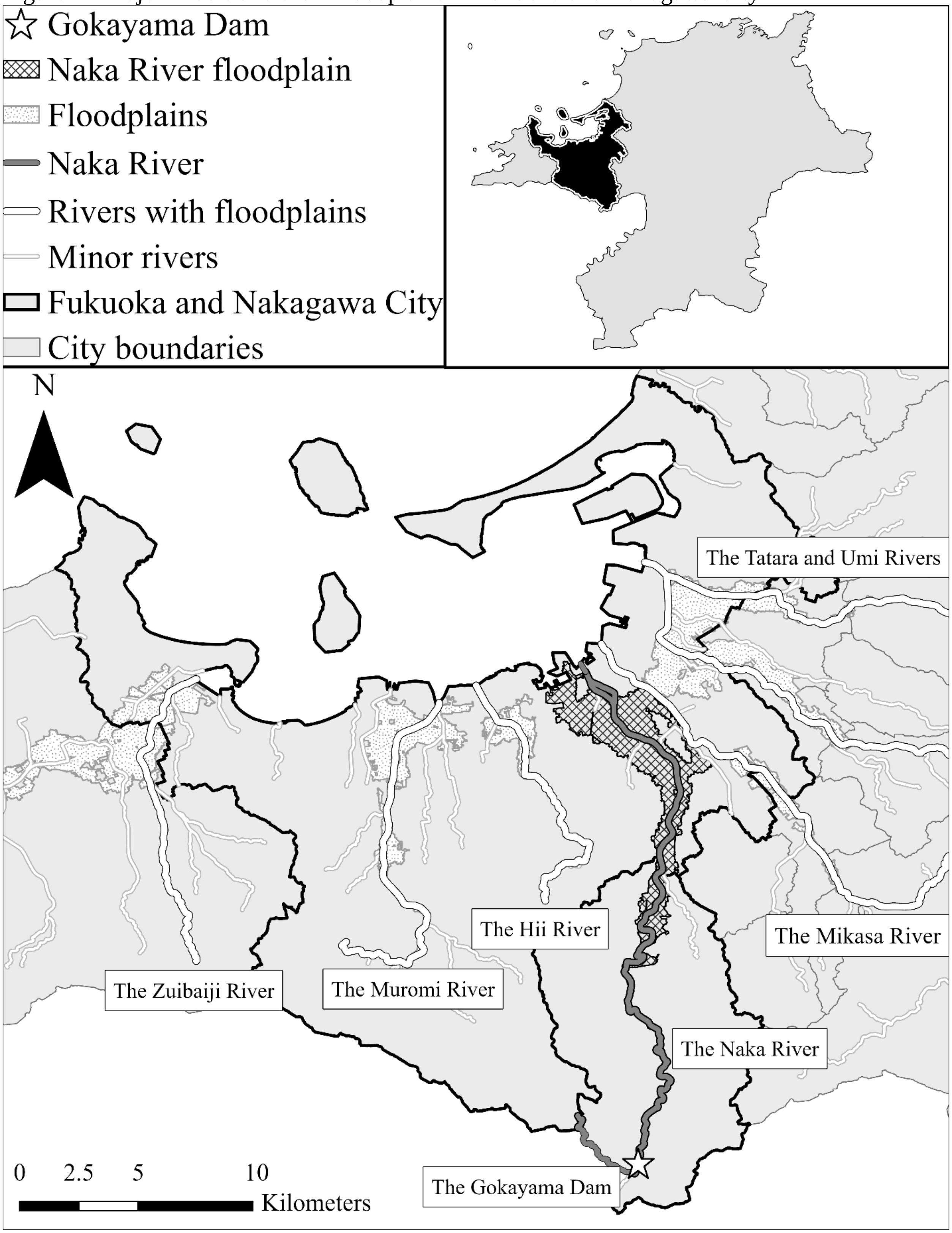
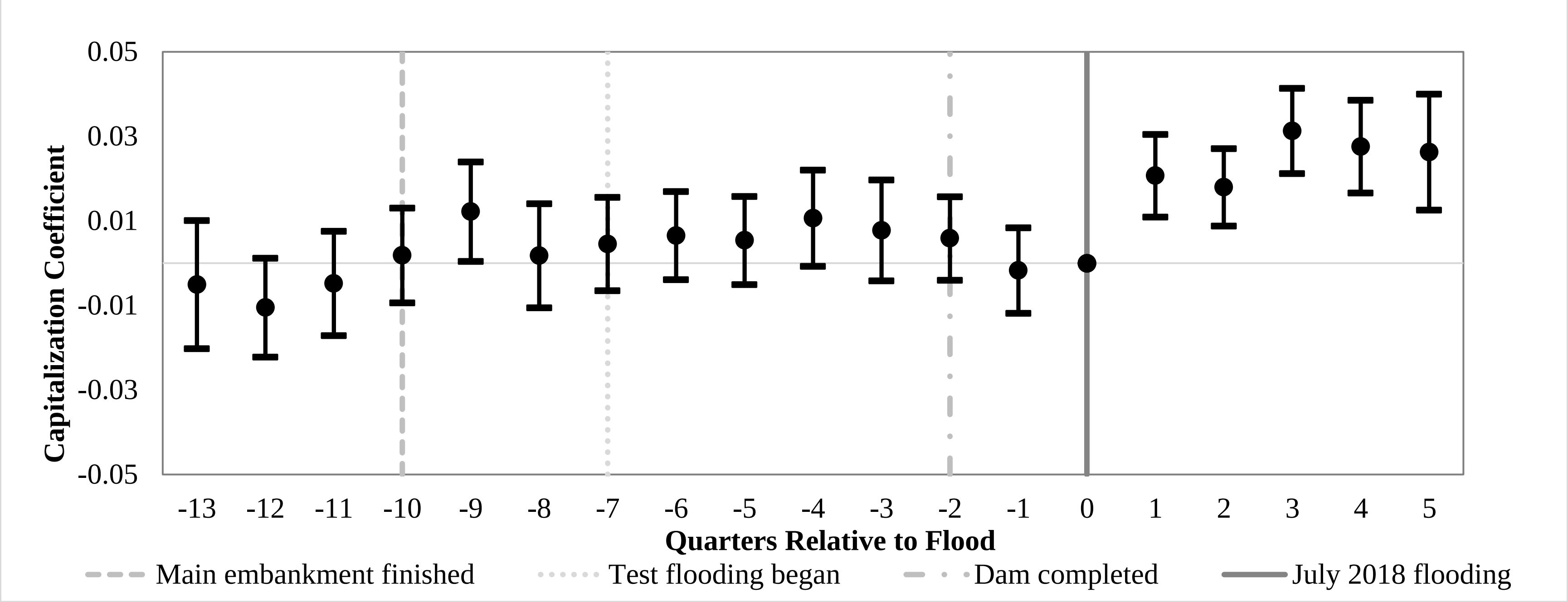


