Hold the Line:
Identifying determinants of the installation of coastal armoring

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The Story

Coastline Preservation

Property Protection

http://www.naplesnews.com/story/news/special-reports/2016/11/11/shrinking-shores-how-florida-leaders-failing-states-famous-beaches/92052156/

Outline

Motivation & Goals

Choice Sets & Tradeoffs

Data

Model

Simulation

Remaining Activities

Motivation

Nearly 40% of all Americans live in a coastal county

Estimated 50% of the Oregon coastline is eroding

- Coastal erosion damages in the US are approximately $500M

By 2100, the cost to the US of storm surge and sea-level rise net of adaptation will exceed $990B (Neuman et al. (2015))

- The single largest expenditure to combat this problem is expected to be shoreline armoring

Research Goals

Modeling

- Quantify drivers of the homeowner decision for armoring installation
  - Risky geomorphology matters
  - Social learning matters
  - Cooperation among neighbors matters

Simulation

- Probabilistically determine armoring “hot spots” over time

Policy Impacts

- Identify sensitivity of armoring decision to variations in Goal 18

Choice Set

Options to combat erosion are limited

Selective Abandonment

Beach Nourishment

Engineered Structures
(Seawalls, Riprap Revetments)

Armoring in Oregon

Beach access a public right since the “Beach Bill” in 1967

Planning and Development “Goal 18” aims to preserve the natural coastline and ensure access

- Goal 18 grants armoring eligibility for properties developed prior to 1977
  - ~9,000 parcels along the coast
  - ~3,500 eligible outright
  - ~1,000 eligible through community/town exception

Current Example (Rockaway Beach)

The state is entrenched in a legal battle with a homeowner who was denied armoring permits, covered in the local article "Should this house be saved?"[1]

"I hope that you do not allow him to put riprap (there), Because if you do, there will be a domino effect, and I will be sitting in front of you next year asking to put riprap in front of my house" – Neighbor Alice Pyne

1. https://www.oregonlive.com/pacific-northwest-news/index.ssf/2016/07/should_this_house_be_saved_coa.html

Photo Source: http://www.tillamookheadlightherald.com/news/latest-riprap-appeal-set-for-august-hearing/article_770d8256-4949-11e6-aa7e-cffa637d8384.html

Other News

Speaking of Science

California will face a terrible choice: Save cliff-side homes or public beaches from rising seas

Homes along the edge of the coast in Santa Barbara County, Calif., in 2005. (Patrick Barnard/Pacific Coastal and Marine Science Center/U.S. Geological Survey)

By **Darryl Fears** July 11 Email the author

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Sea Level Rise Could Double Erosion Rates of Southern California Coastal Cliffs

Release Date: JULY 9, 2018

Coastal cliffs from Santa Barbara to San Diego might crumble at more than twice the historical rate by the year 2100 as sea levels rise.

U.S. Geological Survey scientists combined several computer models for the first time to forecast cliff erosion along the Southern California coast. Their peer-reviewed study was published in a recent issue of the American Geophysical Union's *Journal of Geophysical Research - Earth Surface*.

The research also showed that for sea-level rise scenarios ranging from about 1.5 feet to 6.6 feet by 2100, bluff tops along nearly 300 miles of Southern California coasts could lose an average of 62 to 135 feet by 2100 – and much more in some areas.

"Sea cliff retreat is a serious hazard," said USGS research geologist and lead author Patrick Limber. "Unlike beaches, cliffs can be stable for decades between large landslides that remove several feet of bluff top."

USGS developed this forecast to help managers and policy makers understand how the coastline is going to respond to sea level rise over the 21st century, enabling them to make better-informed decisions.

Coastal cliff erosion rates vary depending on sea level rise, wave energy, coastal slope, beach width and height, and rock strength.

