Value of Disappearing Beaches:

Hedonic model with Endogenous width

AERE Session: Environmental Applications of Hedonic Methods
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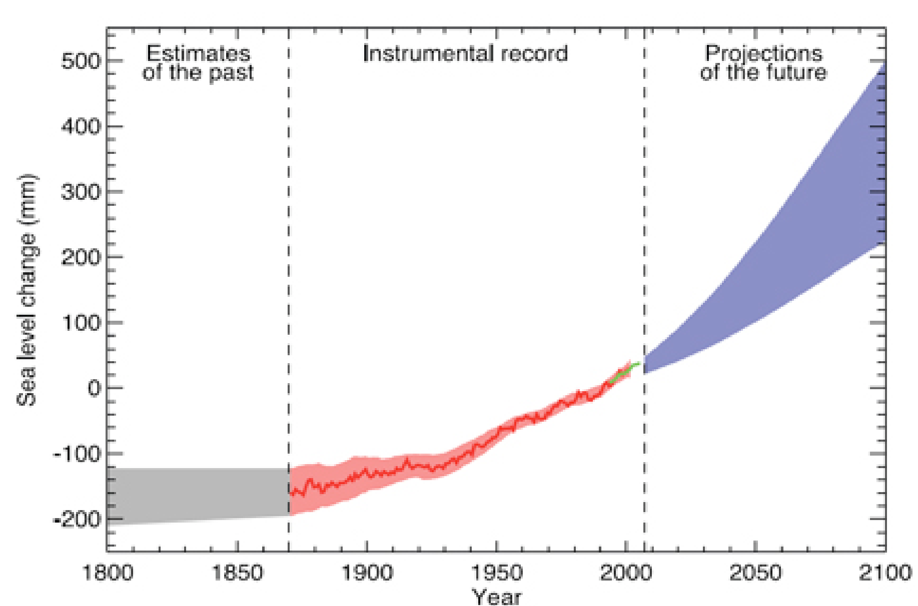
Why do we care?

- 90 % Sandy beaches in the US face erosion

- US coastal population increased by over 33 million since 1980

- Policy Intervention
- Beach Nourishment: Process of periodically re-building the beach by replacing lost sand

Source: www.noaanews.noaa.gov/stories2006/s2622.htm



Why do we care?

What is the value of policy intervention?

Can shoreline stabilization be sustained?

Value of beach nourishment capitalized in property value?

Why do we care?

What is the value of policy intervention?

Can shoreline stabilization be sustained?

Value of beach nourishment capitalized in property value?

Reliable estimates of value of beach width

Value of Beach Width: Hedonic Model

$$\ln(P_i) = \alpha X_i + \beta Z_i + \gamma d_i + \mu L_i + \varepsilon_i$$

Market price

Property attributes

Beach attributes

Distance

Location Specific Dummy

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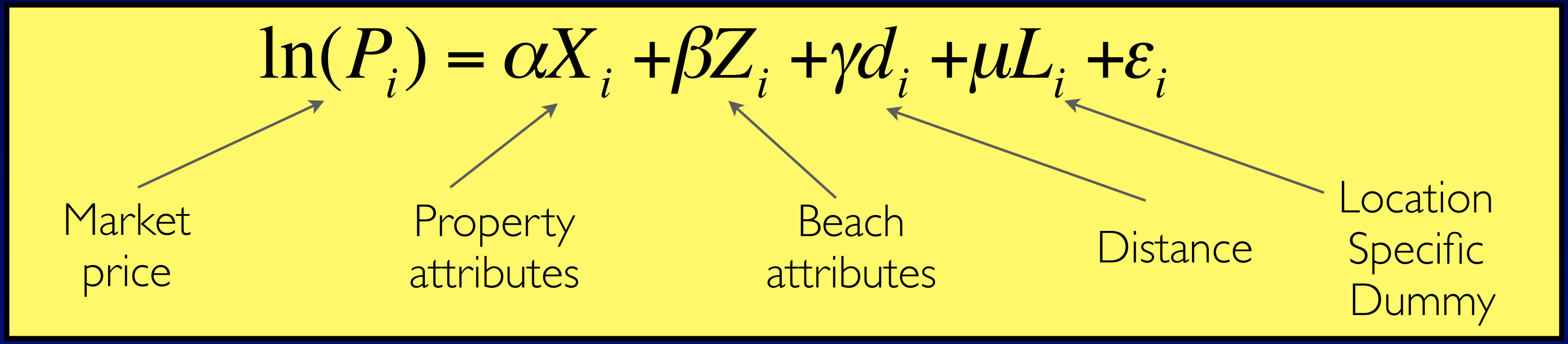