Figure 3 – Capitalization Effects across Time



Appendix A: Additional Tables and Figures

Appendix Table A1 – Description of Variables

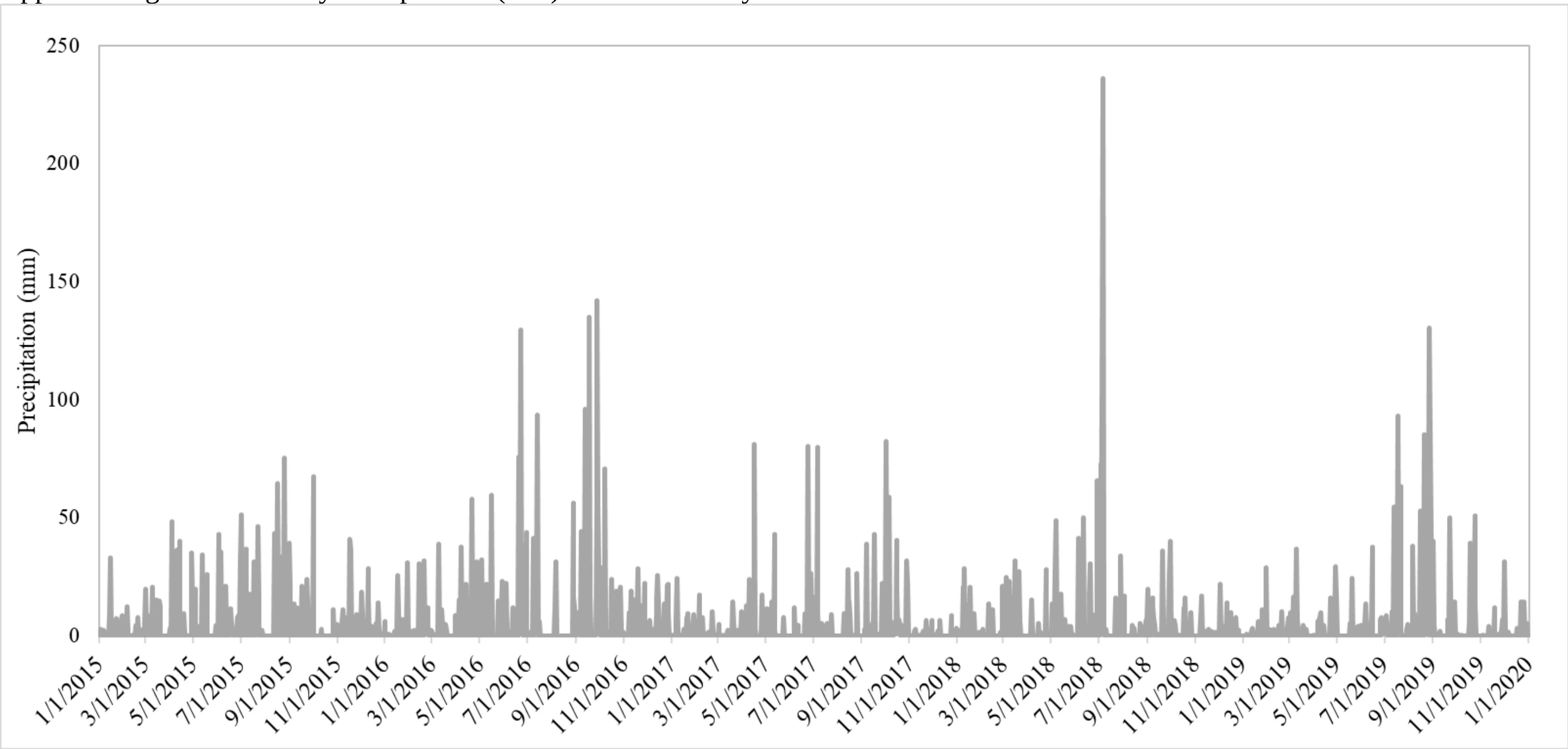
VARIABLES	DESCRIPTION	SOURCE
Monthly Rent (2015 USD)	Monthly rent	NII
Floor Area (square meters)	Size of unit	NII
Number of Bedrooms	Number of bedrooms	NII
Floor	Floor of rental unit	NII
Months Advertised	Number of months rental unit was advertised online	NII
Living Room (0/1)	Living room	NII
Dining Room (0/1)	Dining room	NII
WC (0/1)	Toilet and bathroom are in separate rooms	NII
Heated Toilet (0/1)	Self-heated toilet	NII
AC (0/1)	Air conditioner included	NII
Stove (0/1)	Stovetop unit included	NII
Fridge (0/1)	Refridgerator included	NII
Washer Hookups (0/1)	Washing machine hookups	NII
Storage (0/1)	Extra storage space in rental unit	NII
Walk-in Closet (0/1)	Walk-in closet	NII
One Room Apt (0/1)	One room/studio apartment	NII
Elevator (0/1)	Building has an elevator	NII
Security Camera (0/1)	Building has security cameras	NII
Bicycle Parking (0/1)	Building has bicycle or scooter parking	NII
Fiber Internet (0/1)	Building has fiber internet	NII
CATV (0/1)	Building has a cable TV connection	NII
Steel (0/1)	Building is made from steel	NII
Concrete (0/1)	Building is made from concrete	NII
Medium Water Depth (0/1)	Expected inundation level is 1 - 2 meters	MLIT
High Water Depth (0/1)	Expected inundation level exceeds 2 meters	MLIT
Sale Month	The year the rental unit was leased	NII
Sale Year	The month the rental unit was leased	NII
Year Built	The year the rental unit was constructed	NII
Year Built 1970 (0/1)	Rental unit was built between 1970 and 1979	NII
Year Built 1980 (0/1)	Rental unit was built between 1980 and 1989	NII
Year Built 1990 (0/1)	Rental unit was built between 1990 and 1999	NII
Year Built 2000 (0/1)	Rental unit was built between 2000 and 2009	NII
Year Built 2010 (0/1)	Rental unit was built between 2010 and 2019	NII
Distance to Station (minutes)	Walking distance to the nearest train station	NII
Distance to River (100s of meters)	Distance to the nearest first or second-class river	MLIT
Distance to Park (100s of meters)	Distance to the nearest public park	MLIT
Distance to School (100s of meters)	Distance to the nearest school	MLIT
Distance to Bullet Train (100s of meters)	Distance to the nearest bullet train station	MLIT
Naka River (0/1)	Rental unit is located in the Naka River floodplain	MLIT
Post (0/1)	Rental unit was leased after June 2018	NII

Notes: NII = National Institute of Informatics; MLIT = Ministry of Land, Infrastructure, Transport and Tourism.