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Source: https://www.washingtonpost.com/news/speaking-of-science/wp/2018/07/11/california-will-have-a-terrible-choice-save-cliff-side-homes-or-public-beaches-from-rising-seas/?noredirect=on&utm_term=.341b1305a1a4
Source: https://www.usgs.gov/news/sea-level-rise-could-double-erosion-rates-southern-california-coastal-cliffs

Contribution

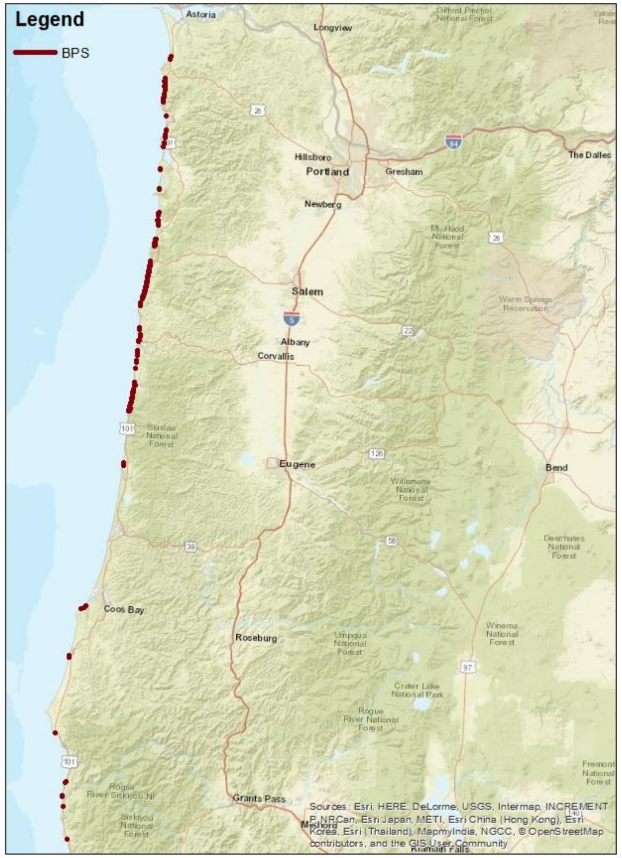
Literature

- Economics literature has yet to address the armoring decision process
- Non-Economics literature on armoring focuses purely on geomorphological characteristics

Policy

- Storms are expected to worsen, sea-levels are rising and most coastal structures are immovable
  - Understanding how policy influences the coastline evolution will be key for long term planning and development

Oregon Data



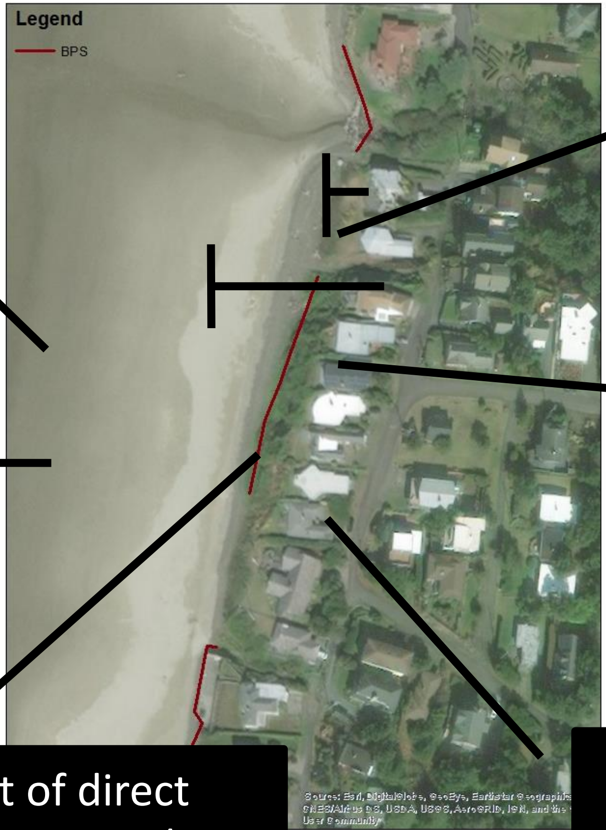
- All Coastal Parcels ~9,000
  - G18 Eligible ~4,500
    - Tillamook / Lincoln ~2,800
      - Armored ~1,200
      - Unarmored ~1,600
    - Other Counties ~1,700
  - G18 Ineligible ~4,500