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Endogeneous Beach Width

Property Value = f(Beach Width)

Beach Width = f(Nourishment(Costs, Benefits(Property Value)))

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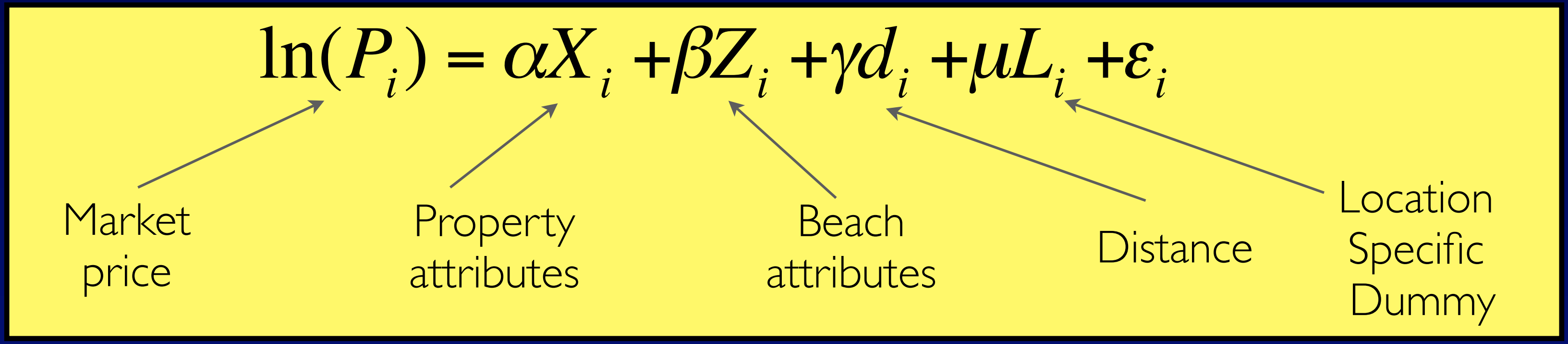

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Instrument for Beach Width

Variation in coastal Geo-morphology

Physical Beach Attributes

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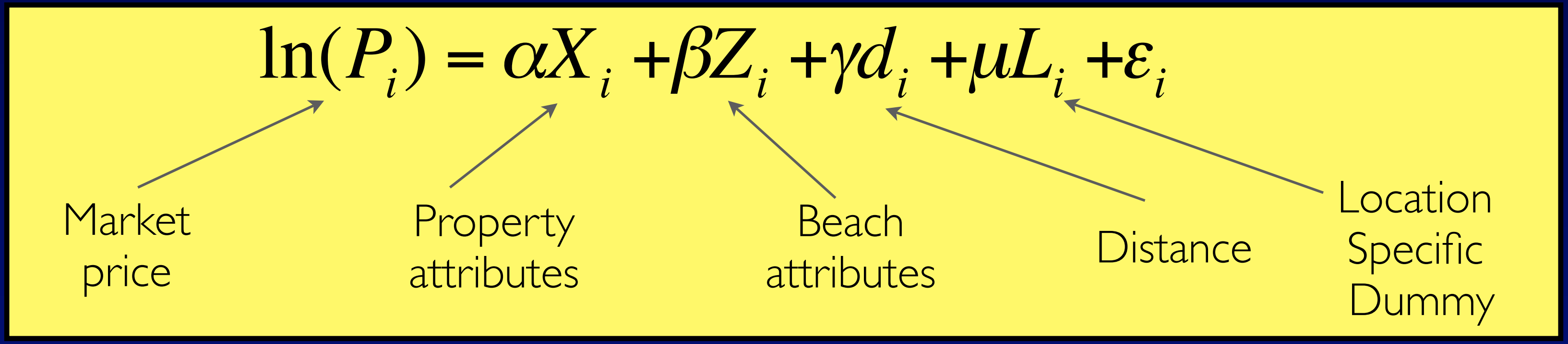