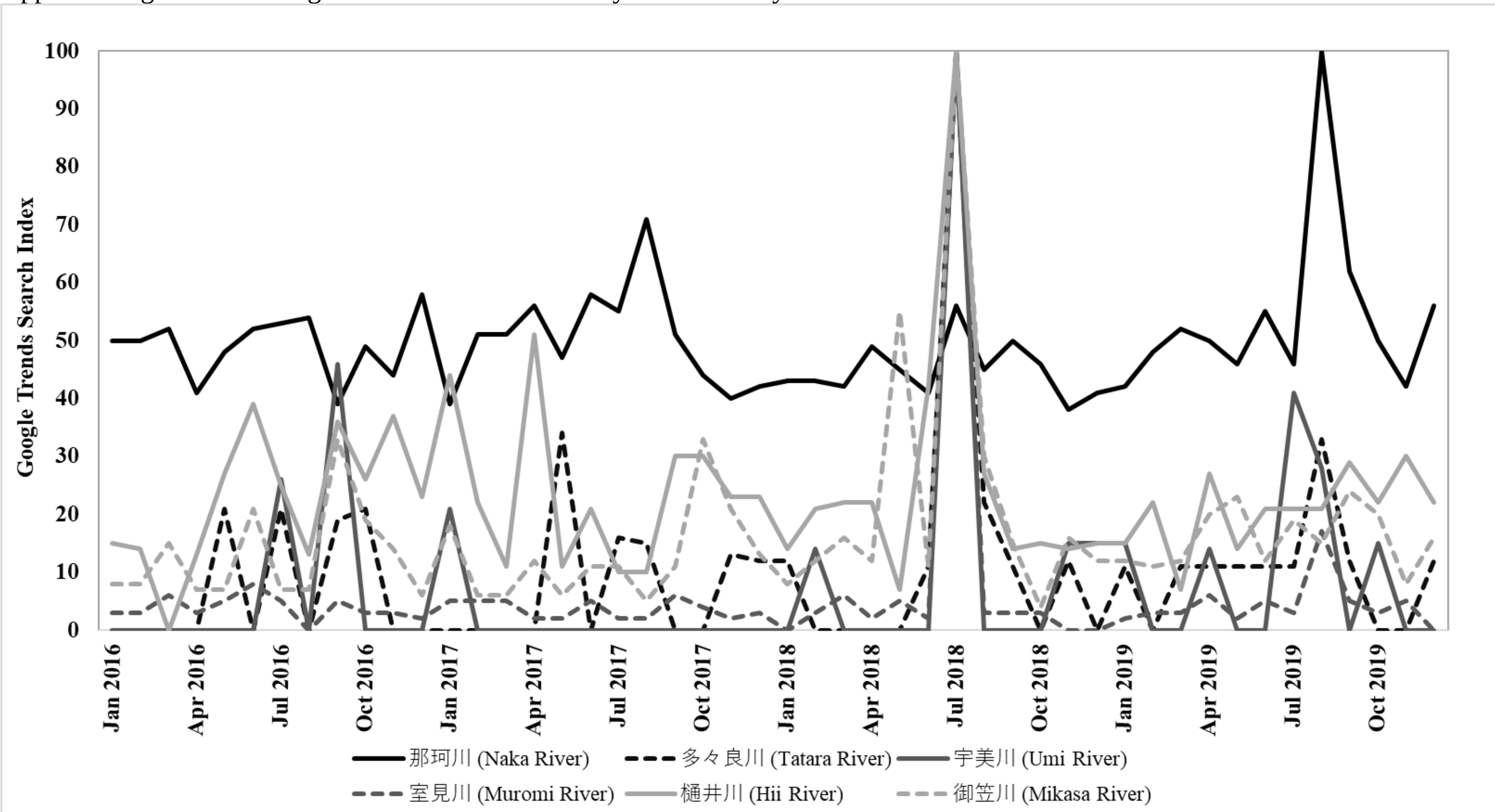
Appendix Table A2 – Comparison of Apartment Units Rented Once Versus Multiple Times

VARIABLES	One-time Rental (1)	Multiple Rentals (2)	Difference (1) - (2)	VARIABLES	One-time Rental (1)	Multiple Rentals (2)	Difference (1) - (2)
Monthly Rent (2015 USD)	540.388	516.619	23.769***	Bicycle Parking (0/1)	0.931	0.931	>0.001
			(1.442)				(0.002)
Square Meters	37.006	36.959	0.047	Fiber Internet (0/1)	0.803	0.730	0.073***
			(0.128)				(0.003)
Number of Bedrooms	1.428	1.380	0.048***	CATV (0/1)	0.825	0.738	0.087***
			(0.006)				(0.003)
Floor	4.700	4.089	0.610***	Steel (0/1)	0.114	0.168	-0.054***
			(0.026)				(0.003)
Months Advertised	4.005	4.389	-0.383***	Concrete (0/1)	0.807	0.701	0.105***
			(0.041)				(0.003)
Living Room (0/1)	0.397	0.401	-0.004	Post (0/1)	0.311	0.320	-0.008**
			(0.004)				(0.004)
Dining Room (0/1)	0.547	0.558	-0.011***	Sale Month	6.209	6.280	-0.071**
			(0.004)				(0.029)
WC (0/1)	0.568	0.532	0.035***	Sale Year	2017.283	2017.233	0.050***
			(0.004)				(0.011)
Heated Toilet (0/1)	0.455	0.450	0.005	Year Built	1999.586	2000.011	-0.425***
			(0.004)				(0.085)
AC (0/1)	0.549	0.672	-0.123***	Medium Water Depth (0/1)	0.195	0.207	-0.012***
			(0.004)				(0.003)
Stove (0/1)	0.563	0.483	0.079***	High Water Depth (0/1)	0.024	0.037	-0.013***
			(0.004)				(0.001)
Fridge (0/1)	0.029	0.021	0.008***	Distance to Station (minutes)	9.933	11.206	-1.273***
			(0.001)				(0.060)
Washer Hookups (0/1)	0.928	0.915	0.013***	Distance to River (100s of meters)	4.213	3.860	0.353***
			(0.002)				(0.026)
Storage (0/1)	0.716	0.710	0.007*	Distance to Park (100s of meters)	2.615	3.067	-0.452***
			(0.004)				(0.051)
Walk-in Closet (0/1)	0.099	0.091	0.008***	Distance to School (100s of meters)	3.874	4.166	-0.292***
			(0.003)				(0.018)
One Room Apt (0/1)	0.085	0.081	0.004*	Distance to Bullet Train (100s of meters)	39.072	48.510	-9.439***
			(0.002)				(0.395)
Elevator (0/1)	0.739	0.628	0.111***	Naka River (0/1)	0.542	0.411	0.131***
			(0.004)				(0.004)
Security Camera (0/1)	0.698	0.599	0.100***				
			(0.004)				
Observations	74,735	16,904			74,735	16,904	

Appendix Figure A1 – Daily Precipitation (mm) in Fukuoka City



Appendix Figure A2 – Google Search Volume Index by Fukuoka City River



Appendix B: Data Appendix for Commercial Rentals and Housing Transactions

In this appendix, we discuss two additional data sources used to determine whether flood protection is capitalized in commercial rentals and/or housing sales. We begin by describing each data source and reporting summary statistics. Data limitations are then discussed followed by a summary of the results and sensitivity analysis.