Data

Short and long term erosion rates

Structure setback, distance to shoreline, beach width

Total annual hours of water level excedance



Parcel attributes: acreage, housing characteristics, housing values, distance to beach access

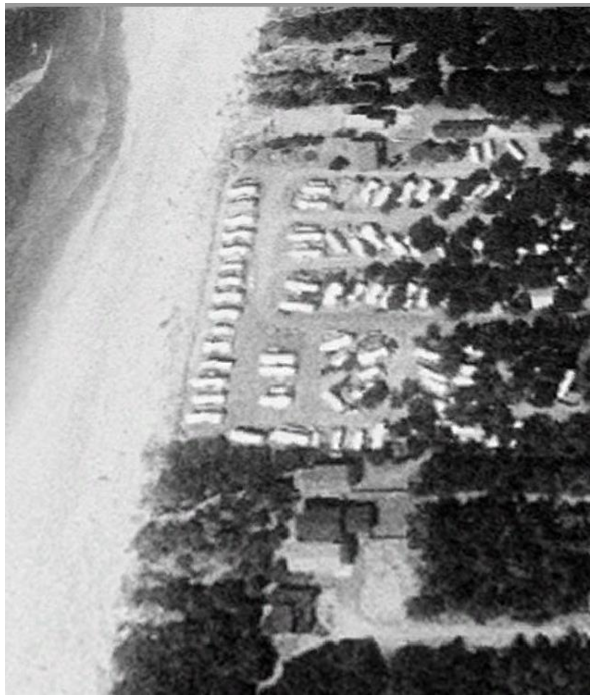
Count of direct neighbors w/ armoring, neighbors w/I 2km

BPS eligibility, approvals, denials, exceptions,

Changes in Risk? Sherwood RV Park (Google Earth)

