

Estimating Option Values and Spillover Damages for Coastal Protection: Evidence from Oregon's Planning Goal 18

Steven J. Dundas¹
Oregon State University
steven.dundas@oregonstate.edu

David J. Lewis
Oregon State University
lewisda@oregonstate.edu

Working Paper
August 1st, 2018 (Please do not cite without permission)

Abstract

Estimating non-market benefits for coastal protection can help inform better decision-making, policy, and funding mechanisms for communities to adapt to climate change. We estimate private values for a future coastal protection option in an empirical setting subject to irreversible loss from coastal erosion and a land-use policy that provides identifying variation in the parcel-level option to invest in coastal protection. Using post-matching regressions, we find a capitalization effect associated with the protection option between 13 – 24 percent for parcels vulnerable to coastal hazards, implying that owners of oceanfront parcels have a subjective annual probability that they will experience an irreversible loss absent the option to protect between 0.7 – 1.5 percent. We also find that, as a result of altered shoreline wave dynamics, a parcel with a private protection option generates a negative externality on protection-ineligible neighbors, raising subjective risk probabilities by 0.7 percent, and potentially generating external costs that may negate the net benefits of the land-use policy in some locations.

Key words: option value; coastal protection; irreversible loss; spillover effects; spatial externalities; private value of climate adaptation

JEL codes: Q51, Q54, Q58.

¹ The authors are, respectively, assistant professor and professor, Oregon State University, Department of Applied Economics, 213 Ballard Extension Hall, Corvallis, OR 97331. The authors thank Meg Reed and the Oregon Department of Land Conservation and Development for access to their Goal 18 database, Laura Barreiro-Fernandez, Eric Didion, and Christopher Parrish for their assistance with geospatial data, W. Jason Beasley for research assistance, and Peter Ruggiero for helpful comments. Additional thanks to participants at the 2016 5th National Forum on Socioeconomic Research in Coastal Systems, the 2016 AAEA Annual Meeting, the 2017 W-3133 Annual Meeting, the 2017 AERE Summer Conference, the 2017 Fall Oregon Resource and Environmental Economics Workshop, the 2018 W-4133 Annual Meeting, the 2018 WEAI Annual Conference and the Applied Economics Working Group at Oregon State University. We acknowledge funding that supported this research from the NOAA National Centers for Coastal Ocean Science Competitive Research Program through NOAA Cooperative Institutes Program award numbers NA11OAR4320091A and NA16OAR4320152 to the Cooperative Institute for Marine Resources Studies at Oregon State University.

People who live in coastal zones around the globe are confronted with a variety of natural hazards that can induce damages, including erosion, tidal flooding, and storm surges. Climate change has the potential to intensify damages from natural hazards through sea-level rise and shifts in the composition of storm events. Historical advantages and current amenities associated with coastal living has led to massive investment in housing and infrastructure that creates significant potential for damage from natural hazards, and therefore, significant economic value from the ability to protect investments in these capital assets from such damage. Empirical evaluation of the economic value and tradeoffs associated with coastal protection can help inform better decision-making, policy, and funding mechanisms for governments and communities to adapt to natural hazard risks given an uncertain future.

This paper estimates the economic benefits derived from the private option to protect coastal oceanfront land from irreversible loss due to erosion. Given the high costs, scale and coordination issues of protection strategies such as beach nourishment, private protection options are typically limited to hardened, engineered shoreline protection structures (SPS), such as seawalls and rip-rap revetments (i.e., rock piles), to prevent the loss of coastal structures.² Recent work by Neumann et al. (2015) motivates the importance of further research in this area, as their results suggest coastal armoring with SPS will represent the majority of U.S. costs (~60% or > \$300 Billion) associated with adaptation to sea level rise by the end of the century. As such, the economic value of the private option to protect oceanfront property represents a private value of adaptation to climate-induced sea level rise. To begin to address this issue, we first present a simple model of a coastal housing market's capitalization of the option to prevent the realization of an irreversible loss. We hypothesize that the market response to a coastal protection option is dependent on a landowner's subjective annual probability of the irreversible loss, which is modeled as a function of parcel characteristics that are likely to influence this probability.

Our empirical strategy uses pooled cross-sectional data from coastal land sales in Oregon from 2004 to 2015 and exploits a unique land-use policy and risk portfolio that allows us to estimate the capitalization effect associated with the parcel-level option to install a SPS. The option to privately install a SPS on a coastal property is determined by a statewide land-use policy – Oregon's Planning Goal 18 – that designates which parcels are eligible to install SPS

² A photograph of SPS (rip-rap) in Neskowin, Oregon is provided in Figure A.1 in the online appendix.

and which parcels are not. Eligibility is restricted to parcels that had physical improvements prior to 1977, and all parcels without such physical improvement by 1977 are ineligible to install protective structures. Goal 18's motivation was to limit armoring of the coastline and thereby prevent beach erosion damages that a landowner's armoring decision induces on neighboring landowners or public beach users through displaced wave action. Our empirical strategy exploits substantial cross-sectional variation (both within and between communities) in the ability of landowners to protect their property from an irreversible loss due to erosion, along with an extremely rich set of parcel variables that represent fine-scale risk and amenity characteristics of land. Since the policy change in question occurred 28 years before our data begins, we use propensity score matching methods to trim the housing transactions and create balance in observable characteristics across parcels that are eligible and ineligible for protection under Goal 18. Econometric estimates indicate that there is a positive but insignificant price effect of having the option to invest in coastal protection for the average parcel. However, for parcels that are vulnerable to coastal risks (i.e., low elevation and eroding shoreline), the price premium for the protection option is significantly different from zero and ranges from 13 to 24 percent of their property value. Using our conceptual model, we show that these estimated capitalization effects imply that landowners' subjective annual probability that they will experience an irreversible loss absent the option to protect is between 0.7 – 1.5 percent.

Unlike beach nourishment and other public (i.e., community-wide) strategies to address shoreline stabilization, coastal armoring in Oregon is a private decision made at the parcel-level. The installation of a SPS on a parcel may change the pattern of sediment dynamics along a coastline by re-directing wave action, which could then increase erosion risk to neighboring properties (Ells and Murray 2012; Ruggiero 2010). By exploiting alternative buffer sizes associated with the definition of “treatment” (protection-eligible) and “control” (protection-ineligible) parcels with respect to the Goal 18 policy, we econometrically evaluate the potential for and magnitude of expected spillover damages that protection-eligible parcels may impose on neighbors that are protection-ineligible. We find that protection-ineligible homes that neighbor protection-eligible homes experience a non-zero spillover damage (spatial externality) on the order of a 7 – 16 percent reduction in property value. This price effect implies the subjective annual risk probability is, on average, 0.7 percent higher on protection-ineligible parcels subject to the externality. The presence of spillover damages from coastal protection implies that there is

a clear economic tradeoff associated with a landowner's ability to protect coastlines through private infrastructure choices. Having this option generates benefits to that landowner, but also generates external costs to neighboring landowners through expected damages arising from altered wave action and erosion. Our analysis finds that the net benefits of the option to protect coastal property are not necessarily positive when factoring in spillover damages from one parcel to neighboring property owners. Our results further suggest that in settings where all landowners are free to install private protection measures, the spillover damages arising from protection decisions will provide incentive for neighbors to invest in their own SPS, thereby leading to a potentially cascading set of shoreline armoring.

Our paper contributes to the literature that evaluates the land market impacts of public infrastructure investment, insurance programs, and land-use regulations on coastlines. Beach nourishment is a prominently studied example of public infrastructure investment and is practiced widely in the eastern U.S. and Europe. Recent research estimates that public beach nourishment can raise property values (Qui and Gopalakrishnan 2018), though Dundas (2017) shows that protection benefits can be partially offset by other aspects of beach nourishment, such as reductions in ocean views from large constructed dunes. Beach nourishment also increases the size of the beach, which has been consistently shown to be valued as an amenity in coastal housing markets (Landry et al. 2003; Gopalakrishnan et al. 2011; Landry and Hindsley 2011; Landry and Allen 2016).

The timing of such investments also matters, as Davlasheridze et al. (2017) find suggestive evidence that *ex-ante* investing in risk-reducing infrastructure by the Federal Emergency Management Agency (FEMA) is nearly twice as successful in damage mitigation as waiting to do similar investments after a hazard event. Insurance programs, such as the National Flood Insurance Program (NFIP), are designed to provide a risk mitigation option for people living in flood-prone areas. Research has shown that price discounts for flood risk are either greater than or equal to the capitalized value of flood insurance premiums (MacDonald et al. 1987; Bin and Kruse 2006; Bin, Kruse, and Landry 2008). Risk perceptions also drive price differentials in coastal housing markets, as shown by studies examining home values before and after major hurricane events (Bin and Polasky 2004; Hallstrom and Smith 2006; Bin and Landry 2013) and flooding events (Atreya et al. 2013). The negative impacts may also attenuate over time if

another event does not occur (Atreya et al. 2013; Bin and Landry 2013). The emphasis of this body of work has focused on risk perceptions associated with a temporary loss.

Our emphasis on a land-use regulation allowing for private protection decisions rather than public and on the potential for irreversible loss brings new evidence to bear on challenges associated with current coastal management. Our work contributes to the literature by estimating a parcel-level option value for private coastal protection that protects from risks but arguably provides no other amenities such as are found in beach nourishment. The magnitude of our benefit estimates for having a coastal protection option exhibit convergent validity with recent estimates on the protective benefits from beach nourishment (Dundas 2017; Qiu and Gopalakrishnan 2018) and seawalls (Jin et al. 2015).³ Second, our conceptual framework allows us to calculate implicit subjective risk probabilities of expected irreversible loss using our empirical results on the capitalization effect of the protection option. Third, we identify potential spillover damages of private coastal protection decisions on neighboring property, and our results suggest the magnitude of these effects may be economically significant and thereby casts doubt on whether the *net* economic benefits from private coastal armoring are positive. Previously, Smith et al. (2009) and Gopalakrishnan et al. (2016) recognized the need to account for spatial externalities when optimizing beach nourishment frequency, and Gopalakrishnan et al. (2017) demonstrated the potential for coastal protection spillover damages with an empirically-calibrated numerical model of nourishment decisions made at a community scale. Our results are unique in the literature in that we find empirical evidence of the spillover damages through economically important tradeoffs associated with the fact that private coastal protection choices may generate private benefits to the individuals making the choice, but external costs to neighbors from altered erosion dynamics. Our results thus provide a rich set of evidence about the economic tradeoffs associated with policies regarding private coastal protection.

Finally, by finding evidence of a coastal spatial externality from SPS, our paper adds evidence to a set of land-use analyses that quantify the presence of spatial externalities on land use. Past studies have found a wide variety of evidence of spatial externalities across landowner decisions in non-coastal settings, such as suburban development (Irwin and Bockstael 2002),

³ Dundas (2017) finds the protection value associated with dune and beach nourishment policy ranges from 20 to 26 percent when decomposed from ancillary flows (e.g., ocean views, access) also impacted by the policy intervention. Qiu and Gopalakrishnan (2018) find beach nourishment increases home values in Kitty Hawk, NC by 12 – 17 percent and Jin et al. (2015) show presence of a seawall may increase housing prices by 10 percent in Massachusetts.

conversion to organic agriculture (Lewis et al. 2011), and adoption of conservation easements (Lawley and Yang 2015).

1. POLICY SETTING

In 1973, Governor Tom McCall made a speech to the Oregon Legislature to propose a suite of new land-use regulations to curb “*sagebrush subdivisions, coastal condomania, and the ravenous rampages of suburbia*” in the state. The first 14 goals of McCall’s plan became law in late 1974, and Goals 16–19 related to coastal resources were adopted in 1976. Together, these 19 goals comprise the set of land-use regulations known as Oregon’s Statewide Planning Goals (State of Oregon 2010). The goals are statewide guidelines administered by the Department of Land Conservation and Development (DLCD) that inform mandatory comprehensive plans at the local level (i.e., city and county). Our focus is on Goal 18, which provides guidelines for protecting beach and dune areas of the Oregon coast from some development outcomes and reducing impacts from natural hazards. A portion of Goal 18 limits the ability of oceanfront landowners to apply for a permit for a SPS to mitigate erosion vulnerability. Eligibility is restricted to lots where physical improvements (i.e., either a home or a vacant lot with utility connections or nearby street construction) existed prior to January 1st, 1977. Local authorities can enact stricter rules if desired, including requiring compliance with construction setbacks from hazard areas to remain eligible (e.g., Rockaway Beach).⁴ The primary motivation for Goal 18 was to limit the armoring of the Oregon coast and incentivize less risky development of oceanfront properties.

Landowners of protection-eligible parcels can apply to Oregon Parks and Recreation Department (OPRD) for a SPS permit, but a construction permit is only granted if a geological survey determines the parcel is subject to an immediate threat of irreversible loss from coastal erosion and the parcel complies with all local ordinances. Landowners of protection-ineligible parcels do not have the right to apply for a SPS permit and therefore can do little to protect their home if it becomes vulnerable to erosion risk. It is important to note that shoreline stabilization actions for protecting property in Oregon are typically undertaken at the parcel level, as large,

⁴ In 2015, an oceanfront property in Rockaway Beach challenged local and state determination of parcel ineligibility under Goal 18. The SPS application was denied as alterations to the property violated local comprehensive plans resulting in the ineligibility determination. The property owner recently (Dec. 2016) withdrew the appeal, but further legal action is possible.

coordinated efforts, such as beach replenishment, are not common.⁵ In fact, there have been no federal or state interventions to nourish beaches in Oregon, whereas over 2,000 replenishment events have occurred in other coastal US states since 1923 (Program for the Study of Developed Shorelines 2017). The focus of our conceptual model (Section 2) and empirical analysis (Sections 4 and 5) is driven by the variation in the private option for coastal protection codified by this land-use policy.