Commercial Rental Data

Information on commercial rentals (office and retail locations) was collected from the National Institute of Informatics, which is also the source for our apartment listing data (At Home Co. Ltd., 2020). As a result, many of the attributes that describe the apartment rentals are also available for commercial properties including: the size of the unit, the presence or lack of building amenities (i.e. security cameras, fiber internet, elevator, etc.), and the year in which the building was constructed. These two attribute vectors are not identical, however, which we describe in more detail in Appendix Table B1. In general, the market for commercial rentals is far less active than the market for apartments. A total of 5,456 floodplain commercial properties were leased between 2015 and 2019 as compared to 91,639 apartments. We provide summary statistics for the former and latter group in Appendix Table B2 and Table 1, respectively.

Housing Transactions

Unlike many other countries, Japan does not release data on the sale of specific properties as this is considered confidential. Real estate agencies are asked to report their transactions to the MLIT instead. The MLIT processes this data to ensure the anonymity of the buyer and seller and then releases an altered form of the data to the public in quarterly reports. We collect these reports and keep only transactions of single-family homes within our study area. Due to MLIT's data anonymization, we are only able to identify the neighborhood or *chocho* (see Section 4) of each transaction as well as the quarter in which the property sold.[1] The lack of detail pertaining to when the transaction occurred is less of a concern as the first two quarters in 2018 coincide with the pre-treatment period (January – March and April – June), while the third and fourth quarters are during the post-treatment period (July – September and October – December). One benefit of the data is that information on housing sales is available prior to our study period (2015 – 2019). We therefore extend our panel to increase the precision of our estimates by collecting transactional data from 2010 to 2019 and report summary statistics of this in Appendix Table B3.

Since each transaction is classified at the *chocho* level, we are unable to perfectly identify which properties are inside or outside of a floodplain. We resolve this issue using a conservative approach by assuming a property is within a floodplain if *any* part of its *chocho* is within a floodplain. This assumption will incorrectly label many properties as within a floodplain when, in actuality, they are not. This will attenuate the DD estimate towards zero as properties outside of the Naka River floodplain will be considered treated despite never receiving a treatment.

Estimation and sensitivity analysis

We re-estimate models 1 – 3 using housing sales and commercial rental data. Each model is estimated twice, once for each property type, using only floodplain transactions. Coefficient estimates from the commercial rental (housing) regressions are reported in Appendix Table B4

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[1]Additionally, the MLIT measures distance to the nearest train discretely, preventing us from including as a control a continuous distance to station measure like we do in the baseline model. Instead, we form three dummies indicating if the property is within 5 minutes of the station ($\text{Station } 0-5$), between 5 minutes to 10 minutes away ($\text{Station } 5-10$), and between 10 minutes to 15 minutes away ($\text{Station } 10-15$). The excluded category are properties more than 15 minutes on foot from the nearest station. Our results are robust to alternative specifications.

(Appendix Table B5), while Table 5 combines and abbreviates these estimates. Under models 12 - 17, we find flood protection provided by the Gokayama Dam increased downstream commercial rents by 8.3% to 9.5% and housing prices by 9.6% to 11.6%. Both ranges suggest flood protection is capitalized to a greater extent in commercial properties and housing sales compared to apartment rentals. It should be noted in model 14 that the indicator for expected flood water exceeding 2 meters is dropped due to perfect collinearity with the neighborhood fixed effect.

One of the limitations with the housing data is the inability to determine each property's exact spatial location, making it difficult to precisely define treatment status. As a robustness check, we allow the DD estimate to vary based on the percentage of land area within each *chocho* that is within a floodplain. We create three dummies indicating if the *chocho* has up to 33% of its land area within a floodplain (Flood1), between 33% and 66% of its land area within a floodplain (Flood2), and more than 66% of its land area within a floodplain (Flood3). These dummies are then interacted with the DD term and included as regressors in model B1 of Appendix Table B6. We expect capitalization rates will increase with higher floodplain percentages due to a reduction in measurement error. The results from model B1 supports this conclusion with the magnitude of the DD coefficient increasing from 0.8% to 24.9% as the percentage of floodplain land increases. Taken together, the DD coefficients from models 14 – 17 are likely a lower bound when describing the relationship between property values and dam flood protection.