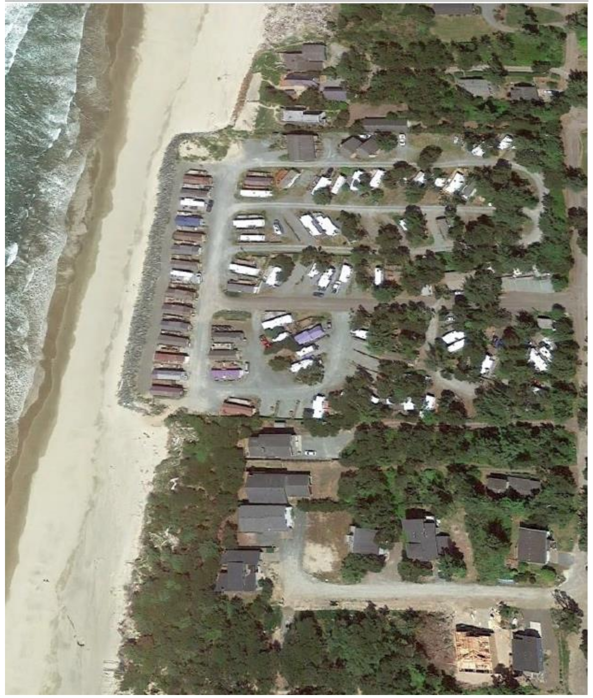
1994

2000



2005

2017



Summary Statistics

Variable	Description	WITH BPS Mean	WITH BPS Std. Dev.	WITH BPS Obs	WITHOUT BPS Mean	WITHOUT BPS Std. Dev.	WITHOUT BPS Obs
yearbuilt	Year of House Construction	1965	716	262	1964	870	1,730
universalbldngsqrft	Square Footage	2,258.610	4,299.884	259	1,738.643	2,968.299	1,725
bedrooms	# of Bedrooms	2.6	1.5	259	2.1	1.5	1,725
impr_rmv_000s	RMV Improvement Value (2015 000s)	89.129	206.637	262	41.896	109.426	1,730
lnd_rmv_000s	RMV Land Value (2015 000s)	209.097	231.645	262	102.578	216.556	1,730
calc_acres	Acreage	0.379	0.571	262	0.745	6.668	1,730
min	Minimum Bare Earth Elevation	12.467	11.960	262	24.130	28.114	1,730
mean	Mean Bare Earth Elevation	19.331	15.358	262	37.053	31.106	1,730
epr_st	Short Term (50 yr) Erosion Rate	-1.081	0.865	262	-0.257	1.210	1,730
lrr_lt	Long Term (100 yr) Erosion Rate	-0.009	0.505	262	0.187	0.740	1,730
d_beach	Distance to Nearest Beach	0.051	0.020	262	0.093	0.079	1,730
d_posssps	2009 LIDAR Setback Distance to Structures	0.016	0.013	262	0.037	0.055	1,730
d_light	Distance to a Lighthouse	15.156	7.165	262	11.919	8.269	1,730
an_2014_0k	Time Varying: Direct Armored Neighbor Count in 2014	1.538	0.610	262	0.005	0.083	1,730
an_2014_2k	Time Varying: Armored Neighbors Count w/I 2km in 2014	61.519	28.046	262	0.155	2.601	1,730
d_sps_2014	Time Varying: Setback Distance to Structures in 2014	0.015	0.006	262	0.035	0.037	1,730
d_sh_2014	Time Varying: Structure Distance to Shoreline in 2014	0.004	0.006	262	0.018	0.038	1,730
beach_width14	Time Varying: Beach Width in 2014	0.011	0.006	262	0.017	0.025	1,730

Theory

Option Value

$$NV_{it} = ENPV(R_{it} = 0) + OPV_{it} + L_t(N_{it}) - ENPV(R_{it} = 1) < 0$$

Specify the net value as a land function value and random component

$$NV_{it} = LV(X_{it}, N_{it}, Z_t | \mathbf{R}_{it}) + \epsilon_{it}$$

With minor assumptions on neighboring impacts, can also show how armoring begets additional armoring – leading to excessive installation

Empirical Specification

Final Model: Correlated Random Effects Linear Probability Model

$$LV(X_{it}, N_{it}, Z) = \mathbf{X'}_{it}\beta + N'_{it}\alpha + \delta Z_t + \overline{\mathbf{X}}'_{it}\gamma$$

- X = Time Varying & Time Invariant Parcel Features
  - Parcel Characteristics (Value, location, acreage)
  - Geomorphology (beach width, structure setback, TWL)
- N = Number of neighbors armored at time t
- Z = Time controls, including measures of severe storm events
- $\bar{X}$= Average of time-variant measures

Results

Three main drivers

- Storms, erosion, elevation

Overall takeaway

- Risky geomorphological characteristics lead to greater armoring

CRE LPM - Lincoln/Tillamook, no neighbor effects

	bps
Acres	-0.0010340
	(-1.95)
Acres Sqr	0.0000041*
	(2.09)
Total RMV	0.0000000***
	(6.55)
Min Elev	-0.0000881***
	(-4.16)
Dist Beach	-0.0000135***
	(-11.07)
ST Erosion	-0.0019174***
	(-9.25)
Dist Shrelne	-0.0000104*
	(-2.06)
Dist VegLne	0.0000005
	(0.49)
Time	0.0005745***
	(11.82)
El Nino	0.0529814***
	(10.33)
N	44377

t statistics in parentheses

* p<0.05, ** p<0.01, *** p<0.001

Results

Social learning and strategic effects of coalition formation have a meaningful impact in terms of clustering identification