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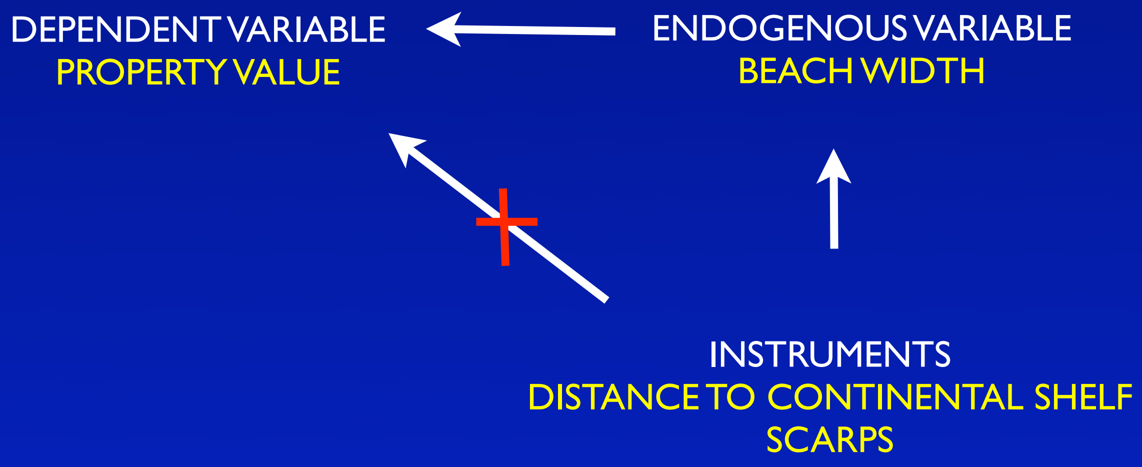
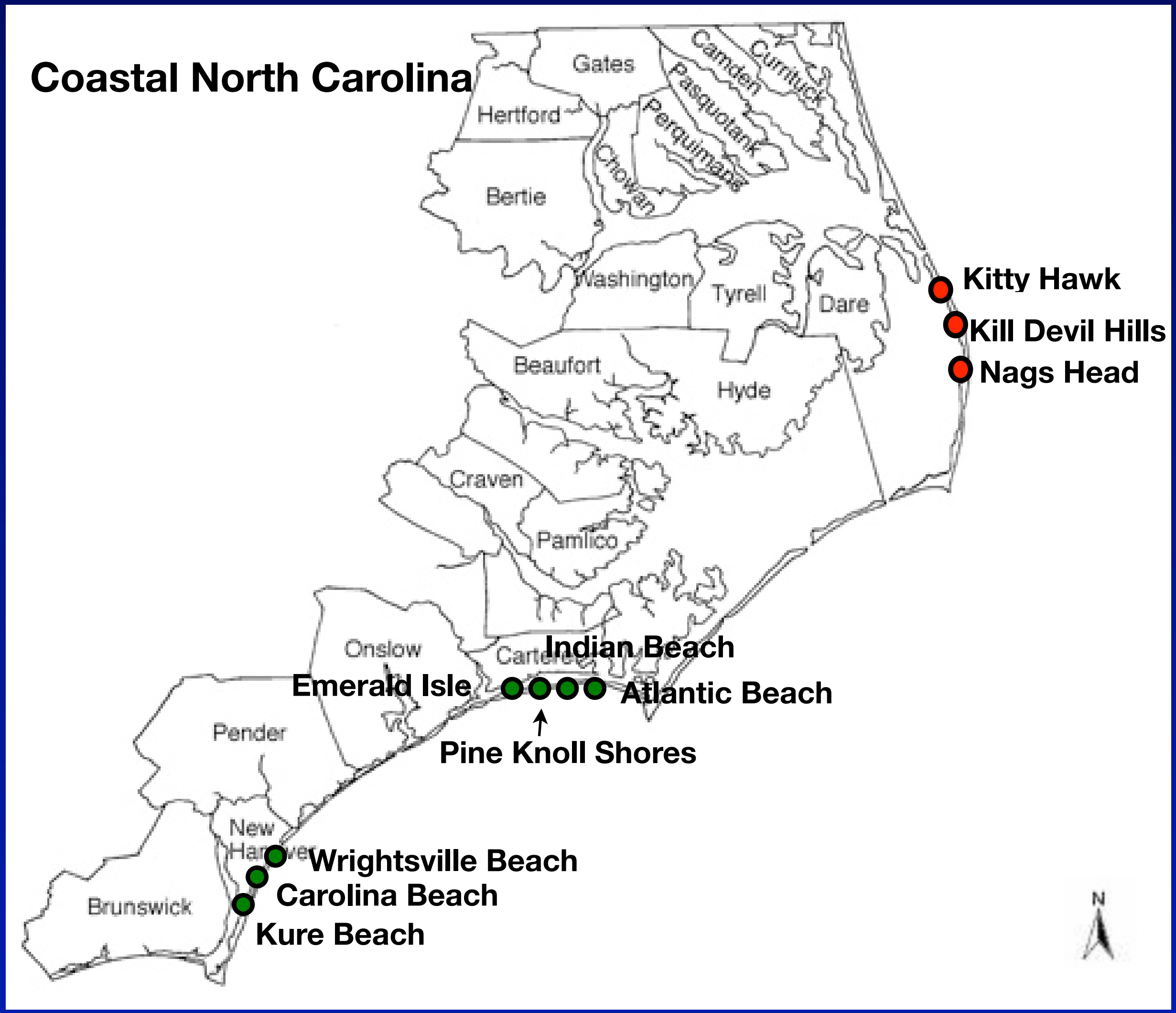