Appendix Table B1 – Data Availability Across Apartments, Commercial Rents, and Single-Family Homes

VARIABLES	DESCRIPTION	APTS	COMM	HOUSE	VARIABLES	DESCRIPTION	APTS	COMM	HOUSE
Monthly Rent (2015 USD)	Monthly rent	YES	YES	NO	Elevator (0/1)	Building has an elevator	YES	YES	NO
Sale Price (2015 USD)	Sale price	NO	NO	YES	Security Camera (0/1)	Building has security cameras	YES	YES	NO
Floor Area (square meters)	Size of unit or house	YES	YES	YES	Bicycle Parking (0/1)	Building has bicycle or scooter parking	YES	NO	NO
Lot Size (square meters)	Parcel lot size	NO	NO	YES	Fiber Internet (0/1)	Building has fiber internet	YES	YES	NO
Frontage (meters)	Width of the parcel lot	NO	NO	YES	CATV (0/1)	Building has a cable TV connection	YES	NO	NO
Number of Bedrooms	Number of bedrooms	YES	YES	NO	Steel (0/1)	Building is made from steel	YES	YES	YES
Floor	Floor of rental unit	YES	NO	NO	Concrete (0/1)	Building is made from concrete	YES	YES	YES
Whole Building (0/1)	Rental unit is the entire building	NO	YES	NO	Medium Water Depth (0/1)	Expected inundation level is 1 - 2 meters	YES	YES	NO
Several Floors (0/1)	Rental unit spans across several floors	NO	YES	NO	High Water Depth (0/1)	Expected inundation level exceeds 2 meters	YES	YES	NO
Months Advertised	Number of months rental unit was advertised online	YES	YES	NO	Sale Month	The month the property was leased or sold	YES	YES	NO
Living Room (0/1)	Living room	YES	NO	NO	Sale Quarter	The quarter the property was leased or sold	YES	YES	YES
Dining Room (0/1)	Dining room	YES	NO	NO	Sale Year	The year the property was leased or sold	YES	YES	NO
WC (0/1)	Toilet and bathroom are in separate rooms	YES	NO	NO	Year Built	The year the building was constructed	YES	YES	YES
Separate Toilet (0/1)	Separate bathrooms for men and women	NO	YES	NO	Year Built 1970 (0/1)	Building was built between 1970 and 1979	YES	YES	YES
Heated Toilet (0/1)	Self-heated toilet	YES	NO	NO	Year Built 1980 (0/1)	Building was built between 1980 and 1989	YES	YES	YES
AC (0/1)	Air conditioner	YES	YES	NO	Year Built 1990 (0/1)	Building was built between 1990 and 1999	YES	YES	YES
Stove (0/1)	Stovetop unit	YES	NO	NO	Year Built 2000 (0/1)	Building was built between 2000 and 2009	YES	YES	YES
Fridge (0/1)	Refridgerator	YES	NO	NO	Year Built 2010 (0/1)	Building was built between 2010 and 2019	YES	YES	YES
Washer Hookups (0/1)	Washing machine hookups	YES	NO	NO	Distance to Station (minutes)	Walking distance to the nearest train station	YES	YES	YES
Storage (0/1)	Extra storage space in rental unit	YES	NO	NO	Distance to River (100s of meters)	Distance to the nearest first or second-class river	YES	YES	NO
Walk-in Closet (0/1)	Walk-in closet	YES	NO	NO	Distance to Park (100s of meters)	Distance to the nearest public park	YES	YES	NO
One Room Apt (0/1)	One room/studio apartment	YES	NO	NO	Distance to School (100s of meters)	Distance to the nearest school	YES	YES	NO
Office (0/1)	Office Space	NO	YES	NO	Distance to Bullet Train (100s of meters)	Distance to the nearest bullet train station	YES	YES	NO
Store (0/1)	Retail Space	NO	YES	NO	Percent Floodplain	Percentage of neigborhood within a floodplain	N/A	N/A	YES

Notes: APTS = Apartments, COMM = Commercial rental units, HOUSE = Single-family homes