2. A MODEL OF IRREVERSIBLE EXPECTED LOSS

To provide a conceptual framework for our empirical analysis, we develop a simple model of a coastal housing market's capitalization of the option to prevent the realization of an irreversible loss. Our emphasis centers on Oregon's Goal 18 land-use policy that allows owners of protection-eligible coastal parcels to exercise their protection option and install SPS when faced with a potential irreversible loss. In this case, the loss can be considered irreversible because coastal erosion can accelerate land loss and undermine the structural integrity of a home, rendering the building inhabitable and the parcel unsuitable for re-development. This stands in contrast to the literature that uses a state-dependent utility framework to model willingness to pay for a reduction in the probability of flooding or storm events that cause temporary loss (MacDonald et al. 1987; Atreya et al. 2013; Bin and Landry 2013). In our model, protection-eligible parcels that become vulnerable have the option to install a SPS to avoid the possibility of an irreversible loss. In other words, owners of eligible parcels can pay an option price (e.g., Smith 1985) to prevent an irreversible loss and maintain use of their coastal property. We assume this land-use policy is the only mechanism for protecting coastal property, which is consistent with coastal management in Oregon as no beach nourishment events have occurred and no other public policies exist to provide a substitute for the private protection option established by the Goal 18 policy.

Consider coastal housing as a capital asset that generates an annual flow of rents (R) to a landowner. In the coastal land market, there are two sets of assets differentiated by a land-use policy – one set is eligible for a protection option and the other is ineligible. If buyers in this

⁵ Coordination among neighboring parcels to construct a SPS is possible. However, all parcels must be Goal 18 eligible and meet hazard risk criteria to be approved for a permit. In other words, installation of a SPS at a larger spatial scale than the parcel is possible but only under certain conditions. In the permitting data, each permit is associated with an average of 1.96 parcels.

market believe that ρ , the subjective annual probability of the irreversible loss, is greater than zero, then an asset with protection eligibility will command a positive price differential relative to the ineligible asset, *ceteris paribus*. We define this price differential as the capitalization effect (*CE*) of protection eligibility. We assume that ρ is a function of certain parcel characteristics (x) that are likely to influence this subjective probability of the irreversible loss, such as shoreline change rates adjacent to the parcel (*SC*), elevation of the parcel (*Elev*), and the protection eligibility status of neighboring parcels (*PESN*). Our initial (and testable) hypotheses for the effect of these characteristics on ρ are as follows:

$$\frac{\partial \rho}{\partial SC} \leq 0 \quad (1)$$

$$\frac{\partial \rho}{\partial Elev} \leq 0 \quad (2)$$

$$\frac{\partial \rho}{\partial PESN} \geq 0 \quad (3)$$

The first and second expression, respectively, suggest that as *SC* increases (i.e., accretion) or *Elev* increases, an asset owner's subjective probability of an irreversible loss should be lower because the parcel has less exposure to hazards. Conversely, if *SC* is negative (i.e., erosion) or if *Elev* decreases, then ρ should increase. Expression (3) implies that there may be potential for negative spillover effects from private coastal armoring decisions. If a given parcel's neighbor is protection-eligible, then that parcel owner's ρ may increase due to the potential risk of re-directed wave action from the protected neighbor which thereby increases their own risk of irreversible loss.

Assume that owners of both types of assets receive rents R each year that the property is viable (i.e., not threatened with irreversible loss) and eligible owners can exercise their protection option and continue to receive R each year if the asset becomes threatened and subsequently protected. If the asset is compromised and the landowner does not have a protection option (i.e., land erodes and the structure is undermined/uninhabitable), an irreversible loss occurs and the landowner receives no rent ($R=0$).

Now, we derive the land market's price differential for the protection option, expressed as an annual *CE*. Assuming a constant annual $\rho(x)$, we adapt Provencher et al.'s (2012) logic to our application and link the *CE* for the protection option to the asset owner's subjective probability

that the irreversible loss will occur. This probability in the current period ($t=0$) is $\rho(x)$, and so the CE of the ability to protect against a loss that occurs in $t=0$ is equal to the *expected irreversible loss* ($\rho(x) * R$). Conditional on the asset remaining viable through the current period, the CE of the ability to protect against a loss from occurring in the second period ($t=1$) is the same value discounted $(\rho(x)*R)/(1+r)$, where r is the discount rate. The probability that the asset does not experience an irreversible loss in $t=0$ is $1 - \rho(x)$; therefore, the unconditional CE for the ability to protect against a loss that occurs in $t=1$ is $(1 - \rho(x)) * (\rho(x)*R)/(1+r)$. Extending this logic to an infinite horizon, the annual CE of the protection option can be written as:

$$\begin{aligned} CE(x, r, R) &= \rho(x)R + \rho(x)R \left(\frac{1 - \rho(x)}{1 + r} \right) + \rho(x)R \left(\frac{1 - \rho(x)}{1 + r} \right)^2 + \rho(x)R \left(\frac{1 - \rho(x)}{1 + r} \right)^3 + \dots \\ &= \rho(x)R \sum_{t=0}^{\infty} \left(\frac{1 - \rho(x)}{1 + r} \right)^t, \end{aligned} \quad (4)$$

where this infinite series simplifies to:

$$CE(x, r, R) = \frac{\rho(x)*(1+r)}{\rho(x)+r} R. \quad (5)$$

Equation (5) is an expression for the CE of the protection option in terms of the annual rents to the asset (R) that are at risk to the irreversible loss, the subjective probability of the irreversible loss ($\rho(x)$) and the discount rate (r). CE is an increasing function of $\rho(x)$ and R , and a decreasing function of r . In our empirical application, we value the option created by Oregon's Goal 18 policy by estimating differences in sales prices between comparable protection-eligible and protection-ineligible parcels (i.e., the CE). We then use fine-scale spatial data on x to test our hypotheses on how changes in a set of geomorphological and locational factors impact ρ and the CE of having a coastal protection option.

We motivate our exploration into the spatial spillover effects of private coastal protection decisions by returning to equations (3) and (5). Consider the price difference between two assets that are both protection-ineligible and identical in every way except that one is located next to a protection-eligible asset and the other is not. The parcel with the protection-eligible neighbor could face deflected wave action from the neighbor's SPS, which gives them a higher risk of the irreversible loss when compared to the parcel that has no protection-eligible neighbors (equation (3)). In this situation, the presence of $\rho > 0$ implies a market price premium for having no protection-eligible neighbors. In other words, further price differentials expressed as a capitalization effect may emerge between protection-ineligible assets due to the increased risk

that arises from proximity to protection-eligible assets. This simple counterfactual example implies that if (3) holds, there is potential for a negative externality resulting from private coastal protection decisions which should be capitalized in the coastal land market. Our empirical analysis uses this logic to identify and estimate the direction and magnitude of these spillover effects and the impact of the spillover effects on subjective risk of irreversible loss.

3. DATA

The Oregon DLCD monitors Goal 18 and recently produced a GIS dataset characterizing each oceanfront parcel as eligible or not eligible, allowing us to identify parcel-level variation in the option to invest in coastal protection. Of the 9,444 oceanfront parcels in Oregon, 49% are considered eligible, 36% ineligible, with the remaining parcels being either state-owned or deemed undevelopable under other statutes. An example of the parcel-level variation in Goal 18 eligibility within a community is shown in figure 1.

To analyze the impact of protection eligibility on housing prices, deed records and tax assessor data from 2004–2015 were purchased from CoreLogic’s University Data Portal. These data contain transaction price, sales date, street address, and numerous housing characteristics—including number of bedrooms, number of bathrooms, year built, square footage, lot size, among others. Transaction prices are adjusted to 2015 dollars using the Housing Price Index from the Federal Housing Finance Agency. This information is then merged with GIS tax parcel maps obtained from the State of Oregon. Data characterizing the risks and amenities for oceanfront parcels are obtained from existing technical reports, such as shoreline change rates (Ruggiero et al. 2013), and through geoprocessing LiDAR and orthophoto data to generate parcel-level variables (e.g. parcel elevation, setback from statutory vegetation line, existence of a SPS structure, geomorphology, distance to mean high water, lighthouse proximity). This latter process yields a rich characterization of parcel-level risks and amenities.

The data set contains 1,738 transactions of oceanfront homes in Oregon with a Goal 18 eligibility determination from 2004–2015. We restrict our analysis to single-family residences, and then remove transactions that are not deemed arms-length or contain missing data (e.g. no bedrooms). Potential outliers (i.e., lowest and highest 1% of sales prices) are also dropped from the dataset. We then have 1,519 arms-length transactions of single family, oceanfront residences for the analysis. Goal 18 eligible parcels comprise 72 percent of the sample (1,101 transactions)

and summary statistics by eligibility status are displayed in table I. Goal 18 eligible homes have slightly lower average sale prices than non-eligible homes in our sample. The non-eligible homes are also newer, larger, constructed on larger lots, and setback further from the statutory vegetation line at a higher elevation.

A second data set of housing value, known in Oregon as real market value (RMV), was purchased from assessor's offices in Oregon's coastal counties (Clatsop, Coos, Curry, Douglas, Lane, Lincoln, and Tillamook). All Oregon properties have a RMV assessed each calendar year defined as what a parcel would sell for at an arms-length transaction on January 1st of that tax year. RMVs are determined by a combination of physical property inspection and a comparison of sales transaction data from similar properties. In other words, RMVs are not assessed values, but an assessor determination of market value for each year. Previous work has used RMVs to investigate the effects of urban growth boundaries in Oregon (Grout et al. 2011; Bigelow and Plantinga 2017). Here, the RMV data are joined to each oceanfront parcel with a Goal 18 eligibility determination and are used to develop a separate analysis to support the hedonic models with transaction data as described in the next section.

4. EMPIRICAL METHODS – The Value of the Option to Protect

We use a hedonic pricing model to estimate the capitalization effect of having the private protection option on housing prices in the Oregon oceanfront housing market. It is important to note that this policy has been in place for 42 years to date and 28 years prior to the first observation in our data. We therefore assume this policy is well-known by both buyers and sellers in the housing market. However, this does raise identification concerns that we must address since we are using non-experimental data and lack a more customary quasi-experimental framework with pre- and post-policy observations. First and foremost, the treatment (protection-eligible) and control (protection-ineligible) groups are not balanced on observable characteristics, as shown in table I. This is not unexpected, as treatment was defined by the state planning goal in 1976, but does cause concern about estimating the treatment effect since it creates imbalance in observable characteristics between treatment and control groups. To remedy this issue, we trim the transactions data to improve the balance on observables through a matching procedure (Rosenbaum and Rubin 1983; Imbens 2015) before estimation of the hedonic regression. Walls et al. (2017) recently used a similar methodology to estimate the

effects of energy certification on housing prices amidst a broader methodological push for combining matching and post-matching regression techniques (Ferraro and Miranda 2017).

Specifically, we use logit regressions with all independent variables included in our hedonic model and additional geographic controls (latitude and longitude) to generate propensity score estimates of the probability that each parcel is treated with protection-eligibility. Panel A of figure 2 shows the distribution of propensity scores for the treatment (grey) and control (black dash) groups, highlighting the imbalance in covariates. Since our data have more treated observations than controls, a nearest neighbor matching algorithm with replacement keeps all controls and matches to treated observations based on the estimated propensity score. This data trimming procedure reduces the number of observations to 866 transactions but significantly improves the balance on observables between the two groups of homes. Panel B of figure 2 provides visual evidence of the improvement in balance and table II includes summary statistics for each group and the reduction in standardized bias for the matched sample. Figure 3 provides a comparison of observations in the full and trimmed samples, demonstrating the matching process does not fundamentally change the spatial distribution of the market transactions used in our models.

A second identification concern is the potential for correlation of amenities and risk in coastal housing markets (e.g., Bin and Kruse 2006; Bin, Kruse and Landry 2008; Bin et al. 2008; Dundas 2017). We use data on structure setback from statutory vegetation line (as a proxy for ocean views), lighthouse proximity and bluff location of a home to control for housing-related amenities. To characterize coastal risks, we use parcel-level estimates of elevation, shoreline change rates, distance to mean high water and location in the 100-year floodplain. We also control for existing SPS on a parcel. The parcel-level scale of our coastal risk data also allows us to interact the risk variables with a dummy indicating protection-eligibility and formally test our hypotheses in equations (1) and (2). Given that some combination of risks and/or amenities may be unobservable, section 4.2 presents a robustness check on whether we've adequately disentangled amenities and risks using an alternative spatial first-differences estimator.

