様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

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研究課題名（和文）Modeling Linkages Between Land Development And Water Quality in Freshwater Lakes

研究課題名（英文）Modeling Linkages Between Land Development And Water Quality in Freshwater Lakes

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研究成果の概要（和文）：私は、人々が公共財の変化をどのように評価するかをよりよく理解するために、環境経済学界において2つの事を前進させた。まず、非限界厚生分析に適した公共財の需要関数の回復を可能にする新しい計量経済学的手法を導入した。水質を例にとると、従来のMWTPの推計では、水質改善による利益が、需要関数から得られる利益に比べて少なくとも22%過小評価されていることが分かった。
その後の研究では、福岡の賃貸住宅価格がダムの完成にどのように反応したかを調べている。その結果、五ケ山ダムに守られている場合、アパート価格は1.8%上昇することがわかった。この効き目が観測されるのは2018年に西日本を襲った自然災害の後である。

研究成果の学術的意義や社会的意義
Policy interventions often have non-marginal goals in mind. Current methods to value these changes are, however, typically ill-suited for non-marginal analysis. I overcome this problem by developing a method to recover demand curves for public goods, which are valid even for non-marginal analysis.

研究成果の概要（英文）：I make two advancements which helps us to better understand how people value changes in public goods. I first implement a new econometric method that allows for the recovery of demand functions of public goods, which are better suited for non-marginal welfare analysis relative to MWTP. Using water quality as an application, I find traditional MWTP estimates undercount the benefits from water quality improvement by at least 22% or $1,500 per household in comparison to the benefits derived from a demand function.In subsequent research, I examine a new topic by looking at how downstream rental prices in Fukuoka, Japan responded to the completion of an upstream dam. I find apartment prices rose by 1.8% if they were protected by the recently completed Gokayama Dam. This premium is only observed after a natural disaster hit western Japan in 2018, causing residents to update their perceptions of flood risk.

研究分野：Environmental Economics

キーワード：Housing Price　Hedonic　Apartment Rentals　Flood Risk　Water Quality

様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９（共通）

１．研究開始当初の背景

(1) Hedonic valuation of public goods has almost exclusively relied on point estimates of marginal willingness to pay (MWTP) for policy analysis. MWTP estimates are a useful first step when evaluating the welfare implications of a marginal change in a public good. However, extrapolation of these estimates to value large improvements or reductions in public goods relies on empirically untested assumptions. What is needed instead are demand curves, which are valid even when assessing the impacts of non-marginal changes in public goods (Wolf and Klaiber, 2021).

Identifying demand curves of nonmarket goods typically requires the practitioner to estimate separate price functions across hedonic equilibria (Zabel and Kiel, 2000) or make explicit assumptions regarding the functional form of the utility function (Bajari and Benkard 2005). The former approach requires clear market segmentation and the assumption that unobserved preferences are randomly distributed across markets (Zhang et al. 2015). In my research, I relax the need for the second assumption by instrumenting for cross-market variation using imperfect instruments developed from sorting theory (Tiebout, 1957; Nevo and Rosen, 2012). I show the importance of this contribution using water quality as an application, though this same methodology can be used to value a number of other public goods.

(2) Large-scale flooding is becoming increasingly common due to prolonged and intensive rainfall caused by climate change. The Japanese government has responded to this risk by building an extensive network of dams nationwide. It's unclear whether downstream residents are aware of the benefits these public works provide, however, as dams are often built several kilometers away from the area it protects. In addition, residents are typically unaware of flood risk unless there's been a natural disaster recently to remind them of the hazards they face (Bin and Landry, 2013).

To provide clarity on this matter, I examine how apartment rents in Fukuoka, Japan, responded to the completion of the Gokayama Dam and the arrival of Typhoon Prapiroon four months later in July of 2018. The Gokayama Dam is one of the largest flood control structures that protects Fukuoka City as it took over 6 years to complete and is priced at over $600 million. Typhoon Prapiroon, on the other hand, was undoubtedly the first real-world test for the Gokayama Dam as it brought widespread flooding all across western Japan. I use both events to better understand how people living downstream perceive and respond to changes in flood risk.