Appendix Table B2 –Summary Statistics of Commercial Rentals

	Naka River Floodplain (N=4,107)				Other Floodplains (N=1,349)			
	Mean	**Std. Dev.**	**Min**	**Max**	**Mean**	**Std. Dev.**	**Min**	**Max**
Monthly Rent (2015 USD)	3,009.763	2,542.335	285.857	16,487.139	1,880.411	1,785.835	295.128	15,281.001
Floor Area (square meters)	78.420	52.268	20.000	464.660	84.044	66.704	20.130	476.650
Months Advertised	7.160	7.254	1.000	45.000	8.182	8.657	1.000	43.000
AC (0/1)	0.342	0.475	-	-	0.090	0.287	-	-
Separate Toilet (0/1)	0.245	0.430	-	-	0.156	0.363	-	-
Whole Building (0/1)	0.271	0.445	-	-	0.372	0.484	-	-
Several Floors (0/1)	0.009	0.092	-	-	0.029	0.168	-	-
Office (0/1)	0.481	0.500	-	-	0.277	0.447	-	-
Store (0/1)	0.275	0.447	-	-	0.383	0.486	-	-
Elevator (0/1)	0.776	0.417	-	-	0.438	0.496	-	-
Security Camera (0/1)	0.176	0.381	-	-	0.110	0.314	-	-
Fiber Internet (0/1)	0.462	0.499	-	-	0.099	0.298	-	-
Steel (0/1)	0.236	0.425	-	-	0.268	0.443	-	-
Concrete (0/1)	0.758	0.428	-	-	0.669	0.471	-	-
Medium Water Depth (0/1)	0.133	0.340	-	-	0.153	0.361	-	-
High Water Depth (0/1)	0.000	0.000	-	-	0.012	0.108	-	-
Post (0/1)	0.234	0.423	-	-	0.305	0.460	-	-
Sale Month	6.630	3.341	1.000	12.000	6.580	3.301	1.000	12.000
Sale Year	2017	1.296	2015	2019	2017	1.347	2015	2019
Year Built	1984	12.151	1949	2019	1988	11.297	1949	2019
Distance to Station (minutes)	6.281	3.217	1.000	31.000	7.729	6.174	1.000	34.000
Distance to River (100s of meters)	5.575	3.122	0.044	16.162	2.979	2.091	0.161	12.052
Distance to Park (100s of meters)	2.330	1.132	0.153	5.660	2.461	5.198	0.101	105.513
Distance to School (100s of meters)	3.885	1.827	0.254	9.105	4.518	2.006	0.499	12.841
Distance to Bullet Train (100s of meters)	17.485	10.434	1.272	84.475	46.112	59.849	1.304	280.297

Appendix Table B3 – Summary Statistics of Single-Family Homes

	Naka River Floodplain (N=1,325)				**Other Floodplains (N=7,881)**			
	Mean	**Std. Dev.**	**Min**	**Max**	**Mean**	**Std. Dev.**	**Min**	**Max**
Sale Price (2015 USD)	414,133	332,049	10,909	2,368,307	217,188	182,351	7,799	2,501,251
Floor Area (square meters)	179.566	105.900	45.000	500.000	135.702	74.642	45.000	500.000
Lot Size (square meters)	187.947	118.604	60.000	1,400.000	251.643	176.891	60.000	1,400.000
Frontage (meters)	10.936	5.298	1.400	43.000	13.571	6.356	2.000	49.000
Steel (0/1)	0.202	0.401	-	-	0.150	0.357	-	-
Concrete (0/1)	0.129	0.335	-	-	0.037	0.188	-	-
Post (0/1)	0.154	0.361	-	-	0.161	0.368	-	-
Sale Quarter	2.473	1.097	1.000	4.000	2.481	1.113	1.000	4.000