We use the matched sample of transaction data to estimate the impact of protection-eligibility on housing prices as follows:

$$\ln P_{it} = \alpha + \beta G18_i + Elev_i [\delta_1 + \delta_2 G18_i] + SC_i [\omega_1 + \omega_2 G18_i] + \mathbf{X}_{it} \sigma + \eta_{jt} + \nu_t + \varepsilon_{imt} , \quad (6)$$

where the natural log of sales price (P) of home i at time t (adjusted to 2015 dollars) is the dependent variable. $GI8_i$ is the policy variable of interest equal to one if the parcel is protection-eligible, while $Elev_i$ and SC_i are variables quantifying minimum parcel elevation (feet above sea level) and the long-term shoreline change rate (meters per year) at parcel i . The vector X represents structural attributes of each home, which are included in the regression to control for any remaining imbalances in the variables after matching. County-by-year fixed effects (η_{jt}) are used to control for county-specific attributes that change over time and quarter sold fixed effects (ν_t) are used to account for seasonal housing market trends. The model is estimated with robust standard errors clustered by municipality (m), and so the estimates are robust to heteroscedasticity and spatial correlation across parcels within a municipality.

4.1 Estimation Results for the Value to Protect

Table III displays our main model results using the trimmed, post-matching transaction data.⁶ The initial model (column 1) with only housing characteristics suggests the coefficient on Goal 18 eligibility is not significantly different from zero. The second column adds parcel amenity and risk characteristics, as well as interactions with the policy variable of interest and the third column further adds two sets of fixed effects. Results from our preferred model (column 3) suggest that protection eligibility has a positive, statistically and economically significant impact on housing values. The coefficient estimate implies protection-eligibility produces a price premium of 26.7 percent for protection-eligible homes compared to similar protection-ineligible homes.⁷ We also find this value varies with risk exposure (parcel elevation and shoreline change rates) and the direction and magnitude of these interaction effects suggests our hypotheses in equations (1) and (2) in our conceptual framework are true. Specifically, we find the value placed on protection-eligibility is likely to decline 0.4 percent per 1 foot increase in elevation above sea level and decline 9.8 percent for each additional meter of accretion per year. These results also imply that value for protection-eligibility is likely to be higher at lower elevations and may even increase as shoreline change rates become more negative (i.e., erosion). All housing characteristics in the hedonic model have expected signs and relative magnitudes.

⁶ Regression results for the full, unbalanced transaction sample are included in the online appendix as table A.1.

⁷ Percentage effects derived using an adjustment of the estimated coefficient following Halvorsen and Palmquist (1980).

Since we have interactions of discrete and continuous variables that impact the overall effect of protection-eligibility on housing prices, we derive point estimates and standard errors for the discrete change effect of protection-eligibility evaluated at average elevation and shoreline change rates for all parcels and three subset of homes based on risk profile (eroding parcels, lower than average elevation parcels, and eroding, low elevation parcels) using a linear combination of the parameter estimates β , δ_2 , and ω_2 from equation (6) for each model specification. As shown in column (1) of table IV, protection-eligibility for the average oceanfront parcel in the sample (30' elevation and +0.6 m/year shoreline change) has a positive but insignificant effect on price (5% level). Furthermore, no significant effects are found for parcels with accreting shorelines or above average elevation, indicating that the housing market does not value protection-eligibility if exposure to erosion risk is low. We do find positive and marginally significant effects for parcels with eroding shoreline (15 percent) or at lower than average elevations (13 percent). For the 18 percent of parcels in the sample that have both an eroding shoreline and are located at a below average elevation, we find a nearly 24 percent price premium for eligible homes compared to non-eligible homes. An average sales price of approximately \$675,000 implies a price premium for protection-eligibility of approximately \$159,000 for parcels with eroding shorelines and low elevation. Figures 5 and 6 illustrate how the option value for coastal protection varies with elevation and shoreline change rates, respectively. As shown, the effect of having the option for coastal protection is substantively higher for more vulnerable parcels.

Applying our conceptual framework, we can compute an approximation of the annual subjective probability of irreversible loss ($\rho(x)$) implied by the results of our empirical estimation. First, equation (5) can be re-arranged to solve for $\rho(x)$:

$$\rho(x) = \frac{r*CE(x,r,R)}{R(1+r)-CE(x,r,R)} \quad (7)$$

We assume a 5 percent discount rate ($r=0.05$) for simplicity. For the parcels at risk for irreversible loss, the average home in each subset sold for \$616,000 (eroding shoreline-only), \$664,000 (low elevation-only) and \$675,000 (both eroding and low-elevation). This average prices imply annual rents of $R_{Erode} = \$30,800$, $R_{LowElev} = \$33,200$, and $R_{Both} = \$33,750$. The estimated CE (annualized) for protection-eligibility estimated in our preferred models are \$91,800 (\$4,590), \$84,300 (\$4,215), and \$159,300 (\$7,965), respectively. We can then solve for

$\rho(x)$ for each subset of parcels. Here, we show the calculation for parcels that are both low elevation and eroding:

$$\rho(x)_{Both} = \frac{0.05 * 7,965}{33,750 * (1.05) - 7,965} = 0.0145 \quad (8)$$

Similar calculations for the other parcel subsets yields $\rho(x)_{Erode} = 0.008$ and $\rho(x)_{LowElev} = 0.007$.

So, the subjective annual probability that a home will experience an irreversible loss absent the option for protection varies with the risk profile of the parcel and is approximately between 0.7 and 1.5 percent.

4.2 Robustness Checks for the Value to Protect

While our preferred empirical strategy includes specific independent variables that measure risks and amenities of oceanfront property, it is still possible that there are unobservable elements of parcel-level risks and amenities that could potentially confound our identification of the Goal 18 treatment (protection-eligibility) effect. Therefore, as a robustness check to our main results, we develop a spatial first-differences model to difference out risks and amenities that are spatially invariant across neighboring parcels that otherwise vary in their protection-eligibility. We use real-market value (RMV) data as the dependent variable in a model that is the spatial analogue to the repeat-sales model commonly used in the hedonic literature to mitigate bias from time-invariant unobservables. Since RMV is available for all oceanfront parcels in Oregon (including those that sold during our period and those that did not), we identify actual neighbors (i.e., parcels that share a common boundary) that differ in protection-eligibility and create first-differences in RMV across the neighboring parcels.⁸ Since amenities and risks are expected to be almost identical for neighboring parcels, this spatial first differences approach is likely to eliminate any confounding effects to identifying impact of protection-eligibility. The downside to using RMV values is that it may differ from actual sales transactions. Using GIS processes, we find 258 matched pairs of neighboring single family residences along the Oregon coast. Given the panel structure of the RMV data, this implies the potential for 3,096 observations. After removing observations with missing data, we have 2,529 observations for this analysis.

⁸ Unfortunately, the logic of this estimator cannot be applied to the transaction data as only 2 sets of homes meeting the actual neighbor criteria were found.

Each matched pair of neighboring parcels can be represented by a pair of hedonic price functions:

$$\ln RMV_{itg} = \alpha + \beta_g G18_{ig} + \mathbf{X}_{itg} \sigma + \eta_{jt} + \nu_t + \varepsilon_{ijt}, \text{ for } g = 0, 1, \quad (9)$$

where subscript g indicates protection-eligibility group. We then take the difference of those hedonic price functions for each matched pair observation as follows:

$$\begin{aligned} (\ln RMV_{it1} - \ln RMV_{it0}) = & (\alpha - \alpha) + (\beta_1 - \beta_0)(G18_{i1} - G18_{i0}) + (\mathbf{X}_{it1} - \mathbf{X}_{it0})\sigma \\ & + (\eta_{jt} - \eta_{jt}) + (\nu_t - \nu_t) + (\varepsilon_{ijt1} - \varepsilon_{ijt0}). \end{aligned} \quad (10)$$

We are then left with the following spatial first-differences estimation equation:

$$\Delta \ln RMV = \beta_1 + \Delta \mathbf{X}_{it} \sigma + \lambda Year_t + \Delta \varepsilon_{ijt}, \quad (11)$$

where β_1 is the intercept and represents the effect of protection-eligibility, $\Delta \mathbf{X}_{it}$ controls for differences in structural attributes of the homes on neighboring parcels, and $Year_t$ is a fixed effect added to control for time varying factors given the pooled cross-sectional nature of the data.⁹ Locational amenities (e.g. quality of ocean views) should be approximately equal across geographic neighbors, and so those amenities would be differenced out of (10) and (11) and therefore not confound identification of the G18 treatment.

As a second robustness check, we include variables in our hedonic model that account for a second coastal risk. We use the tsunami hazard line created in 1995 by Oregon Senate Bill 379 as an acute risk signal for the housing market.¹⁰ In addition, a 9.0 magnitude earthquake occurred 45 miles off the coast of the Tōhoku region of Japan on March 11th, 2011, which falls during the timeframe of our analysis. This event provided information to coastal land owners about risk associated with far-field tsunami events that may have changed subjective risk assessments for buyers and sellers in the oceanfront housing market.

4.3 Robustness Checks – Estimation Results

The estimates for protection-eligibility for all parcels and the eroding parcels from our spatial first-differences model are presented in panel B of table IV and match reasonably well to the

⁹ Given that RMV data is determined by assessors and is not an actual market price, this data did not provide a reasonable option for investigating the spillover effects with the spatial first-differences model.

¹⁰ The geography of the Oregon Coast is advantageous from a modeling perspective as it allows parcel-level variation in this acute risk. For other acute coastal hazards (e.g., a major hurricane landfall), the risk is not likely to vary at a spatially relevant scale for a given oceanfront housing market, making it difficult (if not impossible) to identify variation related to acute risk in housing prices. For oceanfront parcels in Oregon, 76% are within the tsunami hazard zone.

results from our preferred hedonic model with transaction data. That is, we find a positive and insignificant effect for all parcels and a positive and significant effect of nearly 15 percent for parcels with an eroding shoreline. Since this spatial-first differences model is designed to difference out parcel-level amenities, this result provides evidence that the correlation between amenities and risk are likely not biasing our preferred model results, and our amenity control variables appear to be sufficient for identifying the Goal 18 treatment effect. Yet, the results for low elevation parcels are not significant. There are two potential explanations for this inconsistency. First, elevation is a driver of parcel risk, but it is also inextricably tied to amenities through view and ease of beach access. Therefore, it may be difficult to disentangle these competing effects through an elevation variable. Another potential explanation is that assessors calculating RMV take shoreline change rates into account but do not address elevation when assessing the value of the option to protect against erosion risk.

Estimates from the second robustness check which adds variables characterizing the tsunami hazard information shock are performed using a variant of (6) that includes the tsunami hazard variables and their interactions with our treatment indicator. Coefficients on protection-eligibility and the interactions with elevation and shoreline change rate are relatively stable between models, suggesting information about a second coastal risk did not change assessment of subjective erosion risk in the housing market.¹¹

5. SPILLOVER IMPACTS OF PRIVATE COASTAL PROTECTION OPTIONS

Results presented in section 4 may be impacted by the presence of a spatial spillover (externality) on protection-ineligible parcels related to their eligible neighbor's option to armor (i.e., equation (3)). A private choice to armor shoreline with a protective structure may alter the pattern of sediment dynamics along the coastline such that erosion risks are accentuated on the shoreline of parcels that are nearby to armored neighbors.¹² Indeed, the potential for altered shoreline sediment dynamics was a primary justification for the original Goal 18 policy that limited shoreline armoring. Intuitively, including all parcels in the primary estimation of (6) leaves open the possibility that the estimated effect of the Goal 18 policy is a combination of the

¹¹ Description of this model and the results are provided in the online appendix.

¹² While the existence and magnitude of these potential impacts is still an open empirical question dependent on the position of the SPS, beach slope and other geomorphological and hydrodynamic parameters (Ruggiero 2010; Ells and Murray 2012), it does have the potential to impact risk perceptions of buyers and sellers in a coastal housing market.

effect of protection-eligibility and the effect of the spatial externality associated with close proximity to potential future SPS. To test for and identify the magnitude of a potential spillover from protection-eligibility, we define a second control group where protection-ineligible homes within a specified linear distance of treated parcels are removed from the estimation set. We test three spatial buffers (100', 200', and 500'). Figure 4 provides a schematic representation of our strategy for estimating the spillover effects, highlighting the different control groups used in the various model specifications.

Panel A of table V shows coefficients for protection-eligibility and the interaction terms for our preferred model and for models where the control group was modified to exclude transactions within 100', 200' and 500' buffers of treated parcels. While the estimates for the interaction effects remain fairly stable, there is suggestive evidence of a potential spillover effect as the main effect of protection-eligibility is lower in the spatial buffer models, suggesting that the full model results in section 4 may be picking up both a positive treatment effect from protection-eligibility, and a negative spillover effect from protection-eligibility onto protection-ineligible parcels that are close neighbors.

Panel B of table V shows discrete change effects for the main model compared to the spatial buffer models. The results are consistent in sign and significance with one important exception. Across all parcels types, the discrete change effect of protection-eligibility with the spatial buffer declines between 2.8 and 5 percentage points, and estimates are consistent with the idea that spillover effects are likely present for more proximate parcels (i.e., differences get smaller as buffer gets larger). This provides evidence of the presence of a spillover effect and suggests the effect could be non-trivial.