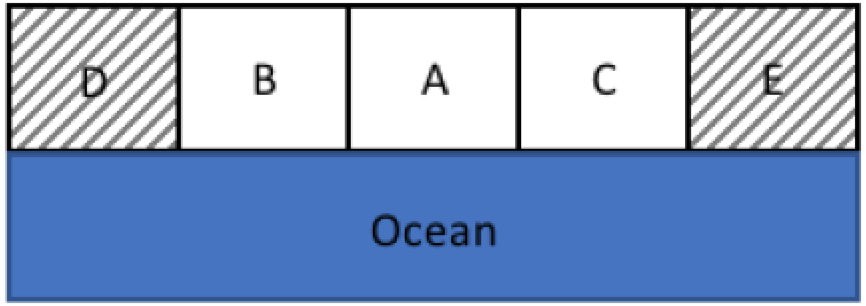
- Dominates geomorphological considerations

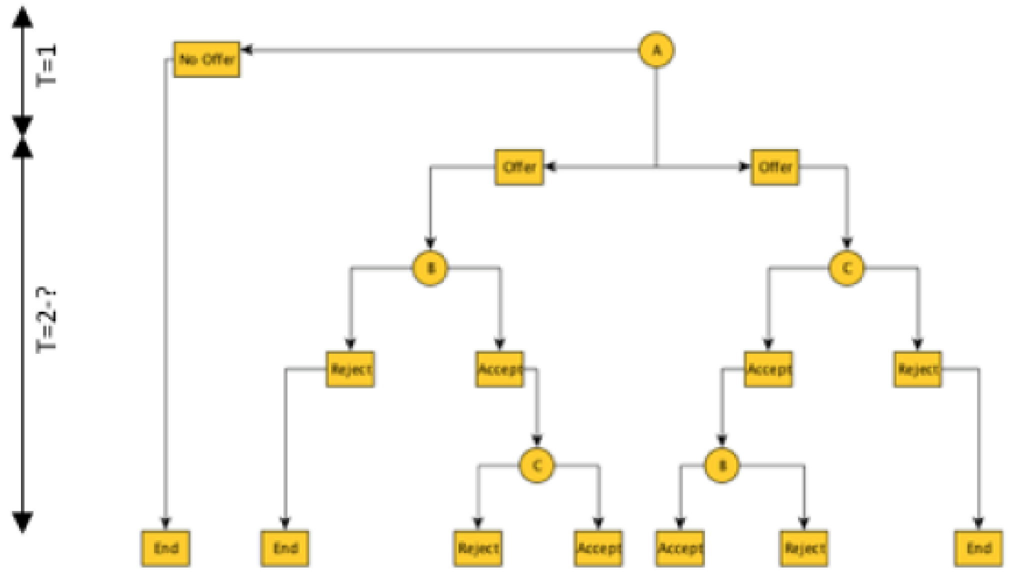
CRE LPM - Lincoln/Tillamook, with neighbor effects

	bps
Acres	-0.000407
	(-1.77)
Acres Sqr	0.000002
	(1.89)
Total RMV	0.000000*
	(2.29)
Min Elev	-0.000019
	(-1.72)
Dist Beach	-0.000005***
	(-7.48)
ST Erosion	-0.000729***
	(-4.92)
Dist Shrelne	-0.000006
	(-1.92)
Dist VegLne	-0.000000
	(-0.33)
Time	0.000421***
	(11.28)
El Nino	0.055297***
	(10.82)
Coalition?	0.060689***
	(9.11)
Dir Armor	0.047051*
	(2.08)
Armr w/i 2km	0.003126***
	(5.64)
N	44377