Sale Year	2015	2.745	2010	2019	2015	2.758	2010	2019
Year Built	1995	17.020	1947	2019	1996	17.492	1946	2019
Distance to Station (minutes)	15.309	10.403	1.000	60.000	18.332	14.145	1.000	90.000
Percent Floodplain	44.461	36.226	1.000	100.000	37.293	32.496	1.000	100.000

Table B4 – Capitalization of Flood Protection in Downstream Commercial Rental Prices

VARIABLES	Model (12)	Model (13)	Model (14)	VARIABLES	Model (12)	Model (13)	Model (14)
Naka River*Post (0/1)	**0.091***	**0.080****	**0.087*****	Concrete (0/1)	-0.084	-0.096**	-0.029
	(0.046)	**(0.040)**	**(0.033)**		(0.054)	(0.048)	(0.055)
Naka River (0/1)	**0.410*****	**0.181*****	-	Year Built 1970 (0/1)	0.013	0.030	0.041
	(0.044)	**(0.061)**	-		(0.055)	(0.053)	(0.048)
Ln Floor Area	1.003***	1.005***	1.012***	Year Built 1980 (0/1)	0.112**	0.137***	0.164***
	(0.022)	(0.022)	(0.022)		(0.053)	(0.052)	(0.046)
AC (0/1)	0.174***	0.175***	0.167***	Year Built 1990 (0/1)	0.157***	0.179***	0.212***
	(0.026)	(0.026)	(0.026)		(0.056)	(0.052)	(0.050)
Separate Toilet (0/1)	0.102***	0.100***	0.096***	Year Built 2000 (0/1)	0.327***	0.324***	0.345***
	(0.023)	(0.021)	(0.019)		(0.058)	(0.056)	(0.051)
Ln Months Advertised	0.002	0.006	0.006	Year Built 2010 (0/1)	0.493***	0.495***	0.588***
	(0.009)	(0.008)	(0.008)		(0.069)	(0.066)	(0.058)
Whole Building (0/1)	0.341***	0.257***	0.154**	Medium Water Depth (0/1)	-0.040	-0.079**	-0.138***
	(0.094)	(0.078)	(0.075)		(0.033)	(0.031)	(0.049)
Several Floors (0/1)	0.121	0.052	0.011	High Water Depth (0/1)[a]	-0.107	0.029	-
	(0.085)	(0.065)	(0.043)		(0.103)	(0.108)	-
Office (0/1)	-0.108***	-0.138***	-0.083***	Ln Distance to Station	-0.079***	-0.086***	-0.028
	(0.029)	(0.028)	(0.025)		(0.026)	(0.024)	(0.022)
Store (0/1)	-0.079	0.009	0.056	Ln Distance to River	-0.017	-0.034*	0.077*
	(0.095)	(0.078)	(0.071)		(0.020)	(0.020)	(0.044)
Elevator (0/1)	0.095***	0.078***	0.023	Ln Distance to Park	0.068**	0.062**	0.001
	(0.026)	(0.024)	(0.025)		(0.030)	(0.028)	(0.035)
Security Camera (0/1)	-0.066*	-0.077**	-0.152***	Ln Distance to School	0.065	0.066*	-0.021
	(0.036)	(0.036)	(0.032)		(0.041)	(0.036)	(0.065)
Fiber Internet (0/1)	0.077**	0.051*	0.078***	Ln Distance to Bullet Train	-0.045***	-0.123***	-0.420***
	(0.032)	(0.030)	(0.029)		(0.015)	(0.044)	(0.124)
Steel (0/1)	-0.049	-0.065	-0.054				
	(0.060)	(0.056)	(0.068)				
Time FE	YEAR x MONTH	YEAR x MONTH	YEAR x MONTH				
Spatial FE	NO	WARD	NBHD				
Observations	5,456	5,456	5,456				
Adjusted R^2	0.763	0.784	0.827				