DEPENDENT VARIABLE
PROPERTY VALUE

ENDOGENOUS VARIABLE
BEACH WIDTH

INSTRUMENTS
DISTANCE TO CONTINENTAL SHELF SCARPS

Study Region & Data



- 🔴 Never Nourished
- 🟢 Nourished at least once

N = 1210

Variable	**Mean**	**S D**
Sale Price (in 1000s of 2004 $)	635.74	622.90
Age of Property	25.13	16.24
Month of Sale (Jan '04 = 1; Dec '07 = 48)	24.49	10.69
Built up area (in 100 sq ft)	32.53	44.03
Number of Bedrooms	3.36	1.66
Number of Bathrooms	2.70	1.53
Multi-Storied	0.47	0.50
Distance from Ocean (ft.)	619.33	475.81
Property Type (=1 if Condo)	0.39	0.49
Beach Width (in feet)	98.10	27.51
Shelly Beach	0.10	0.27
Dunes	0.59	0.46
Scarps	0.27	0.45

Beach Attributes

Beach Width

Vegetated Dunes

Recorded at ~400m intervals

Width measured using GPS

Protective Structures

Shells

Attributes coded as dummy variables
= 1 if present at location

Values interpolated using distance weighted average

Photographs by Jordan Slott

Instruments for Width

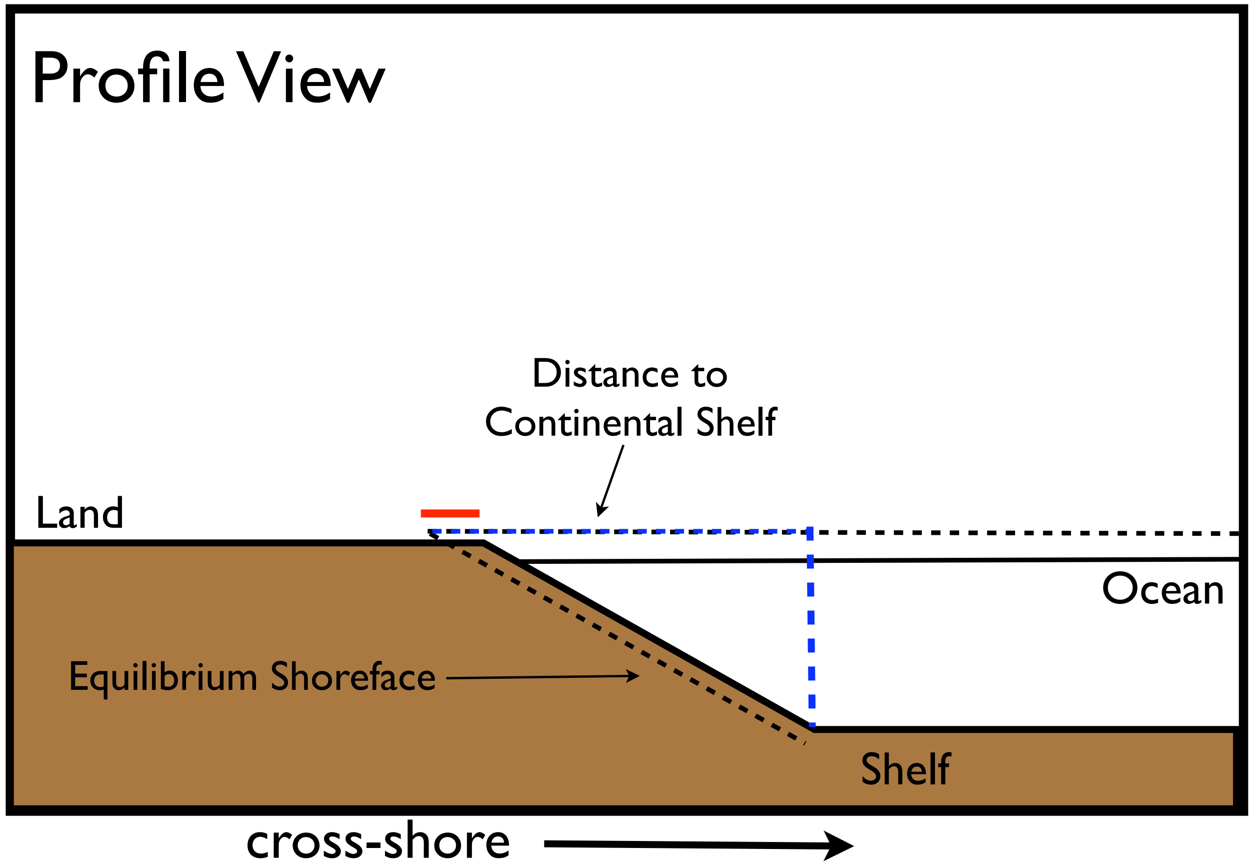