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Conceptual Framework



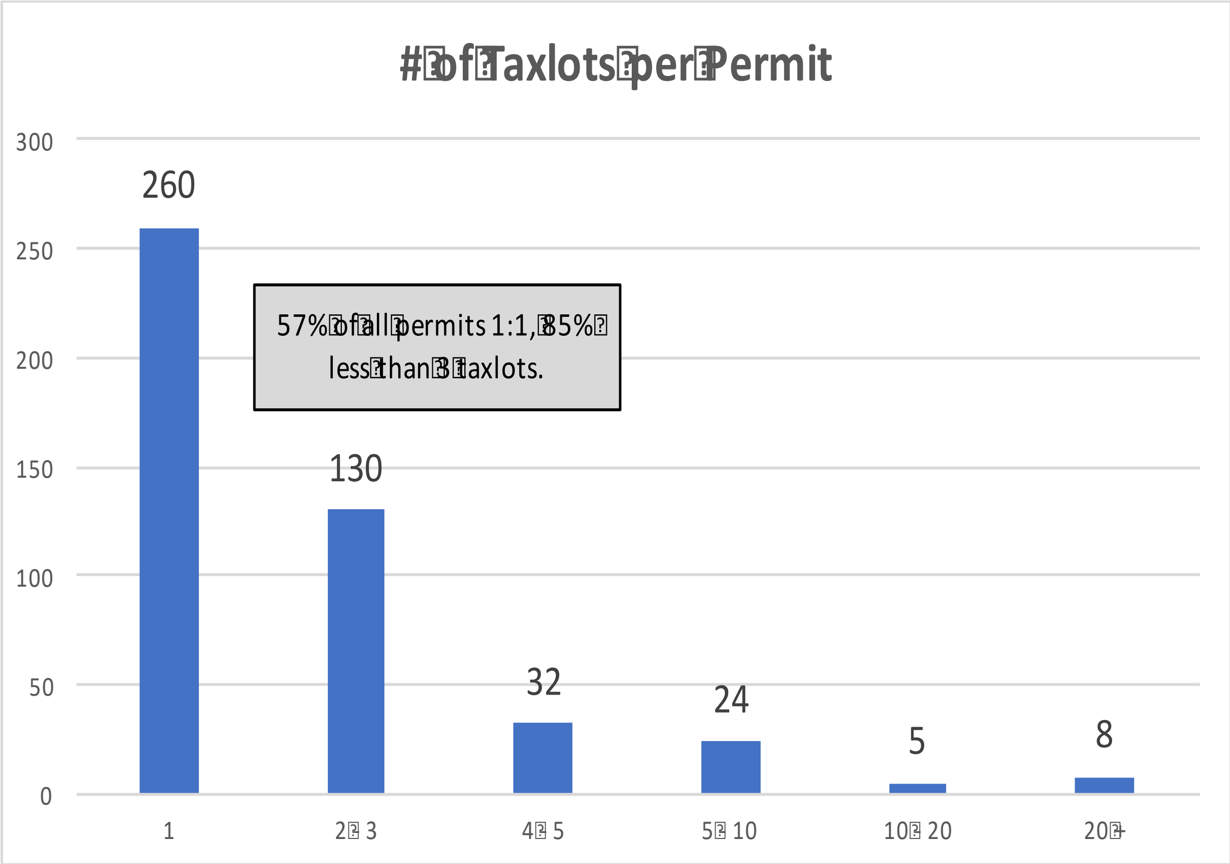


Installation A:	R=1	R=1	R=1	R=1	R=1	R=1	R=1
Installation B:	R=0	R=0	R=1	R=1	R=1	R=0	R=0
Installation C:	R=0	R=0	R=0	R=1	R=1	R=1	R=0
Coalition:	A	A	AB	ABC	ABC	AC	A

Why cooperative structure?

Excluding large scale community initiatives, ~43% of permit applications are for groups of parcels

Anecdotal evidence, along with our theory, suggests that the nature of the process lends itself to shared costs and coordinated efforts



Simulations

Monte Carlo approach, using a game construct with probabilities parameterized from empirical specification

Game Setup

- N players
- Randomized selection (no first mover advantage)
- Payoffs are implicit (no rule for sharing)
- Decisions are irreversible (no penalties required)
- Assumed super additivity (more people in a coalition continues to reduce costs)