２．研究の目的

(1) MWTP estimates are often used to conduct non-marginal welfare policy analysis. This is problematic as first-stage hedonic price estimates only provide a welfare interpretation when considering small changes away from current conditions. I outline an alternative approach which uses information from the first-stage hedonic to recover demand functions for public goods. These demand functions are better suited for non-marginal welfare analysis as they describe latent consumer preferences for public goods which are valid even if large changes in the hedonic price function occur.

To highlight the importance between the two methods, I recover first-stage hedonic price estimates and demand curves for water quality using housing transactions collected from the State of Wisconsin in the United States. I demonstrate how traditional hedonic valuation methods compare to my proposed approach by valuing the welfare implications from a 24.2% reduction in water quality, which is equivalent to a 30-year continuation of current trends. I find first-stage hedonic price estimates undervalue large degradations in water quality by at least 22% ($1,658 per household). The degree of bias generated from the first-stage hedonic varies, however, across climate regions and with lake proximity. My findings highlight the importance of recovering demand functions for public goods as oppose to MWTP estimates when evaluating large changes in public goods.

(2) A number of studies have examined the relationship between housing values and flood risk. No study, to my knowledge, has conducted the same analysis using apartment rental rates. This omission is concerning as apartment renters are a major stakeholder group, especially in Japan where homeownership rates are 5% to 15% less than in the United States and European Union (OECD Social Policy Division,

2021). In addition, renters are typically unaccounted for in hedonic applications due to data limitations and are likely to value flood protection differently than homeowners due to their more transitory nature. Taken together, this suggests the need to recover valuation estimates specifically for renters. I provide an answer to this question by examining how apartment rents change in response to the construction of an upstream dam. I find renters do have a positive willingness to pay for flood protection, though it is significantly less than what is observed within the housing and commercial rental market.

My research also contributes to the flood risk literature by providing benefit estimates for inland flood protection. Only a handful of studies have linked housing prices to dam removal or other inland defenses (Lewis et al., 2008), while no study to my knowledge has looked at how dam construction impacts real estate markets. The relative scarcity of inland flood protection studies may be due to a lack of awareness provided by upstream infrastructure, which are often several kilometers away from the area it protects, causing real estate markets to be unresponsive to objective changes in flood risk.

3．研究の方法

(1) The two-stage methodology I employ to recover demand curves for public goods is an extension of Rosen (1974)'s classical hedonic framework. In the first stage, I estimate a series of hedonic price functions by regressing housing price (*Price*) from housing market *m* on a vector of structural and locational features that define the home (*X)* as well as the amenity of interest (*Z*):

[1] $Price_m = f_m(X, Z|\beta_m)$

Where $f_m(.)$ is the hedonic price function from the *m*th housing market described by the vector of coefficients β_m. Taking the derivative of equation [1] with respect to *Z* then reveals the consumer's MWTP for that amenity:

[2] $MWTP_m^Z = \frac{\partial f_m(X,Z|\beta_m)}{\partial Z}$

An inverse demand function for *Z* can then be estimated within a second-stage regression, where the MWTP estimates from the first stage are used as a dependent variable:

[3] $MWTP_m^Z = g_z(X, Z, O, U|\alpha)$

The MWTP for *Z* depends on the other attributes that define the home (*X*), the quantity of Z consumed (*Z*), observable and unobservable demand shifters designated by *O* and *U*, respectively, and a vector of parameters (α) that describe the shape of the inverse demand function $g_z(.)$. Homebuyers simultaneously choose both the quantity and price they pay for *Z* through their selection of a home (Brown and Rosen, 1982), however, necessitating the need to instrument for *Z*.