We then use the model estimates with and without the spatial buffer to examine the magnitude and the policy implications of the Goal 18 spillover. In this exercise, we define β_F as the discrete change effect of protection-eligibility estimated from the main model without the spatial buffer, and β_{NI} as the effect estimated from the spatial buffer model where subscript *NI* denotes “not-impacted” by the spillover effect. While both of these effects were estimated above, the effect of excluded parcels subject to the externality (β_{SPE}) has not yet been estimated. We can back out this estimate, assuming the effect from the main model is a weighted average of

the effects from the control group in the buffer models (NI) and the control parcels subject to the spillover externality (SPE) as follows:

$$\%C_{NI} * \beta_{NI} + \%C_{SPE} * \beta_{SPE} = \beta_F, \quad (12)$$

where $\%C_{NI}$ is the percentage (69.4 %) of control parcels not impacted by the spillover externality (included in the spatial buffer models) and $\%C_{SPE}$ is the percentage (30.6 %) of control parcels subject to the spillover externality (excluded from spatial buffer models). We can then solve (12) for β_{SPE} and then calculate the spillover effect as:

$$SPE = \beta_{SPE} - \beta_{NI}. \quad (13)$$

For this back-of-the-envelope exercise, we assume 500' is a reasonable approximation for the spatial extent of the externality related to SPS installation.¹³ Estimating SPE using (12) and (13) across each subset of at-risk parcels based shoreline change rates and elevation, we find spillover damages ranging from 7.4 to 16.3 percent.¹⁴ Replacing the *betas* in (12) and (13) with *rhos*, we can calculate the difference in the implicit probability of irreversible loss between the protection-eligible parcels differentiated on exposure to the externality. Using the same $\%C_{NI}$ and $\%C_{SPE}$ as above, $\rho_F = 0.015$ as calculated from the main model for vulnerable parcels, and calculating $\rho_{NI} = 0.012$ from model results in col. 4 of table 5, we estimate $\rho_{SPE} = 0.019$. This calculation shows that the capitalization of the spatial externality associated with proximity to protection-eligible parcels implies an increase in annual subjective probability of an irreversible loss of 0.7 percent. This result holds across the other three classifications of parcels in our analysis – all parcels, low elevation-only parcels, and eroding shoreline-only parcels – where we find similar increases in ρ (0.6 percent, 0.8 percent, and 0.68 percent, respectively).

To further test our strategy to quantify the spillover impacts, we estimate additional hedonic models, including a full model specification (6) with the addition of a spillover dummy (SP) for control parcels subject to the spatial externality (within 500' of a protection-eligible parcel), and a regression with the spillover dummy but estimated only with control parcels that are not protection-eligible, substituting SP for the Goal 18 status variable ($G18$) as follows:

¹³ The other buffers tested (100' and 200') present challenges in estimation as parcels in the SPE group are limited to 41 and 65 parcels, respectively. Furthermore, our personal discussions with coastal geomorphologists lead us to believe 500' is a reasonable approximation for the potential extent of spillover impacts.

¹⁴ A drawback to this approach is that we do not have standard errors on these back-of-the-envelope estimates.

$$\ln P_{it} = \alpha + \lambda SP_i + Elev_i [\mu_1 + \mu_2 SP_i] + SC_i [\tau_1 + \tau_2 SP_i] + \mathbf{X}_{it} \sigma + \eta_{jt} + \nu_t + \varepsilon_{imt} . \quad (14)$$

We find a marginally significant (10% level) 9 percent decline in property value attributable to the spatial externality and these point estimates fall directly in the range of our back-of-the-envelope calculations. This model provides evidence supporting our method to identify the potential magnitude of the spatial externality – although overall precision of the estimates in (14) is limited by the size of our dataset. Summary statistics showing balance on observables among the control parcels designations (table A.3) and estimation results for the additional models (table A.4) are provided in the online appendix.

To see how the estimated spillover impacts may affect the net benefits of Oregon’s Goal 18 policy, we apply our estimates to all 4,768 oceanfront parcels in Oregon governed by Goal 18 that are most vulnerable (eroding shoreline, low elevation).¹⁵ First, we calculate the number of spillovers possible for every protection-eligible parcel (panel A of figure 7). Of the 2,715 protection-eligible parcels, 49 percent do not have potential for spillover effects on protection-ineligible parcels. Of the 51 percent of protection-eligible parcels where that potential exists, 422 have potential to impact only one protection-ineligible parcel, leaving 914 parcels that can potentially have a negative impact on multiple parcels. We then examine four potential scenarios capturing the range of estimated option values (13 – 24 %) and spillover damages (7 – 16 %): 1) maximum benefit (+24%), minimum cost (-7%); 2) minimum benefit (+13%), minimum cost (-7%); 3) maximum benefit (+24%), maximum cost (-16%); and 4) minimum benefit (+13%), maximum cost (-16%). Under scenario 1), a protection-eligible parcel would need to negatively impact a minimum of four protection-ineligible parcels to be considered a net cost. Scenarios 2) and 3) produce similar results, with protection-eligible parcels becoming a net cost with two protection-ineligible neighbors. Under scenario 4), spillovers are likely to generate net costs if there are any protection-ineligible neighbors and up to 50 percent of protection-eligible parcels have net cost potential. These findings are summarized graphically in panel B of figure 7.

This analysis finds that the net benefits of the option to protect coastal property may not be positive when factoring in spillover damages from one parcel to neighboring property owners. In this specific case of Oregon’s Goal 18, grandfathering of eligibility and subsequent land development decisions created a fragmented spatial configuration of policy eligibility that

¹⁵ This represents about 50 percent of all oceanfront parcels in Oregon. The remaining 50 percent of parcels are either at higher than average elevation (>30') or are located on accreting shorelines, or both.

generates externalities on protection-ineligible parcels and perverse incentives for protection-eligible parcels. To the former point, consider the community of Surf Pines in Clatsop County. There are 118 parcels in Surf Pines with a Goal 18 determination, with 35 protection-eligible and 83 protection-ineligible. Assuming a 500' extent for spillover damages, 86 percent of protection-ineligible parcels in Surf Pines would be subject to this externality due to the fragmented application of the Goal 18 policy. The policy is a net cost to Surf Pines under three of the four scenarios explored above, with Goal 18 being a net benefit only under scenario 1) assumptions.

To the latter point regarding perverse incentives, our results suggest that in settings where all landowners have the option to install SPS, the potential for spillover damages provide incentive for neighbors to invest in their own protection, which could lead to a cascading of spatially adjacent shoreline armoring decisions. Suggestive evidence of this can be seen in Rockaway Beach in Tillamook County. In this community, nearly all 233 parcels are protection-eligible under Goal 18 and 36 percent have armored to date. Yet, armoring is located in a spatially continuous line that stretches for over 1 mile of shoreline, protecting all 85 parcels that have made the choice to armor in Rockaway Beach.¹⁶

6. CONCLUSION

Given the potential for continued sea level rise and increased storm events, efforts to stabilize shorelines and protect existing coastal infrastructure are likely to continue at local, state, and federal levels. A recent review by Gopalakrishnan et al. (2018) highlights the economic literature's focus on beach nourishment and community-level decision making for coastal management. Our work here contributes by estimating non-market values for private, parcel-level coastal protection options and identifying the potential for spillover damages arising from these private decisions. We analyzed data on oceanfront housing transactions in Oregon where a statewide land-use regulation provides substantial cross-sectional variation in the parcel-level option to invest in protection from coastal hazards. We estimate positive option values for the ability to protect shoreline of between 13 to 24 percent of land value for parcels vulnerable to erosion risk. We also demonstrate that these values are dependent on the risk profile of the parcel, and parcels at low risk to erosion have no value for the option to invest in protection.

¹⁶ Aerial imagery with parcel designations and existing SPS for both the Surf Pines and Rockaway Beach examples are provided as Figures A.2 and A.3 in the online appendix.

These estimated non-market values for coastal protection are arguably de-coupled from coastal amenities that typically accompany beach nourishment events (i.e., beach width, recreation access). Our conceptual model demonstrates that the capitalization effects we find imply that the subjective annual probability of an irreversible loss from coastal erosion is approximately 0.7 to 1.5 percent (with a 5 percent discount rate).

Furthermore, we find evidence of spillover effects associated with parcel-level coastal protection options that could be as high as a 16 percent reduction in the value of neighboring, protection-ineligible land, implying a 0.7 percent higher subjective risk of irreversible loss for parcels subject to the spatial externality. This provides suggestive evidence that spillovers in private coastal protection decisions may potentially negate the net benefits of the land-use policy in some locations where eligibility is spatially fragmented. Although we do not have the necessary models to consider other beach users, it is likely that the choice to protect private property with SPS will contribute to beach erosion and generate further losses to public beach users who do not own property. Spatial externalities have been acknowledged before as a potential issue in coastal settings (Smith et al. 2009; Gopalakrishnan et al. 2016; Gopalakrishnan et al. 2017) and in land-use decisions in non-coastal settings (Irwin and Bockstael 2002; Lewis et al. 2011; Lawley and Yang 2015). Here, we provide the first empirical evidence of the magnitude of negative spatial externalities associated with private coastal protection options, and our results support evidence of ancillary costs from coastal protection decisions in the public sphere (i.e., beach nourishment) found in Dundas (2017).

Future coastal management can benefit from the integration of non-market values for service flows, estimates of subjective risk probabilities, and the identification of tradeoffs and perverse incentives from private actors into the decision making process. In Oregon, a land-use regulation seeks to provide a public good (beach access) at the expense of a private good (coastal protection), but the grandfathering features of the policy creates winners, losers, and incentives for behavior that may counteract the original intention of the policy. Future work is needed to understand the drivers of both private and public coastal protection decisions along with integration of economic and geophysical models of shoreline change to better predict where certain policies may or may not be needed in the future.

REFERENCES

- Atreya, Ajita, Susanna Ferreira, and Warren Kriesel. 2013. Forgetting the flood? An analysis of the flood risk discount over time. *Land Economics* 89 (4): 577-96.
- Bigelow, Daniel P., and Andrew J. Plantinga. 2017. Town mouse and county mouse: Effects of urban growth controls on equilibrium sorting and land prices. *Regional Science and Urban Economics* 65:104-15.
- Bin, Okmyung, and Craig E. Landry. 2013. Changes in implicit flood risk premiums: Empirical evidence from the housing market. *Journal of Environmental Economics and Management* 65:361-76.
- Bin, Okmyung, Jaime B. Kruse, and Craig E. Landry. 2008. Flood hazards, insurance rates, and amenities: Evidence from the coastal housing market, *Journal of Risk and Insurance* 75 (1): 63–82.
- Bin, Okmyung, Thomas W. Crawford, Jaime B. Kruse, and Craig E. Landry. 2008. Viewscapes and Flood Hazard: Coastal Housing Market Response to Amenities and Risk. *Land Economics* 84 (3): 434-48.
- Bin, Okmyung, and Jaime B. Kruse. 2006. Real estate market response to coastal flood hazards. *Natural Hazards Review* 7 (4): 137–44.
- Bin, Okmyung, and Stephen Polasky. 2004. Flood hazards on property values: Evidence before and after Hurricane Floyd. *Land Economics* 80 (4): 490-500.
- Davlasheridze, Meri, Karen Fisher-Vanden, and H. Allen Klaiber. 2017. The effects of adaptation measures on hurricane induced property losses: Which FEMA investments have the highest returns? *Journal of Environmental Economics and Management* 81:93-114.
- Dundas, Steven J. 2017. Benefits and ancillary costs of natural infrastructure: Evidence from the New Jersey coast. *Journal of Environmental Economics and Management* 85:62-80.
- Ells, Kenneth, and A. Brad Murray. 2012. Long-term, non-local coastline responses to local shoreline stabilization, *Geophysical Research Letters* 39:L19401
- Ferraro, Paul J., and Juan José Miranda. 2017. Panel data designs and estimators as substitutes for randomized controlled trials in the evaluation of public programs. *Journal of the Association of Environmental and Resource Economists* 4 (1): 281-317.
- Gopalakrishnan, Sathya, Craig E. Landry, and Martin D. Smith. 2018. Climate change adaptation in coastal environments: Modeling challenges for resource and environmental economists.