Simulations

Stage 1 – Draw a random, eligible, parcel

Stage 2 – Calculate predicted probability of installation at time period t

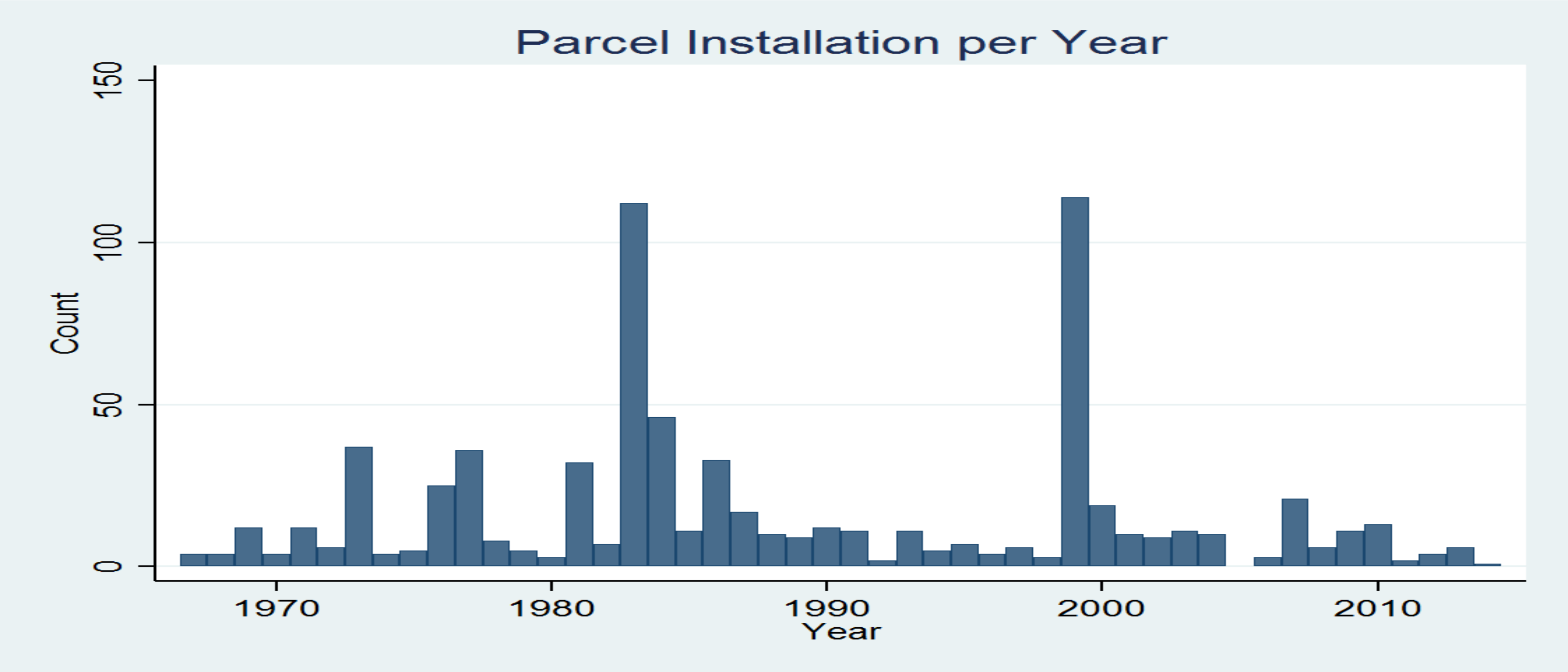
Stage 2a – Compare to random draw and determine armoring status