I overcome this identification problem by developing imperfect instruments for *Z* from sorting theory (Tiebout, 1956; Nevo and Rosen, 2012). In particular, I create a rank-based instrument which measures the average quality or quantity of *Z* across markets (i.e., a higher rank corresponds to a market with more or better-quality *Z* available). Assuming preferences are positively stratified, or that homebuyers with stronger preferences for *Z* move to markets where *Z* is more available, my rank-based instrument then provides a bound estimate for the slope of the demand function specified in equation [3] (Zhang et al. 2015). These demand functions provide more reliable welfare measures than conventional MWTP estimates as demand bounds are valid across multiple hedonic equilibria, while MWTP measures are specific to one equilibrium.

(2) I apply the hedonic pricing method in equation [4] to estimate the value flood protection provides to renters living in Fukuoka Prefecture, Japan.

[4] $Ln\ Rent_{ijt} = \gamma S_{it} + \pi NakaRiver_i + \delta(NakaRiver_i * Post_t) + F_i + \zeta_t + \eta_j + \varepsilon_{ijt}$

Where the natural log of rent for apartment i, leased in location j during time i is given by $Ln\ Rent_{ijt}$. S_{it} is a vector of structural and locational features that define the unit, $NakaRiver_i$ indicates whether the apartment is located within the floodplain protected by the Gokayama Dam (i.e., the Naka River floodplain),

$Post_t$ is a dummy equal to one if the apartment was leased after widespread flooding occurred in western Japan during June of 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.

The specification detailed in equation [4] follows a standard difference-in-difference approach. The first difference, captured by the dummy $\mathsf{NakaRiver}_\mathrm{i}$, controls for any price premiums observed from living within the Naka River floodplain prior to the natural disaster. The second difference, Post_t, captures the average change in rental price across all apartments before and after the natural disaster and is indirectly controlled for through the inclusion of month by year fixed effects (ζ_t). The variable of interest in equation [4] is the interaction between these two differences as it reflects the change in rental values attributable to the protection provided by the Gokayama Dam.

I initially was planning to use this quasi-experimental methodology to examine the relationship between water quality and land development. However, I had to apply this methodology to a different application (i.e., capitalization of flood protection) as I did not have enough money to purchase the data I originally needed.

４．研究成果

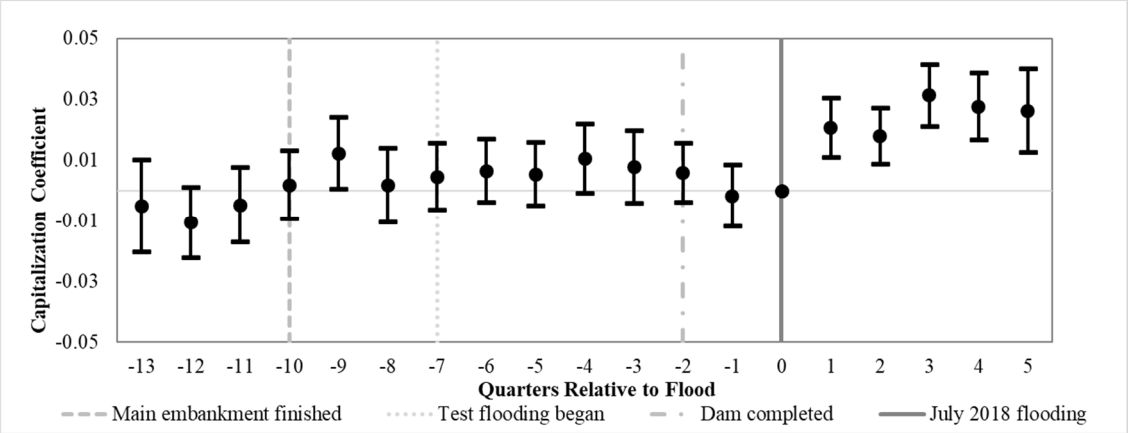
(1) I demonstrate the importance of the two-stage methodology I describe above by applying it to value large changes in water quality. I then compare these welfare estimates with more conventional water quality valuations derived from MWTP. Using micro-level water quality and housing data across the State of Wisconsin within the United States, I find welfare losses of at least $7,554 per household if water quality degrades by 24.2% due to a 30-year continuation of current trends. In contrast, first-stage MWTP indicates homeowners will lose $5,896, or 22% less, from the same reduction in water quality (Wolf et al., 2022). This difference highlights the importance of recovering demand functions as opposed to MWTP and suggests water quality restoration projects and damages from impairment are undervalued when conventional valuation methods are applied.