- Review of Environmental Economics and Policy* 12 (1): 48-68.
- Gopalakrishnan, Sathya, Dylan McNamara, Martin D. Smith, and A. Brad Murray. 2017. Decentralized management hinders coastal climate adaptation: The spatial-dynamics of beach nourishment. *Environmental and Resource Economics* 67 (4): 761-87.
- Gopalakrishnan, Sathya, Craig E. Landry, Martin D. Smith, and John C. Whitehead. 2016. Economics of coastal erosion and adaptation to sea level rise. *Annual Review of Resource Economics* 8:119-39.
- Gopalakrishnan, Sathya, Martin D. Smith, Jordan M. Slott, and A. Brad Murray. 2011. The value of disappearing beaches: A hedonic pricing model with endogenous beach width. *Journal of Environmental Economics and Management* 61 (3): 297-310.
- Grout, Cyrus A., William K. Jaeger, and Andrew J. Plantinga. 2011. Land-use regulations and property values in Portland, Oregon: A regression discontinuity design approach. *Regional Science and Urban Economics* 41 (2): 98-107.
- Hallstrom, Daniel G., and V. Kerry Smith. 2005. Market Responses to Hurricanes. *Journal of Environmental Economics and Management* 50:541-61.
- Halvorsen, Robert, and Raymond Palmquist. 1980. The Interpretation of Dummy Variables in Semilogarithmic Equations. *American Economic Review* 70 (3): 474-75.
- Imbens, Guido W. 2015. Matching Methods in Practice. *Journal of Human Resources* 50 (2): 373-419.
- Irwin, Elena G., and Nancy E. Bockstael. 2002. Interacting agents, spatial externalities and the evolution of residential land use patterns. *Journal of Economic Geography* 2 (1): 31-54.
- Jin, Din, Porter Hoagland, Donna K. Au, and Jun Qiu. 2015. Shoreline change, seawalls, and coastal property values. *Ocean and Coastal Management* 114:185-93.
- Landry, Craig E., and Tom Allen. 2016. Hedonic property prices and coastal beach width. Working Paper, University of Georgia, Athens, GA.
- Landry, Craig E., and Paul Hindsley. 2011. Valuing beach quality with hedonic property models. *Land Economics* 87 (1): 92-108.
- Landry, Craig E., Andrew G. Keeler, and Warren Kriesel, W. 2003. An economic evaluation of beach erosion management alternatives. *Marine Resource Economics* 18 (2): 105-27.
- Lawley, Chad, and Wanhong Yang. 2015. Spatial interactions in habitat conservation: Evidence from prairie pothole easements. *Journal of Environmental Economics and Management* 71:71-

- Lewis, David J., Bradford L. Barham, and Brian Robinson. 2011. Are there spatial spillovers in the adoption of clean technology? The case of organic dairy farming. *Land Economics* 87 (2): 250-67.
- MacDonald, Don N., James C. Murdoch, and Harry L. White. 1987. Uncertain hazards, insurance, and consumer choice: Evidence from housing markets. *Land Economics* 63 (4): 361-71.
- Neumann, James E., Kerry Emanuel, Sai Ravela, Lindsay Ludwig, Paul Kirshen,, Kirk Bosma, and Jeremy Martinich. 2015. Joint effects of storm surge and sea-level rise on US Coasts: new economic estimates of impacts, adaptation, and benefits of mitigation policy. *Climatic Change* 129:337-49.
- Qiu, Yun, and Sathya Gopalakrishnan. 2018. Shoreline defense against climate change and capitalized impact of beach nourishment. Working paper, <https://ssrn.com/abstract=3117979>
- Program for the Study of Developed Shorelines. 2017. Western Carolina University. <http://beachnourishment.wcu.edu/>
- Provencher, Bill, David J. Lewis, and Kathryn Anderson. 2012. Disentangling preferences and expectations in stated preference analysis with respondent uncertainty: The case of invasive species prevention. *Journal of Environmental Economics and Management* 64: 169-82.
- Rosenbaum, Paul R., and Donald B. Rubin. 1983. The central role of the propensity score in observational studies for causal effects. *Biometrika* 70 (1): 41-55.
- Ruggiero, Peter. 2010. Impacts of shoreline armoring on sediment dynamics. In *Puget Sound Shorelines and the Impacts of Armoring—Proceedings of a State of the Science Workshop*, ed. H. Shipman, M. N. Dethier, G. Gelfenbaum, K. L. Fresh, and R. S. Dinicola. U.S. Geological Survey Scientific Investigations Report 2010-5254..
- Ruggiero, Peter, Meredith G. Kratzmann, Emily A. Himmelsoss, David Reid, Jonathan Allan, and George Kaminsky. 2013. National assessment of shoreline change: Historical shoreline change along the Pacific Northwest Coast. U.S. Geological Society Open-File Report 2012-1007.
- Smith, V. Kerry. 1985. Supply uncertainty, option price, and indirect benefit estimation. *Land Economics* 61 (3): 303-7.
- Smith, Martin D., Jordan M. Slott, Dylan McNamara, and A. Brad Murray. 2009. Beach

nourishment as a dynamic capital accumulation problem. *Journal of Environmental Economics and Management* 58 (1): 58–71.

State of Oregon. 2010. Oregon's Statewide Planning Goals & Guidelines: Oregon Department of Land Conservation and Development

Report. http://www.oregon.gov/LCD/docs/goals/compilation_of_statewide_planning_goals.pdf

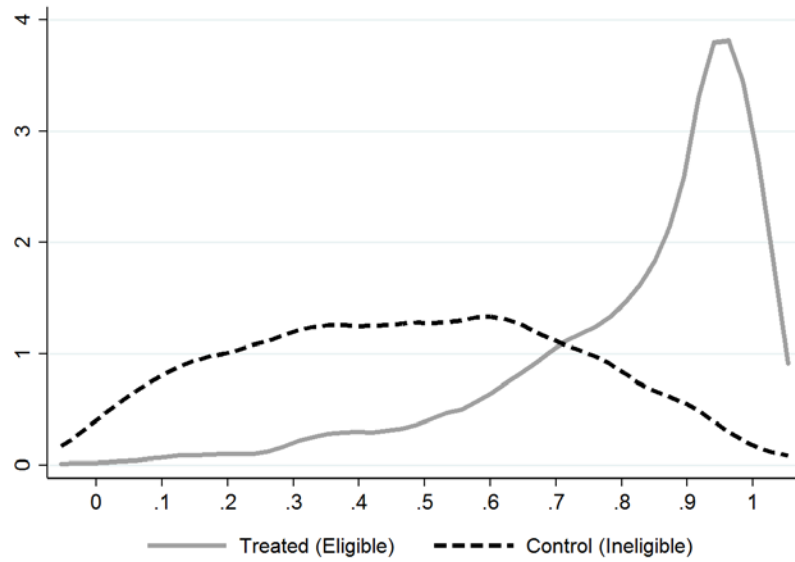
Walls, Margaret, Todd Gerarden, Karen Palmer, and Xian Fang Bak. 2017. Is energy efficiency capitalized into home prices? Evidence from three U.S. cities. *Journal of Environmental Economics and Management* 82:104-24.

Figure 1. Map of Oregon Coast and Example of Oceanfront Parcels



Figure 2. Propensity Score Histograms

Panel A: Full Sample ($N=1519$)



Panel B: Post-match Sample ($N=866$)

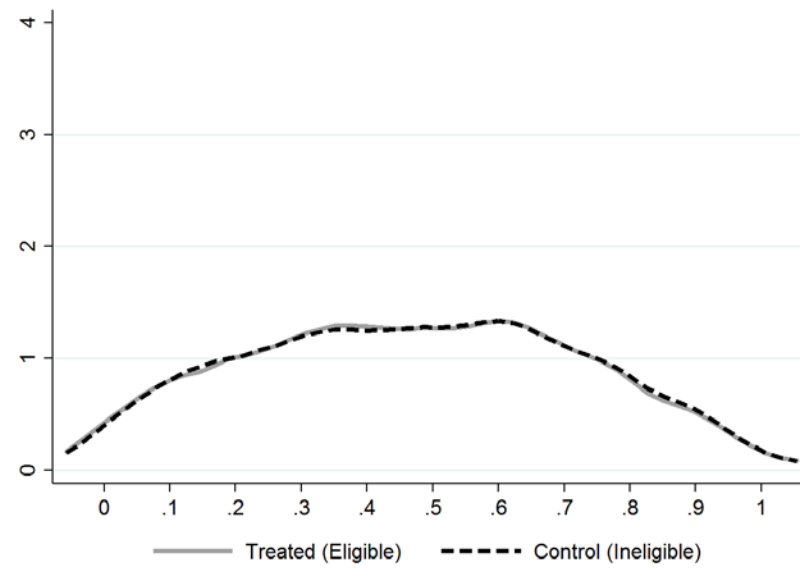
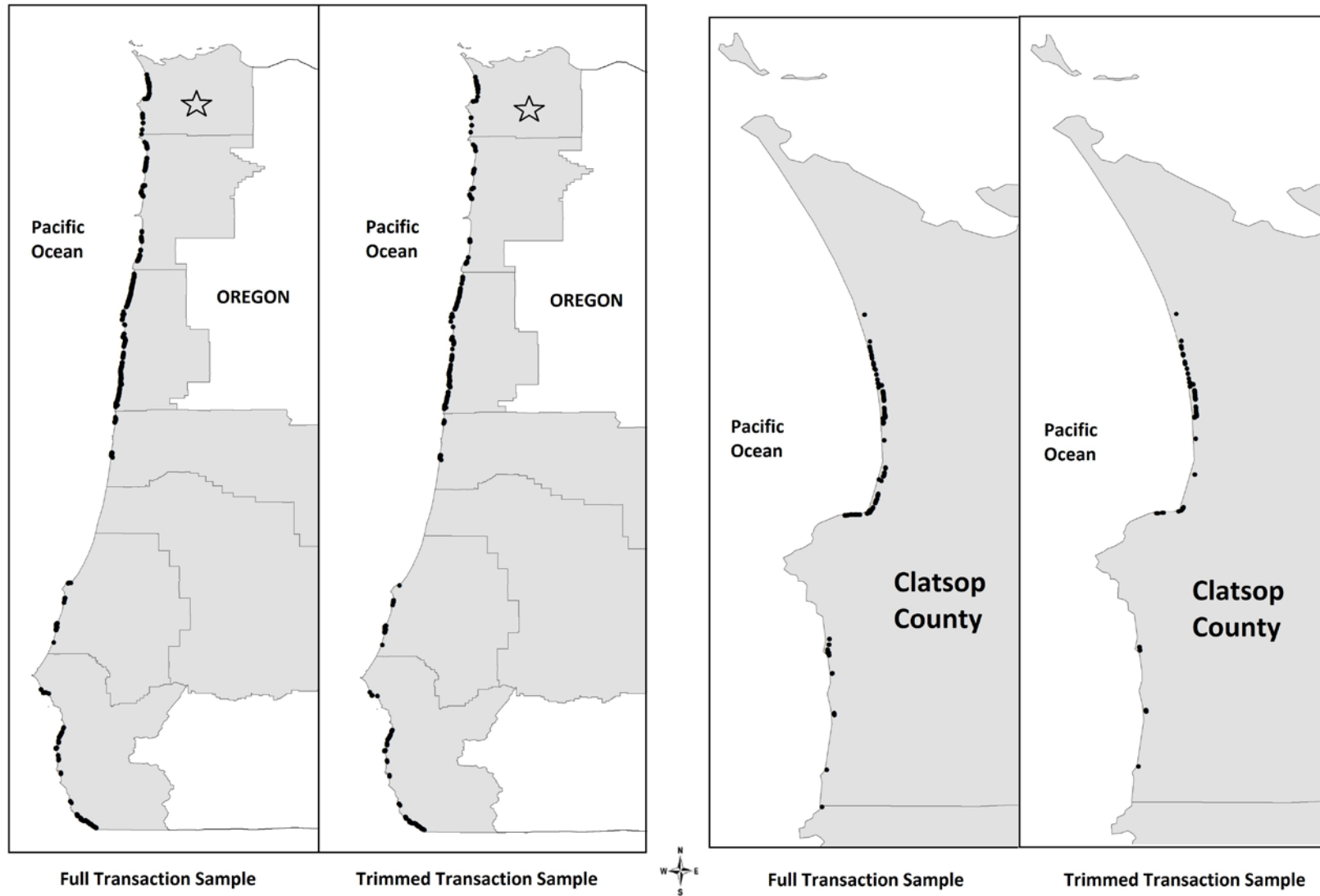
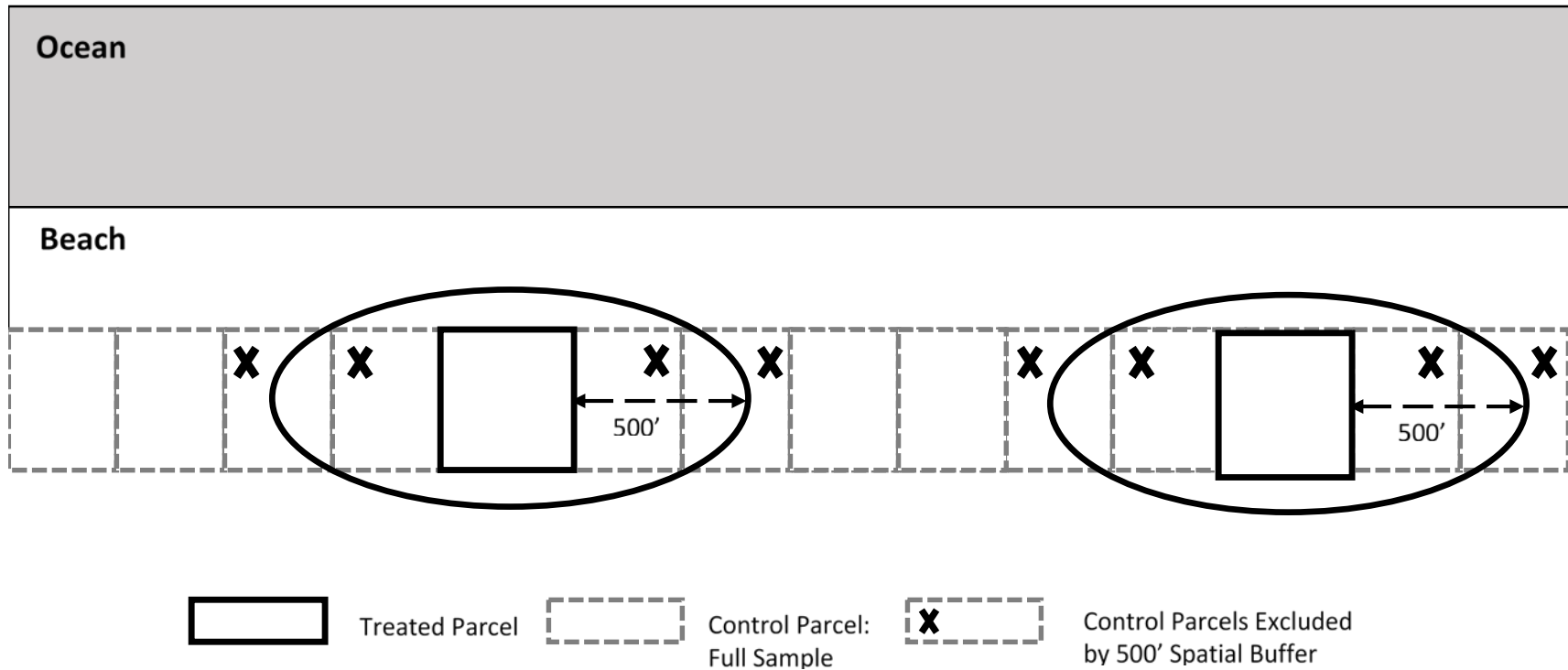