Notes: [a]High water depth is dropped from Model 3b due to perfect collinearity with the neighborhood spatial fixed effects
*, **, *** denotes significance at the 10%, 5%, and 1% level respectively.
Robust standard errors are clustered at the neighborhood level.

Table B5 – Capitalization of Flood Protection in Downstream Housing Prices

VARIABLES	Model (15)	Model (16)	Model (17)
Naka River*Post (0/1)	**0.092***	**0.095****	**0.110*****
	(0.048)	**(0.042)**	**(0.036)**
Naka River (0/1)	**0.445*****	**0.264*****	**-**
	(0.038)	**(0.068)**	**-**
Ln Floor Area	0.845***	0.602***	0.452***
	(0.030)	(0.024)	(0.019)
Ln Lot Size	0.071***	0.343***	0.470***
	(0.026)	(0.020)	(0.018)
Frontage (meters)	-0.005***	-0.001	0.003***
	(0.001)	(0.001)	(0.001)
Steel (0/1)	0.159***	0.146***	0.087***
	(0.021)	(0.017)	(0.017)
Concrete (0/1)	0.348***	0.316***	0.221***
	(0.043)	(0.028)	(0.025)
Year Built 1970 (0/1)	0.011	0.041	0.096***
	(0.047)	(0.036)	(0.032)
Year Built 1980 (0/1)	0.201***	0.217***	0.249***
	(0.047)	(0.033)	(0.031)
Year Built 1990 (0/1)	0.362***	0.413***	0.482***
	(0.048)	(0.036)	(0.033)
Year Built 2000 (0/1)	0.741***	0.728***	0.756***
	(0.050)	(0.038)	(0.037)
Year Built 2010 (0/1)	1.145***	1.129***	1.146***
	(0.048)	(0.037)	(0.034)
Station 0 - 5 (0/1)	0.301***	0.282***	0.159***
	(0.054)	(0.031)	(0.027)
Station 5 - 10 (0/1)	0.276***	0.238***	0.121***
	(0.037)	(0.022)	(0.020)
Station 10 - 15 (0/1)	0.186***	0.144***	0.046***
	(0.031)	(0.020)	(0.016)
Time FE	YEAR x QUARTER	YEAR x QUARTER	YEAR x QUARTER
Spatial FE	NO	WARD	NBHD
Observations	9,206	9,206	9,206
Adjusted R^2	0.596	0.747	0.807

Notes: *, **, *** denotes significance at the 10%, 5%, and 1% level respectively.
Robust standard errors are clustered at the neighborhood level.

Table B6 – Robustness to Floodplain Definition

VARIABLES	Model (B1)	VARIABLES	Model (B1)
Naka River*Flood1*Post (0/1)	**0.008**	Year Built 1970 (0/1)	0.096***
	(0.027)		(0.032)
Naka River*Flood2*Post (0/1)	**0.185****	Year Built 1980 (0/1)	0.249***
	(0.073)		(0.031)
Naka River*Flood3*Post (0/1)	**0.222*****	Year Built 1990 (0/1)	0.482***
	(0.071)		(0.033)
Ln Floor Area	0.452***	Year Built 2000 (0/1)	0.757***
	(0.019)		(0.036)
Ln Lot Size	0.470***	Year Built 2010 (0/1)	1.147***
	(0.018)		(0.034)
Frontage (meters)	0.003***	Station 0 - 5 (0/1)	0.160***
	(0.001)		(0.027)
Steel (0/1)	0.087***	Station 5 - 10 (0/1)	0.121***
	(0.017)		(0.020)
Concrete (0/1)	0.220***	Station 10 - 15 (0/1)	0.045***
	(0.025)		(0.016)
Time FE	YEAR x QUARTER		
Spatial FE	NBHD		
Observations	9,206		
Adjusted R^2	0.807		

Notes: *, **, *** denotes significance at the 10%, 5%, and 1% level respectively. Robust standard errors are clustered at the neighborhood level.