I further find that the demand for water quality is heterogeneous across two spatial delimiters: lake proximity and climate regions. In particular, homeowners living within 250 meters of a lake are willing to pay $8,539 to prevent a 24.2% reduction in water quality, while homeowners living between 250 meters and 500 meters are only willing to pay $5,307. Similarly, homeowners living in colder and more northern climates have a higher willingness to pay for water quality compared to their southern counterparts (Wolf et al., 2022). This may be due to the relative scarcity of ice-free lake days in northern Wisconsin. It should be noted that the welfare bias observed within the pooled sample still persists even when accounting for this additional heterogeneity, with first-stage MWTP estimates biased by as much as 38%.

(2) I find using my difference-in-difference estimator that apartments protected by the Gokayama Dam in Fukuoka Prefecture, Japan, are 1.8% more expense relative to apartments located in other floodplains. I attribute this price differential solely to the flood protection provided by the dam as this price increase is observed only after widespread flooding occurred and test the dam in July of 2018. To show this result more clearly, I allow the difference-in-difference term in equation [4] to vary across time and plot the coefficients and their 95% confidence intervals from this analysis in Figure 1.

The difference-in-difference coefficient is statistically insignificant in almost all of the periods prior to the flooding event. However, immediately after July of 2018, the capitalization coefficient increases discretely to approximately 3% and remains positive until the end of the study period. This indicates renters had not considered flood risk or the potential benefits provided by an upstream dam until there was a natural disaster to remind them of these differences across space. Interestingly there is no price effect when the main embankment was completed, when test flooding began or even when the dam was finished, suggesting renters may not be fully aware of when objective changes in flood risk occur.

Figure 1 – Capitalization Effects across Time



I further find that flood protection benefits are 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. Overall, 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.

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５．主な発表論文等

〔雑誌論文〕　計3件（うち査読付論文　2件／うち国際共著　2件／うちオープンアクセス　1件）

１．著者名 Wolf David、Gopalakrishnan Sathya、Klaiber H. Allen	４．巻 -
２．論文標題 Staying afloat: The effect of algae contamination on Lake Erie housing prices	５．発行年 2022年
３．雑誌名 American Journal of Agricultural Economics	６．最初と最後の頁 -
掲載論文のDOI（デジタルオブジェクト識別子） 10.1111/ajae.12285	査読の有無 有
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１．著者名 Wolf David、Klaiber H. Allen、Gopalakrishnan Sathya	４．巻 68
２．論文標題 Beyond marginal: Estimating the demand for water quality	５．発行年 2022年
３．雑誌名 Resource and Energy Economics	６．最初と最後の頁 101299～101299
掲載論文のDOI（デジタルオブジェクト識別子） 10.1016/j.reseneeco.2022.101299	査読の有無 有
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１．著者名 Wolf David, Kenji Takeuchi	４．巻 -
２．論文標題 Who Gives a Dam? Capitalization of Flood Protection in Fukuoka, Japan	５．発行年 2022年
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掲載論文のDOI（デジタルオブジェクト識別子） なし	査読の有無 無
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〔学会発表〕　計8件（うち招待講演　3件／うち国際学会　3件）

１．発表者名 David Wolf
２．発表標題 Willingness to Pay for Water Quality in Lake Erie: The Effect of Algae Contamination on Housing Prices
３．学会等名 85th Annual Midwestern Economic Association（国際学会）
４．発表年 2020年

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David Wolf

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Willingness to Pay for Water Quality in Lake Erie: The Effect of Algae Contamination on Housing Prices

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David Wolf

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26th Annual Society for Environmental Economics and Policy Studies (SEEPS)

４．発表年
2021年

〔図書〕　計0件

〔産業財産権〕

〔その他〕

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６．研究組織

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７．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計0件

８．本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関