Figure 3. Spatial Distribution of Transactions



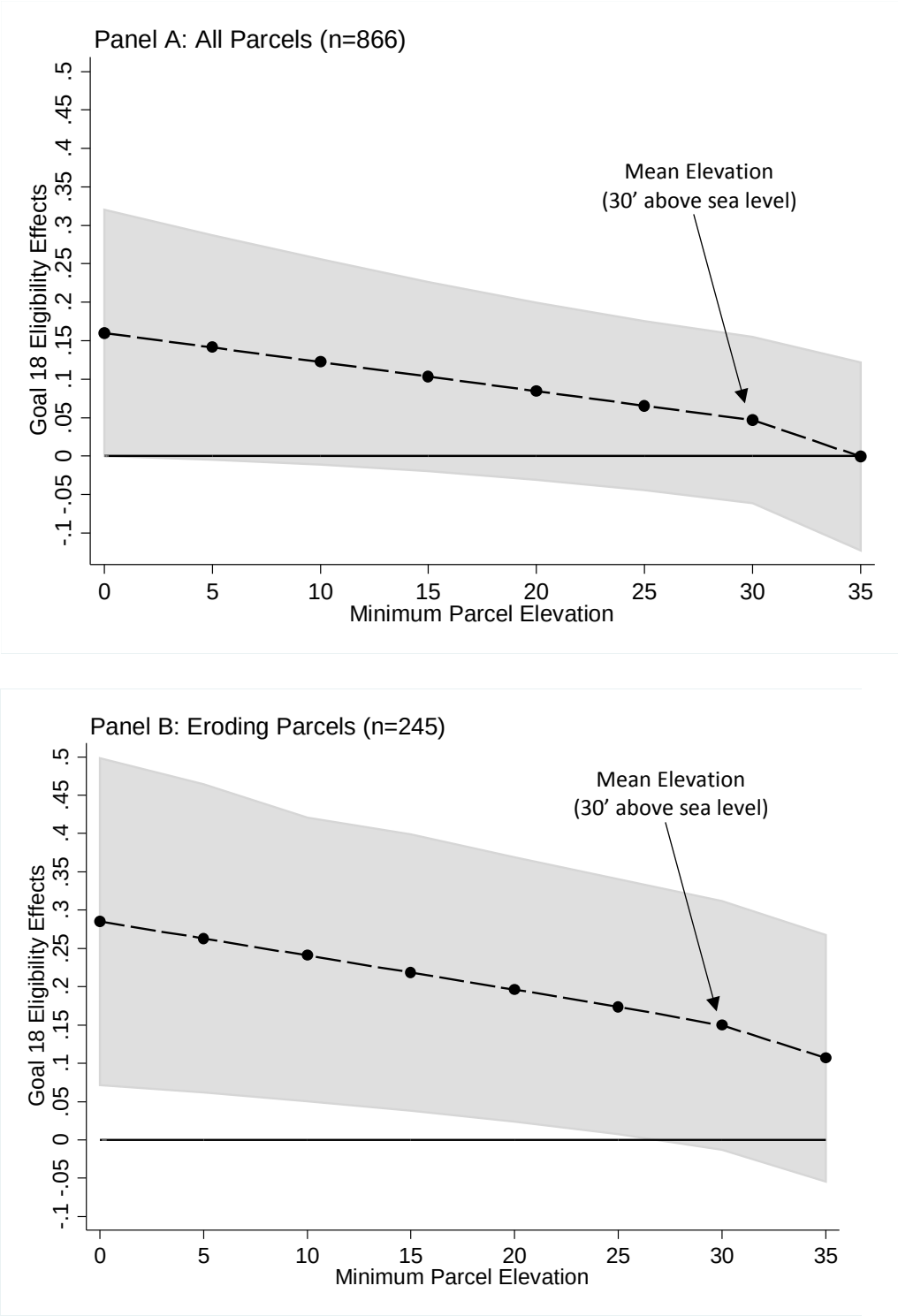
Note: Dots represent transactions and the grey shading indicates Oregon's seven coastal counties. The star on the maps on the left indicates Clatsop County (inset on right).

Figure 4. Schematic Representation of Spillover Effect Identification for 500' Buffer



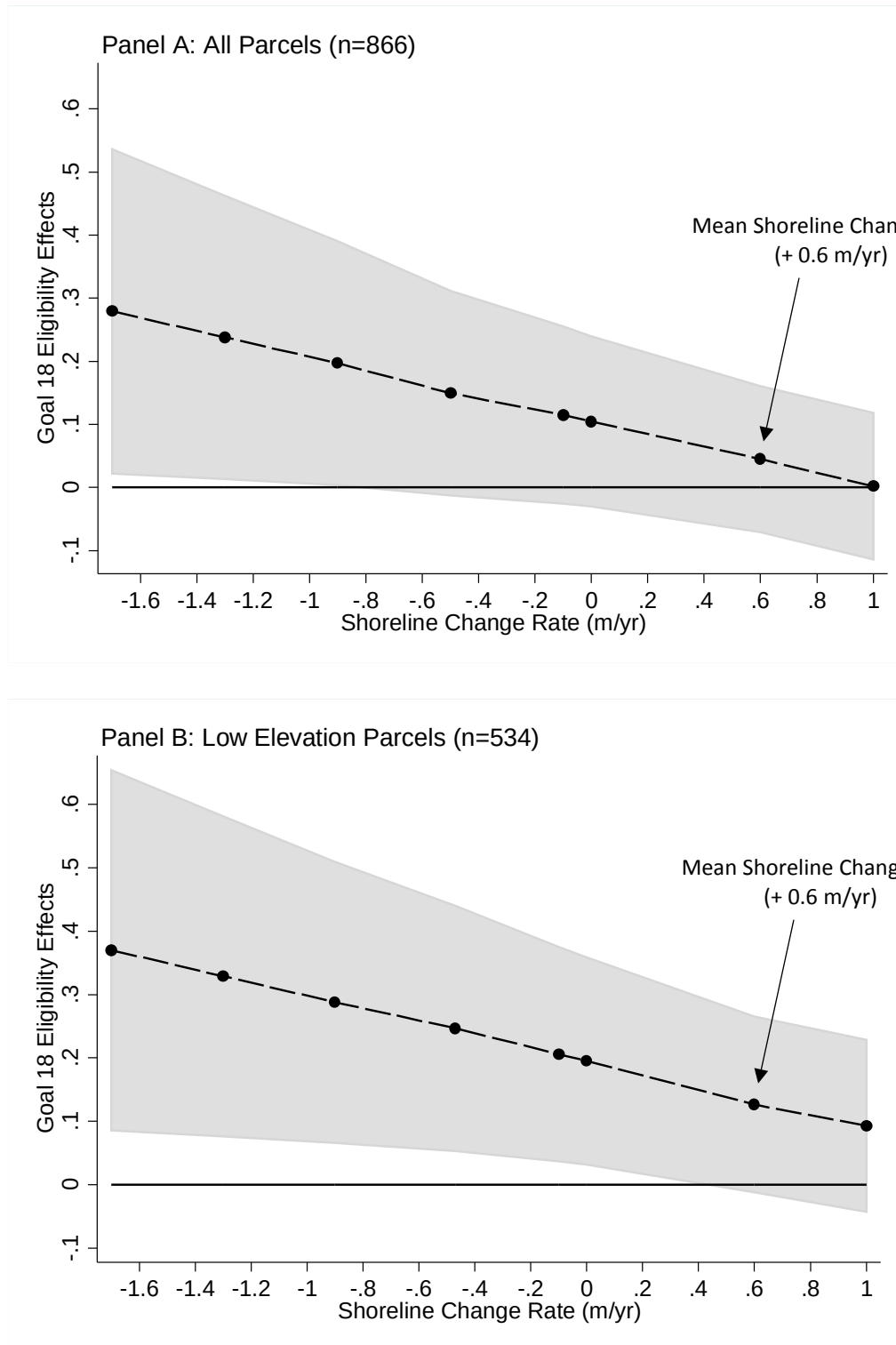
Note: In the full model, all treated (black) and control (grey dash) parcels are included. In the spatial buffer model, all control parcels marked with an X are removed prior to estimation.

Figure 5. Effect of Goal 18 Eligibility with Varying Elevation



Note: Dots represent point estimates and the shading indicates the 95 percent confidence interval.

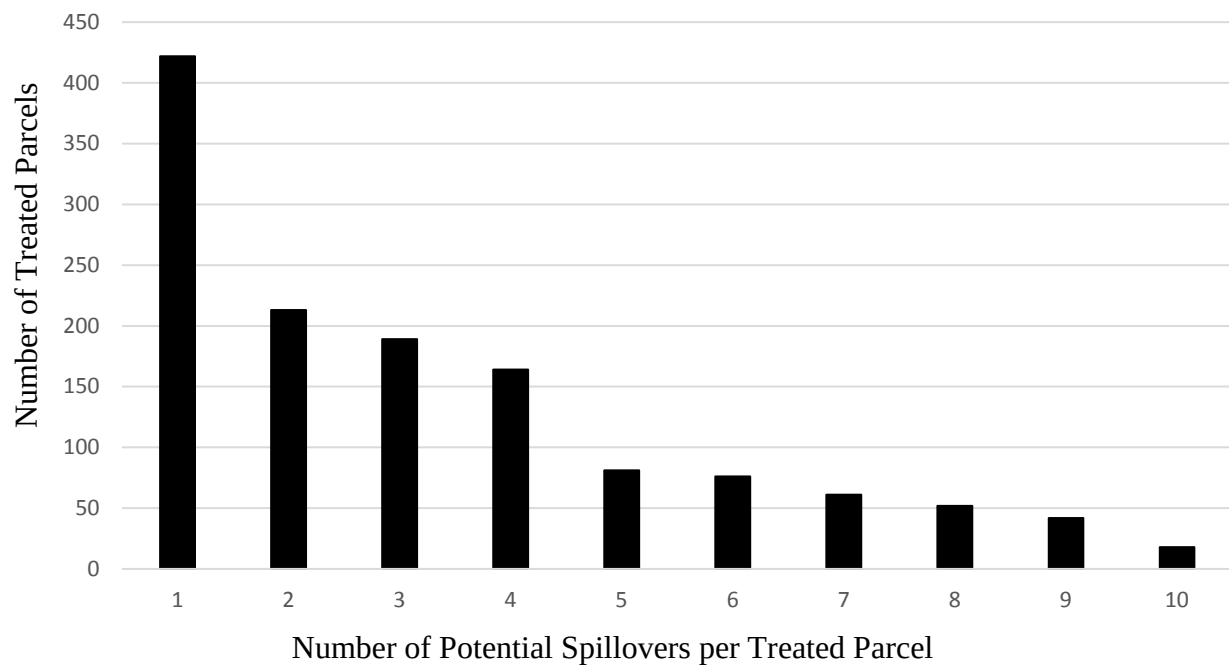
Figure 6. Effect of Goal 18 Eligibility with Varying Shoreline Change Rates



Note: Dots represent point estimates and the shading indicates the 95 percent confidence interval.