Distance to Continental Shelf

Dist. to 20m iso-bathemetry line correlated with slope of shoreface

Sea Level Rise leads to more erosion when the shoreface profile has lower slope

Prolonged erosion decreases the shoreface slope

Simplified Beach Dynamics



Adapted (modified) from Smith *et al.*, 2009

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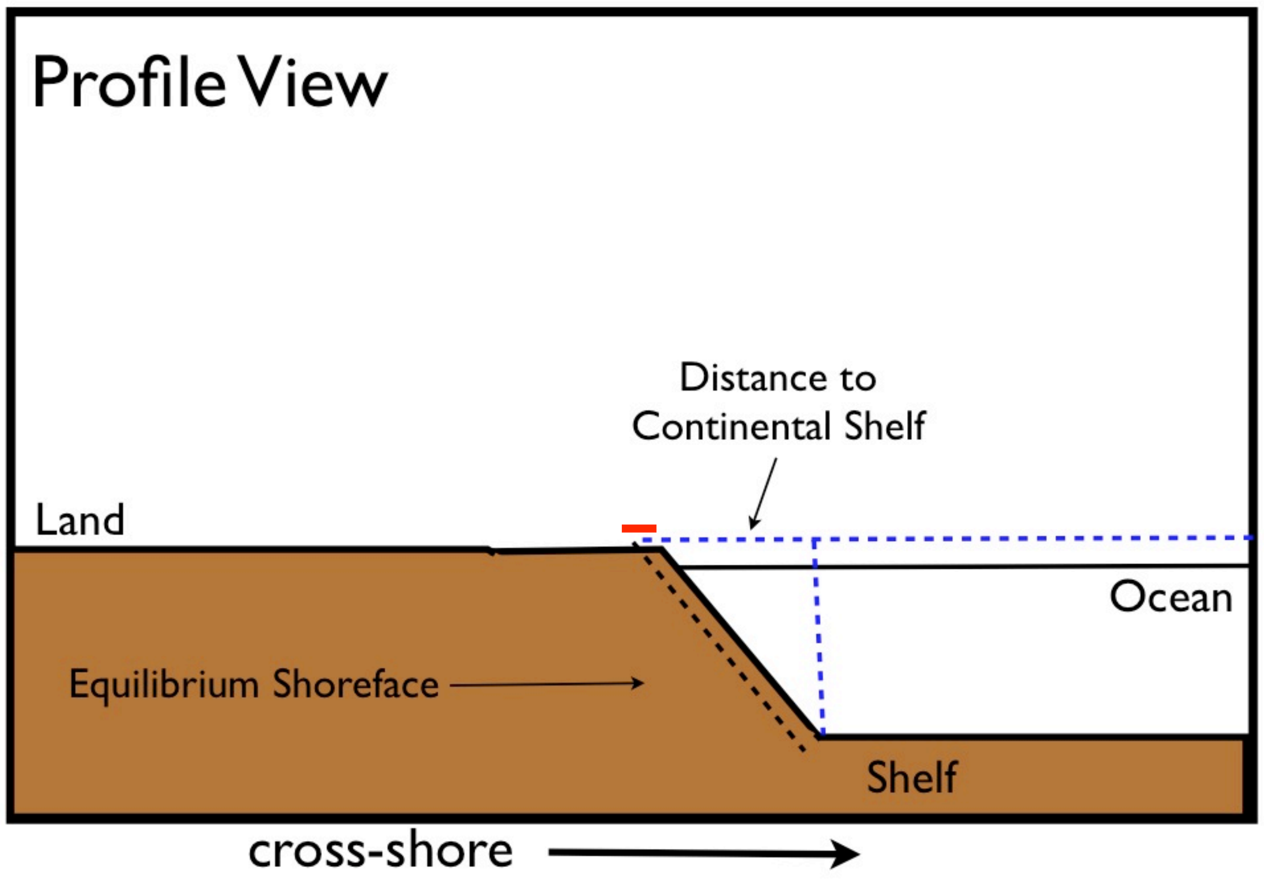
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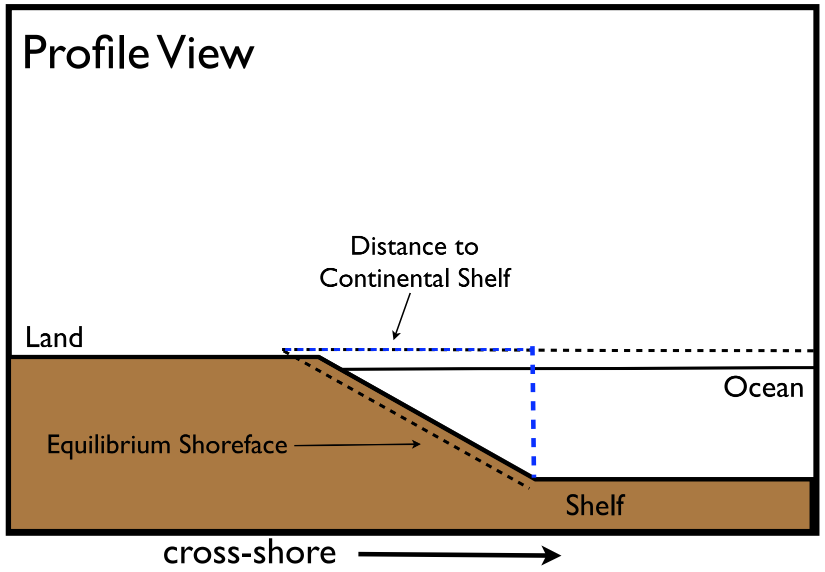
Instruments for Width