Stage 2b – If armoring, then iterate through neighbors for coalition

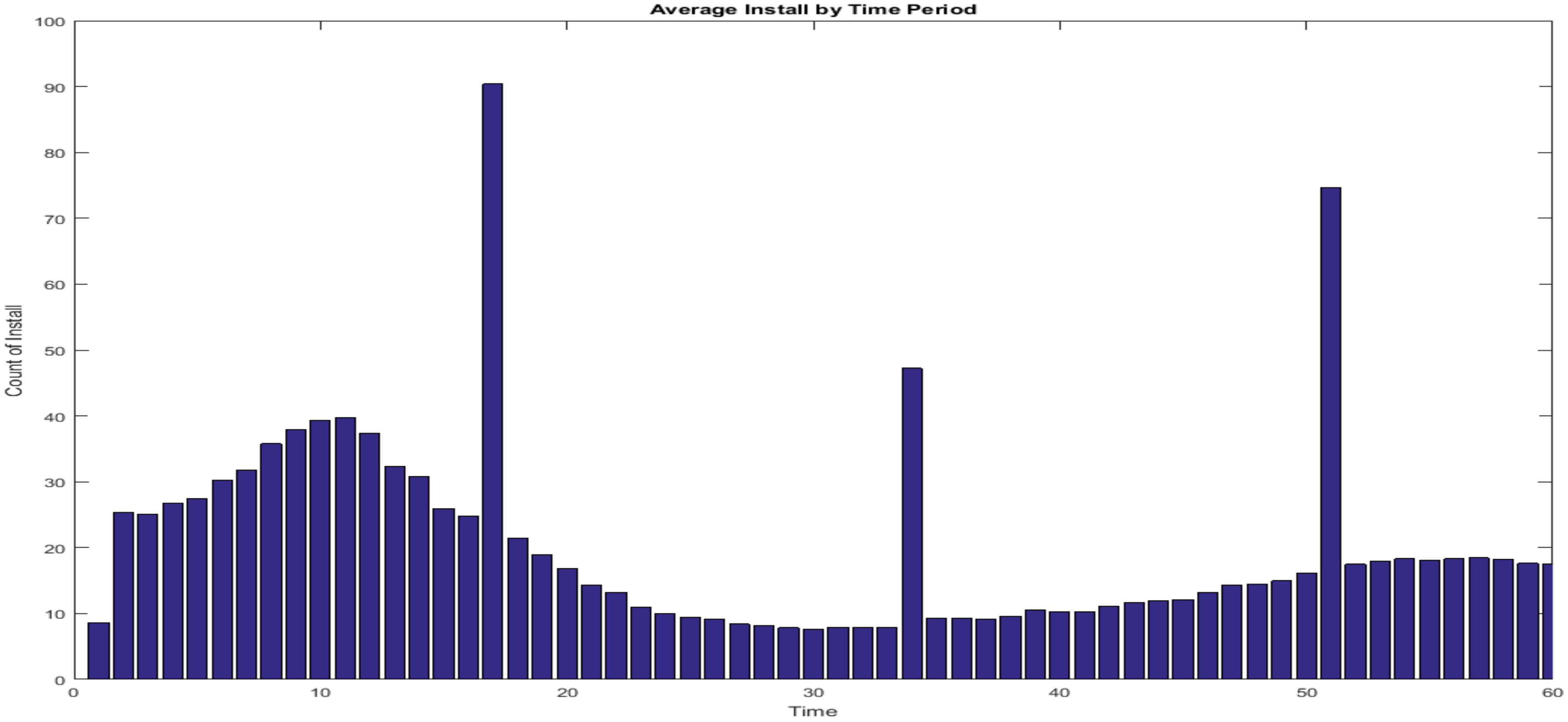
Stage 3 – Iterate through remaining parcels for period t

Stage 4 – Iterate through T periods

Historical Armoring Pattern



Simulated Total Armoring



- Average of 111 iterations (smoothed)
- El Nino seasons are peaks
- Comparisons To Perform:
    - Impact of coalition
    - Impact of social learning
    - Policy scenarios
- Summaries to Perform:
    - Where is armoring
    - Profile of likely to armor

Next Steps

Complete simulations (visualizations, comparisons)

Produce tradeoffs between km of beach preservation and likely property damage between policy options

Incorporate climate change scenarios & couple model with geomorphological models of sediment transport

Conclusion

Conclusion

- Important to understand the factors surrounding clustering and location of armoring
- Important to understand how policy levers change these outcomes
- Important to understand the tradeoffs in protection and preservation in an appropriate timescale

Thank you! Questions?