Figure 7. Potential Spillover Impacts for Oregon’s Goal 18 Policy

Panel A: Distribution of Potential Parcel-Level Spillover Impacts



Panel B: Potential for Spillover Damages to Generate Net Costs per parcel

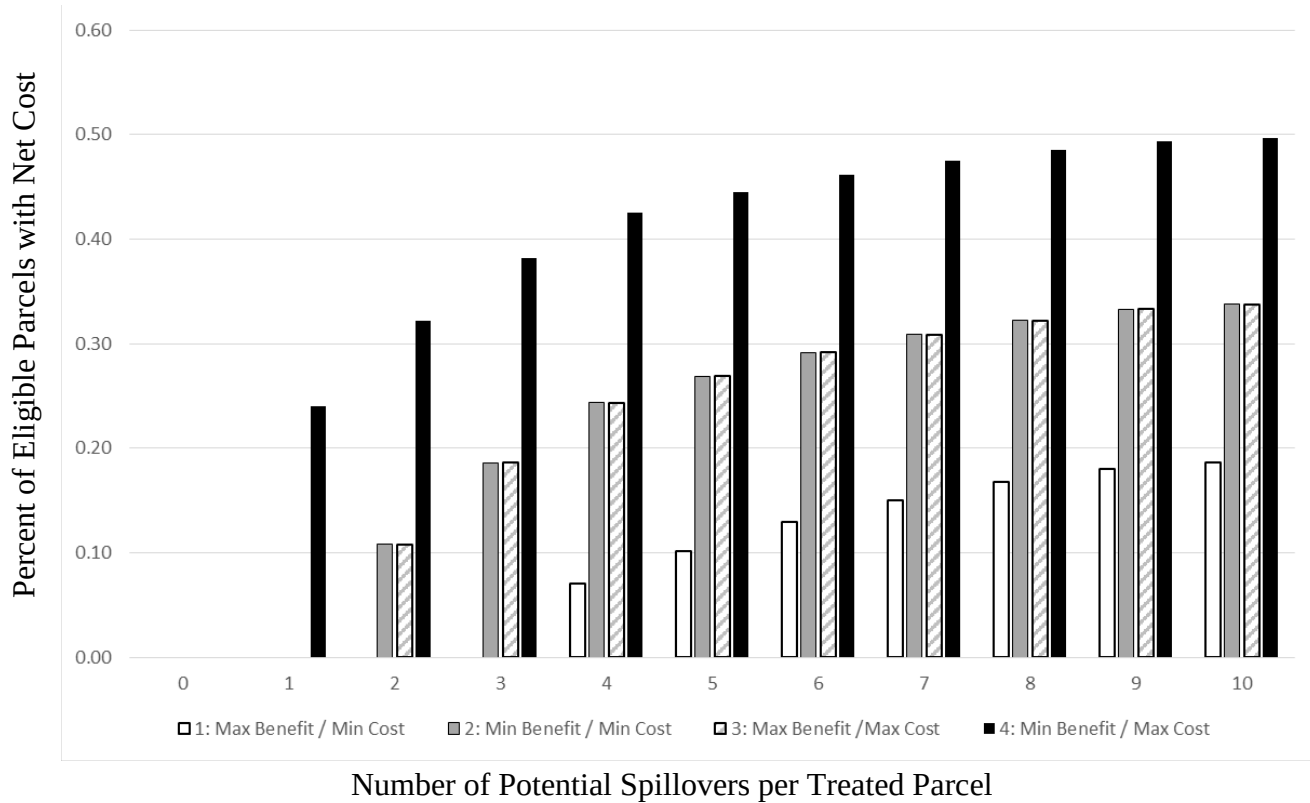


Table 1. Summary Statistics by Protection Eligibility Status

	Goal 18 Eligible: Treatment (N=1,101)				Goal 18 Ineligible: Control (N=418)			
	Mean	Std. Dev	Min.	Max.	Mean	Std. Dev.	Min.	Max.
Price (US 2015\$)	\$589,666	\$375,973	\$76,995	\$2,687,642	\$622,667	\$421,994	\$93,452	\$2,773,400
Market Improvement Value	\$221,482	\$184,634	\$2,150	\$1,683,006	\$327,888	\$230,327	\$23,820	\$1,333,019
Shoreline Δ Rate (m/yr)	0.38	0.83	-1.74	4.03	0.85	1.22	-1.1	5.13
Minimum Elevation (ft)	21.03	26.63	0	192	42.2	59.9	0	504
Structure Setback (ft)	158	194	6.3	2,435	345	333	22.2	2,615
Age	42.1	25.0	0	111	20.1	12.7	0	93
Bedrooms	3.08	1.33	1	11	2.95	1.14	1	8
Bathrooms	2.30	1.05	1	8	2.61	0.93	0.5	7
Square Footage	2,144	1,076	228	9,249	2,642	1,105	462	7,525
Lot Size (ft ²)	19,254	27,404	436	214,315	32,067	50,450	1,776	534,481
Garage	0.75	0.43	0	1	0.82	0.39	0	1
Air Conditioning	0.06	0.24	0	1	0.14	0.35	0	1
Dist. to Lighthouse (ft)	59,210	40,494	639	149,049	40,886	36,610	533	149,482
Bluff location	0.15	0.36	0	1	0.21	0.41	0	1
Dist. Mean High Water (ft)	102	104	0	909	173	162	0	835
100-Year Floodplain	0.71	0.46	0	1	0.46	0.50	0	1
SPS on Parcel	0.31	0.46	0	1	0.06	0.25	0	1

Note: Authors calculations from transaction, tax assessor, and geospatial data sets.

Table 2. Summary Statistics Post-Nearest Neighbor Matching by Protection Eligibility Status

	Goal 18 Eligible: Treatment (<i>N</i> =448)		Goal 18 Ineligible: Control (<i>N</i> =418)		Reduction in Standardized Bias
	Mean	Std. Dev	Mean	Std. Dev.	
Price (US 2015\$)	\$613,848	\$422,239	\$622,667	\$421,994	74.9
Market Improvement Value	\$316,497	\$170,861	\$327,888	\$230,327	88.9
Shoreline Δ Rate (m/yr)	0.58	1.11	0.85	1.22	49.4
Minimum Elevation (ft)	29.7	26.6	42.2	59.9	41.0
Structure Setback (ft)	323	441	345	333	92.0
Age	17.3	15	20.1	12.7	82.7
Bedrooms	2.91	0.91	2.95	1.14	62.9
Bathrooms	2.57	0.85	2.61	0.93	85.6
Square Footage	2,383	973	2,642	1,105	45.4
Lot Size (ft ²)	33,429	47,416	32,067	50,450	91.4
Garage	0.72	0.45	0.82	0.39	+
Air Conditioning	0.07	0.26	0.14	0.35	15.4
Dist. to Lighthouse (ft)	43,489	38,927	40,886	36,610	17.1
Bluff location	0.21	0.41	0.21	0.41	100
Dist. Mean High Water (ft)	151	177	173	162	75.7
100-Year floodplain	0.58	0.49	0.46	0.50	53.5
SPS on Parcel	0.18	0.38	0.06	0.25	45.9
Year	2008.29	3.44	2008.36	3.72	60.1
County	3.80	1.91	3.77	2.15	94.4
Latitude	44.23	1.16	44.24	1.35	98.3
Longitude	-124.14	0.17	-124.13	0.17	87.1

Note: Sample generated using a nearest neighbor matching algorithm with replacement matching on propensity score (probability of being Goal 18 eligible). The resulting sample keeps all Goal 18 non-eligible parcels and 448 eligible parcels that provide the best balancing of the covariates between the two groups. The reduction in standardized bias (SB) is $|SB_F - SB_M| / SB_F$ where F and M subscripts denote full and matched sample, respectively. SB is the difference in the sample means divided by the average sample standard

deviation. + denotes variables where full sample matched well and therefore standardized bias increased slightly in the matched sample.

Table 3. Post-Match Regression Results

Variables	(1) Initial Model		(2) No Fixed Effects		(3) Preferred Model	
	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Goal 18	0.009	0.062	0.189	0.116	0.237**	0.095
Goal18*Shoreline Δ rate			-0.078	0.056	-0.103**	0.048
Goal18*elevation			-0.004*	0.002	-0.004**	0.002
Min. Elevation (ft)			-0.001	0.001	-0.0001	0.0007
Shoreline Δ rate (m/yr)			0.027	0.050	0.028	0.048
Setback (ft)			-0.001*	0.0002	-0.001*	0.0002
Bedrooms	0.511***	0.116	0.482***	0.071	0.193**	0.091
Bed ²	-0.066***	0.014	-0.059***	0.010	-0.033***	0.010
Bathrooms	0.053	0.069	0.042	0.057	-0.000	0.059
Bath ²	0.0004*	0.0002	0.0003	0.0002	-0.000	0.0001
Square Footage	0.0002	0.0002	0.0001	0.0001	0.0002**	0.0001
Sq. Feet ²	-2.8e-09	1.9e-08	5.4e-09	1.2e-08	1.0e-09	1.0e-08
Lot Size (ft ²)	-2.5e-06	1.7e-06	-8.3e-07	1.6e-06	3.7e-06**	1.4e-06
Lot ²	1.2e-11***	3.7e-12	5.7e-12**	2.6e-12	4.3e-12	2.5e-12
Age of Home	-0.004	0.012	0.006	0.0001	0.015*	0.008
Age ²	5.8e-05	0.0001	-5.0e-05	0.0001	-0.0002*	0.0000
Garage	-0.089	0.183	-0.032	0.141	0.158	0.102
Air Conditioning	0.081	0.216	0.312	0.196	0.101	0.155
Dist. Mean High Water (ft)			0.001	0.001	0.0001	0.0008
Dist. MHW ²			5.6e-07	1.3e-06	3.6e-07	1.4e-06
Bluff- location			-0.201**	0.095	0.029	0.083
100-Year Floodplain			0.071	0.124	-0.104	0.128
Dist. to Lighthouse (ft)			-2.4e-06	2.6e-06	3.2e-07	1.1e-06
SPS on parcel			0.080	0.199	0.015	0.160
Quarter FE	No		No		Yes	
County by Year FE	No		No		Yes	
Constant	11.88***	0.241	11.95***	0.328	12.41***	0.342
Observations	866		866		866	
R-squared	0.149		0.252		0.500	

Notes: Restricted to Single Family Residences. Robust standard errors are clustered by city.

***p<0.01, ** p<0.05, * p<0.1.

Table 4. Goal 18 Eligibility Results

	Estimate	Std. Error
Panel A: Discrete Change Effect of Goal 18 Eligibility		
All parcels (N=866)	0.045	0.059
Eroding parcels (N=246)	0.149*	0.083
Low Elev. <= 30' (N=534)	0.127*	0.071
Eroding, Low Elev. (N=155)	0.236**	0.095
Panel B: Spatial First Difference Model		
All parcels (N=2,622)	0.016	0.031
Eroding parcels (N=837)	0.154***	0.050
Low Elev. <= 30' (N=1,699)	-0.033	0.028
Eroding, Low Elev. (N=439)	0.020	0.047

***p<0.01, ** p<0.05, * p<0.1.

Table 5. Spillover Effect Model Results

	(1) Preferred Model		(2) 100' buffer		(3) 200' buffer		(4) 500' buffer	
	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Panel A: Model Results								
Goal 18	0.237**	0.095	0.189**	0.086	0.203*	0.088	0.211*	0.095
Goal18*Shoreline Δ rate	-0.103**	0.048	-0.093**	0.044	-0.100**	0.047	-0.096*	0.051
Goal18*elevation	-0.004**	0.002	-0.004**	0.002	-0.004**	0.002	-0.005**	0.002
Observations	866		825		801		738	
R-squared	0.50		0.53		0.54		0.55	
Panel B: Discrete Change Effect of Goal 18 Eligibility								
All parcels (N=866)	0.045	0.059	0.011	0.051	0.017	0.051	0.011	0.066
Eroding parcels (N=245)	0.149*	0.083	0.106*	0.069	0.119*	0.072	0.109	0.090
Low Elev. $\leq 30'$ (N=534)	0.127*	0.071	0.087	0.066	0.096	0.066	0.102	0.085
Eroding, Low Elev. (N=155)	0.236**	0.095	0.186**	0.083	0.202**	0.087	0.203*	0.111

Notes: Panel A models are restricted to Single Family Residences. Robust standard errors are clustered by city. In panel B, standard errors calculated using the Delta method. *** p<0.01, ** p<0.05, * p<0.1.

ONLINE APPENDIX

Estimating Option Values and Spillover Damages for Coastal Protection: Evidence from Oregon's Planning Goal 18

Steven J. Dundas and David J. Lewis

Information about Tsunami Risk in Oregon's Oceanfront Housing Market

As a robustness check, we include variables that account for tsunami risk and an information shock related to that risk that occurred during our study period. To quantify an acute risk in this market, we use the tsunami hazard line created in 1995 by Oregon Senate Bill 379.¹ Through the Oregon Building Code, the line's purpose is to limit construction of critical and essential facilities in the tsunami inundation zone, but it also serves as a risk signal for the housing market. The line was determined by numerical simulations of tsunami waves and measuring the inland flooding limit.² In addition to the existence of the tsunami hazard line, an information shock about this risk occurred during the time frame of this analysis. On March 11th, 2011, a 9.0 magnitude earthquake occurred 45 miles off the coast of the Tōhoku region of Japan. This seismic event sent tsunami waves across the Pacific Ocean, with 3'–5' waves arriving in Oregon the next morning. Although no homes were damaged, a major disaster was declared by President Obama (DR-1964) that eventually obligated over \$5.6 million to repair damages to parks and recreational facilities along the Oregon Coast.³ This event provided information to coastal land owners about risk associated with far-field tsunami events that may have changed subjective risk assessments for buyers and sellers in the oceanfront housing market.

We use to the original specification in (4) and then add variables characterizing the acute risks over the timeframe of the analysis and interactions with the Goal 18 policy variable to estimate the multi-hazard hedonic price function as:

$$\ln P_{it} = \alpha + \beta G18_i + Elev_i [\delta_1 + \delta_2 G18_i] + Ero_i [\omega_1 + \omega_2 G18_i] + Tsu_i [\mu_1 + \mu_2 G18_i] + Post_{it} [\lambda_1 + \lambda_2 G18_i] + \kappa G18_i * Tsu_i * Post_{it} + \mathbf{X}_{it} \sigma + \eta_{jt} + \nu_t + \varepsilon_{ijt} , \quad (A.1)$$

where Tsu_i is equal to one if the parcel i is located in the tsunami hazard zone and $Post_{it}$ is equal to one if the sale occurs after March 2011, accounting the information shock provide by the Tohoku earthquake and tsunami event. Results are provided below in Table A.2.