Distance to Continental Shelf

Shelf-line identified using bathymetry data (ETOPO2, NOAA)

GIS euclidean distance measure

Simplified Beach Dynamics



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Presence of Scarps

Steep slope on the erosional face of a dune that is formed by wave action

Indicative of prolonged erosion

Tests for Endogeneity

Null Hypothesis: H_0: Regressor is exogenous			
Wu-Hausman F test:	9.972	F(1,1190)	P-value = 0.002
Durbin-Wu-Hausman chi-sq test:	10.055	Chi-sq(1)	P-value = 0.002

Tests for instrument relevance

FIRST STAGE REGRESSION SUMMARY RESULTS		
	TSLS (Semi-log)	TSLS (Double-log)
First Stage F-statistic	34.82	51.6
First Stage Partial R-squared	0.06	0.05

Results

DEPENDENT VARIABLE: LN(SALE PRICE) OBSERVATIONS = 1210

	1	**2**	**3**	**4**
VARIABLES	OLS (Semi-log)	OLS (Double-log)	TSLS (Semi-log)	TSLS (Double-log)
Built-up Area (100s sq. ft)	0.004***	0.003***	0.005***	0.005***
Number of Bedrooms	0.060***	0.063***	0.081***	0.087***
Number of Bathrooms	0.145***	0.148***	0.125***	0.123***
Multi-Storied	0.093***	0.112***	0.006	0.013
Property Type (=1 if Condo)	-0.230***	-0.205***	-0.202***	-0.215***
Age	-0.00026	-0.000634	-0.002*	-0.002
Month of Sale (=1 if Jan 2004; = 48 if Dec 2007)	-0.000001	-0.00004	-0.001	-0.001
Beach Width (Feet)	0.002***	0.190***	0.006**	0.485**
Distance to Ocean (Feet)	-0.00003***	-0.127***	-0.0002***	-0.110***
Dunes	-0.053	-0.044	0.089**	0.117**
Shells	0.372***	0.406***	0.338***	0.319***
R-squared	0.507	0.495	0.491	0.507

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OLS Results comparable to other studies (Pompe & Reinhart, 1995)

Coefficient on width nearly triples in the TSLS model

The Resource Problem

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- Housing markets directly influenced by physical coastal processes
- Beach as a dynamic natural resource that generates value

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Value of Beach reflected in property values (Empirical results)

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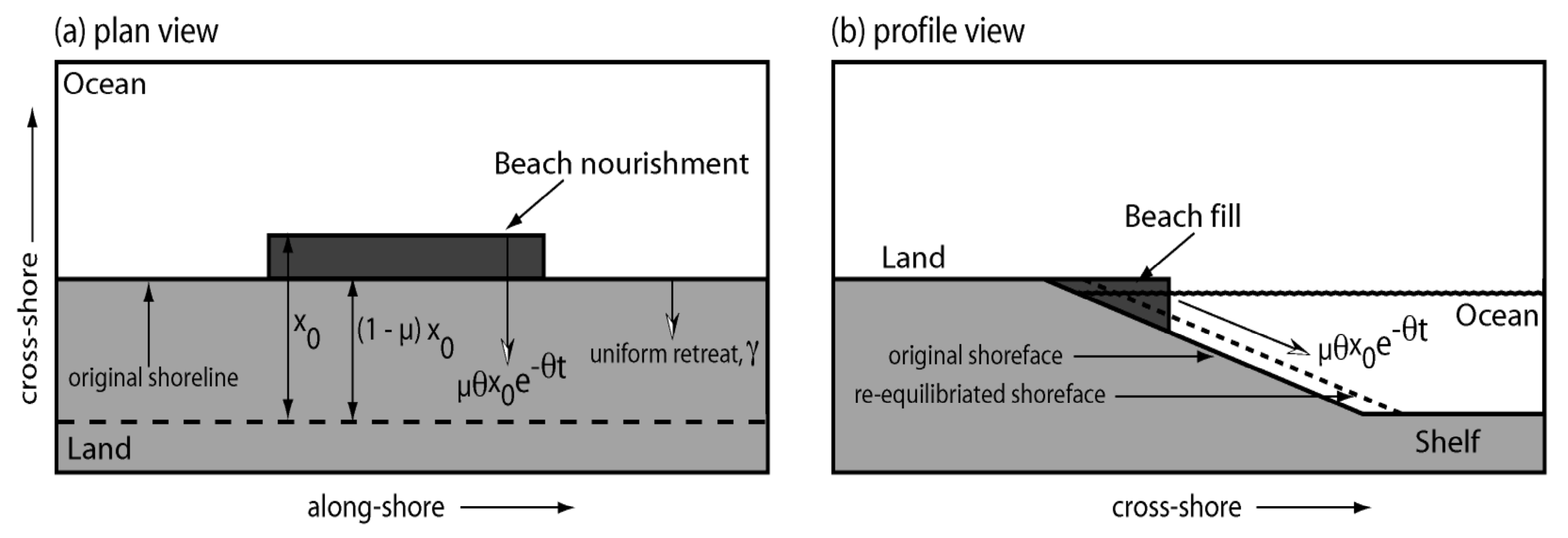
Model for Optimal Beach Management