¹ Hazard lines using inundation modeling were developed for the Oregon coast for five different levels of tsunamis were made public in 2013. These scenario-based hazard overlays have been slow to be adopted by coastal communities and the impacts of the updated hazard information provided by these maps are beyond the scope of this analysis.

² Priest, G.R., 1995. Explanation of mapping methods and use of the tsunami hazard maps of the Oregon coast: Oregon Department of Geology and Mineral Industries Open-File Report O-95-67, 95 p. Web: <http://www.oregongeology.org/pubs/ofr/O-95-67.pdf>

³ Original damage estimates were approximately \$6.7 million. More information of this disaster declaration can be found here: <https://www.fema.gov/disaster/1964>

Table A.1. Regression Results with Full Sample of Transaction Data

Variables	(1) Initial Model		(2) No Fixed Effects		(3) Preferred Model	
	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Goal 18	0.044	0.061	0.086	0.110	0.032	0.093
Goal18*Shoreline Δ rate			-0.003	0.048	0.014	0.042
Goal18*elevation			-0.003*	0.001	-0.002	0.001
Min. Elevation (ft)			-0.001*	0.0007	-0.0004	0.0007
Shoreline Δ rate (m/yr)			0.034	0.052	0.026	0.049
Setback (ft)			-0.0004*	0.0002	-0.0004**	0.0002
Bedrooms	0.232**	0.087	0.222***	0.077	0.031	0.068
Bed ²	-0.025***	0.008	-0.024***	0.008	-0.007	0.008
Bathrooms	0.050*	0.027	0.050*	0.029	0.025	0.029
Bath ²	0.0003**	0.0002	0.0003	0.0002	0.000	0.000
Square Footage	0.0002*	0.0001	0.0002*	0.0001	0.0003***	0.0000
Sq. Feet ²	-6.7e-09	1.3e-08	-8.0e-09	1.2e-08	-1.8e-08	1.2e-08
Lot Size (ft ²)	-3.5e-06**	1.4e-06	-1.9e-06	2.0e-06	1.0e-07	1.3e-06
Lot ²	1.3e-11***	3.6e-12	9.9e-12***	3.6e-12	5.1e-12**	2.5e-12
Age of Home	0.004	0.005	0.005	0.004	0.008**	0.003
Age ²	-2.9e-05	4.7e-05	-0.0001	0.0001	-0.0001**	0.0000
Garage	-0.051	0.121	-0.019	0.109	0.080	0.060
Air Conditioning	0.232*	0.123	0.265*	0.148	0.024	0.051
Dist. Mean High Water (ft)			0.001*	0.001	0.001	0.001
Dist. MHW ²			-1.1e-06	1.3e-06	-7.3e-07	1.2e-06
Bluff location			-0.069	0.075	0.083	0.074
100-Year Floodplain			-0.072	0.078	-0.114	0.069
Dist. to Lighthouse (ft)			-2.4e-08	1.9e-06	1.2e-06**	4.9e-07
SPS on parcel			0.063	0.094	0.035	0.081
Quarter FE	No		No		Yes	
County by Year FE	No		No		Yes	
Constant	12.16***	0.129	12.09***	0.166	12.56***	0.205
Observations	1519		1519		1519	
R-squared	0.129		0.165		0.337	

Note:

Restricted to Single Family Residences. Robust standard errors are clustered by city. *** p<0.01, ** p<0.05, * p<0.1.

Table A.2. Post-Match Regression Results with Acute Hazard Covariates

Variables	Preferred Model		Multiple Hazard Model	
	Estimate	Std. Error	Estimate	Std. Error
Goal 18	0.237**	0.095	0.255**	0.116
Goal18*Shoreline Δ rate	-0.103**	0.048	-0.091**	0.046
Goal18*elevation	-0.004**	0.002	-0.005*	0.002
Min. Elevation (ft)	-0.0001	0.0007	0.0002	0.0008
Shoreline Δ rate (m/yr)	0.028	0.048	0.022	0.046
Setback (ft)	-0.0005*	0.0002	-0.0005*	0.0003
Bedrooms	0.193**	0.091	0.209**	0.087
Bed ²	-0.033***	0.010	-0.036***	0.010
Bathrooms	-0.000	0.059	-0.009	0.058
Bath ²	-0.000	0.0001	-0.000	0.000
Square Footage	0.0002**	0.0001	0.0002**	0.0000
Sq. Feet ²	-1.04e-09	1.02e-08	8.55e-11	1.05e-08
Lot Size (ft ²)	3.66e-06**	1.38e-06	4.30e-07	1.51e-06
Lot ²	4.31e-12	2.54e-12	4.20e-12	2.64e-12
Age of Home	0.015*	0.008	0.014*	0.008
Age ²	-0.0002*	0.0000	-0.0002*	0.000
Garage	0.158	0.102	0.151	0.104
Air Conditioning	0.101	0.155	0.105	0.153
Dist. Mean High Water	0.0001	0.0008	-0.0000	0.0008
Dist. MHW ²	3.60e-07	1.39e-06	-4.94e-07	1.44e-06
Bluff location	0.029	0.083	0.027	0.087
100-Year Floodplain	-0.104	0.128	-0.146	0.110
Dist. to Lighthouse (ft)	3.18e-07	1.05e-06	3.06e-07	1.03e-06
SPS on property	0.015	0.160	0.009	0.161
Tsunami Zone			0.082	0.121
Goal18*TsuZone			-0.101	0.113
Post- Tohoku			-0.252	0.230
Goal18*Post			0.116	0.181
Goal18*TsuZone*Post			0.149	0.189
Quarter FE	X		X	
County by Year FE	X		X	
Constant	12.41***	0.342	12.39***	0.367
Observations	866		866	
R-squared	0.500		0.505	

Notes: Restricted to Single Family Residences. Robust standard errors are clustered by city.

***p<0.01, ** p<0.05, * p<0.1.

Table A.3. Summary Statistics by Spillover Proximity for Control Parcels

	Spillover Controls (<i>N</i> =128)		Other Controls (<i>N</i> =290)		Normalized Difference
	Mean	Std. Dev	Mean	Std. Dev.	
Price (US 2015\$)	\$610,293	\$429,957	\$628,129	\$419,065	-0.04
Market Improvement Value	\$318,027	\$243,274	\$332,240	\$224,671	-0.06
Shoreline Δ Rate (m/yr)	0.78	0.99	0.87	1.31	-0.08
Minimum Elevation (ft)	27.7	34.3	48.6	67.3	-0.41
Structure Setback (ft)	322	283	355	353	-0.10
Age	20.4	12.2	20.0	13.0	0.03
Bedrooms	3.05	1.20	2.90	1.07	0.13
Bathrooms	2.49	0.79	2.67	0.98	-0.20
Square Footage	2,502	1050	2,704	1,124	-0.19
Lot Size (ft ²)	25,147	34,006	35,122	55,980	-0.22
Garage	0.75	0.43	0.84	0.36	-0.23
Air Conditioning	0.16	0.37	0.13	0.33	0.09
Dist. to Lighthouse (ft)	42,762	38,051	40,059	35,992	0.07
Bluff location	0.27	0.45	0.18	0.39	0.21
Dist. Mean High Water (ft)	154	130	181	173	-0.18
100-Year floodplain	0.55	0.50	0.42	0.49	0.26
SPS on Parcel	0.08	0.27	0.14	0.35	-0.19

Table A.4. Results of Spillover Models

	Estimate	Std. Error
Panel A: Control Only Regression		
Spillover Parcel (SP) Dummy	-0.090*	0.052
Panel B: Discrete Change Effect (Control Only w. interactions)		
All parcels (N=418)	-0.089*	0.053
Eroding parcels (N=114)	-0.092	0.069
Low Elev. $\leq 30'$ (N=252)	-0.080	0.059
Eroding, Low Elev. (N=66)	-0.075	0.087
Panel C: Full Model with SP dummy		
Spillover Parcel Dummy	-0.028	0.061
Panel D: Discrete Change Effect (Full Model w. interactions)		
All parcels (N=866)	-0.026	0.062
Eroding parcels (N=245)	-0.115	0.099
Low Elev. $\leq 30'$ (N=534)	-0.013	0.063
Eroding, Low Elev. (N=155)	-0.107	0.122

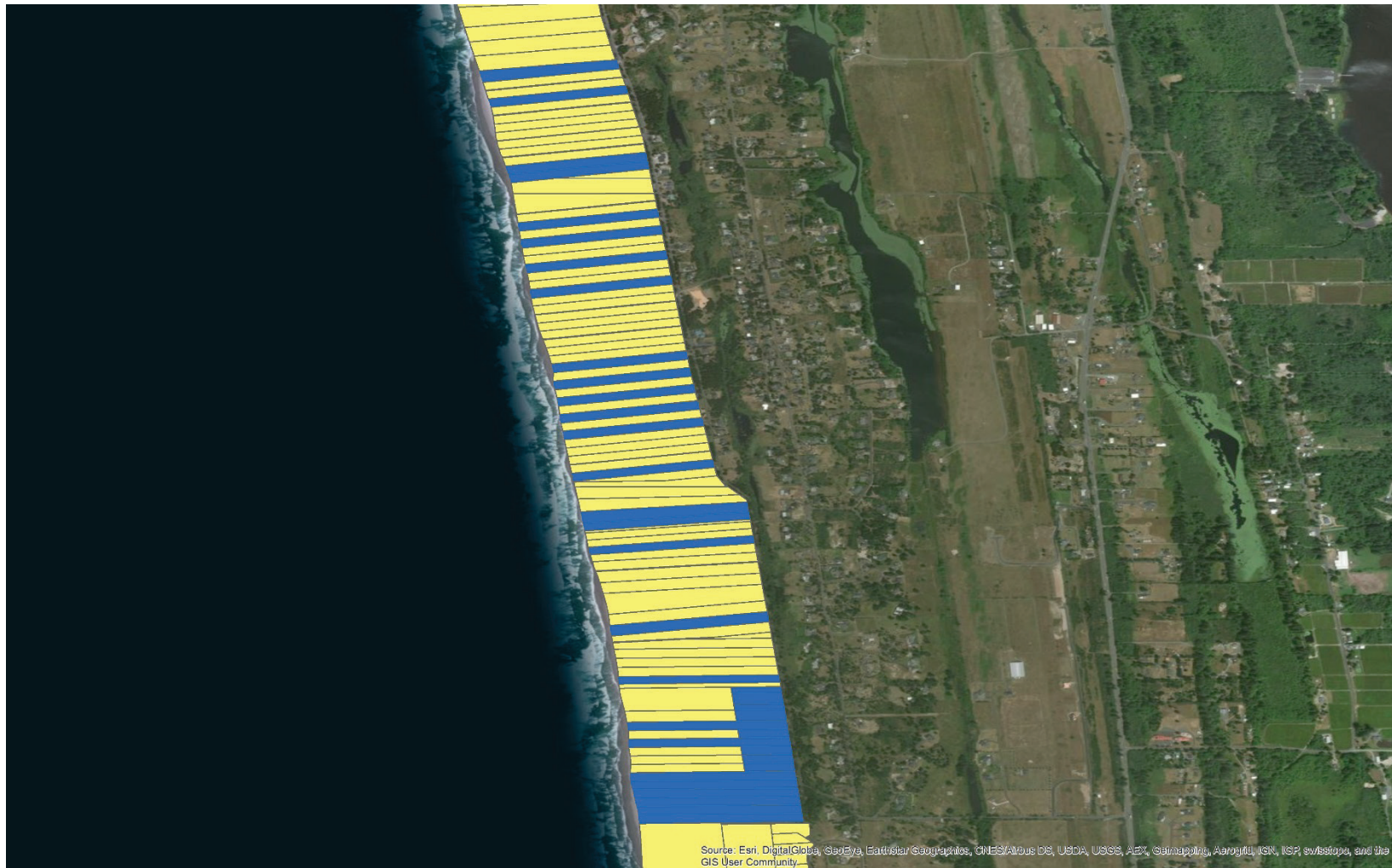
***p<0.01, ** p<0.05, * p<0.1.

Figure A.1 Photograph of SPS (rip-rap) in Neskowin, Oregon



Note: Photo taken April 12th 2018 by Steven J. Dundas

Figure A.2 Spatial Configuration of Goal 18 Policy in Surf Pines, Oregon



Note: Blue parcels are Goal 18 eligible (treated) and yellow parcels are ineligible (control).

An aerial photograph of a coastal area. A red line runs along the shoreline, likely indicating a proposed project or boundary. Blue dashed lines are visible along the coast, possibly representing existing infrastructure or property lines. The image shows a mix of natural coastal features like waves and sandbars, and developed areas including buildings, parking lots, and green spaces. The red line follows the curve of the beach and extends into the water in some areas. The blue dashed lines are more linear, following the edge of the developed land. The overall scene is a detailed view of a coastal environment with human-made structures and natural elements.