Simplified Dynamics of Beach Erosion and Nourishment



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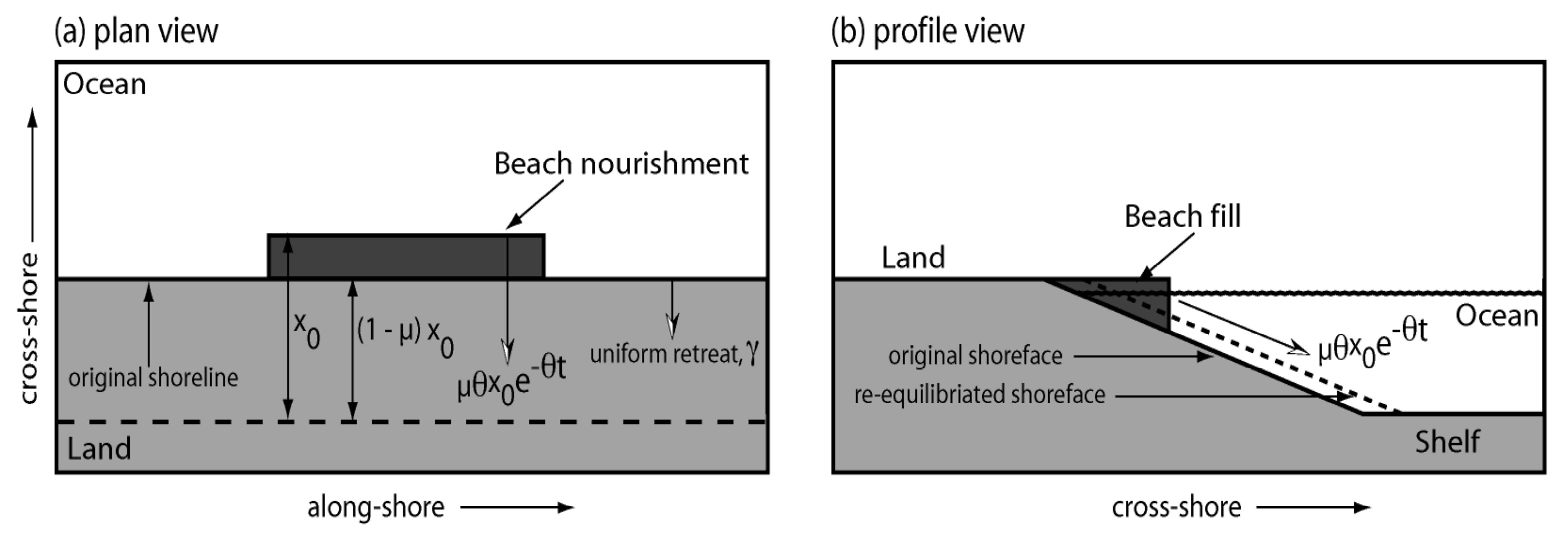

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Faustmann problem applied in reverse

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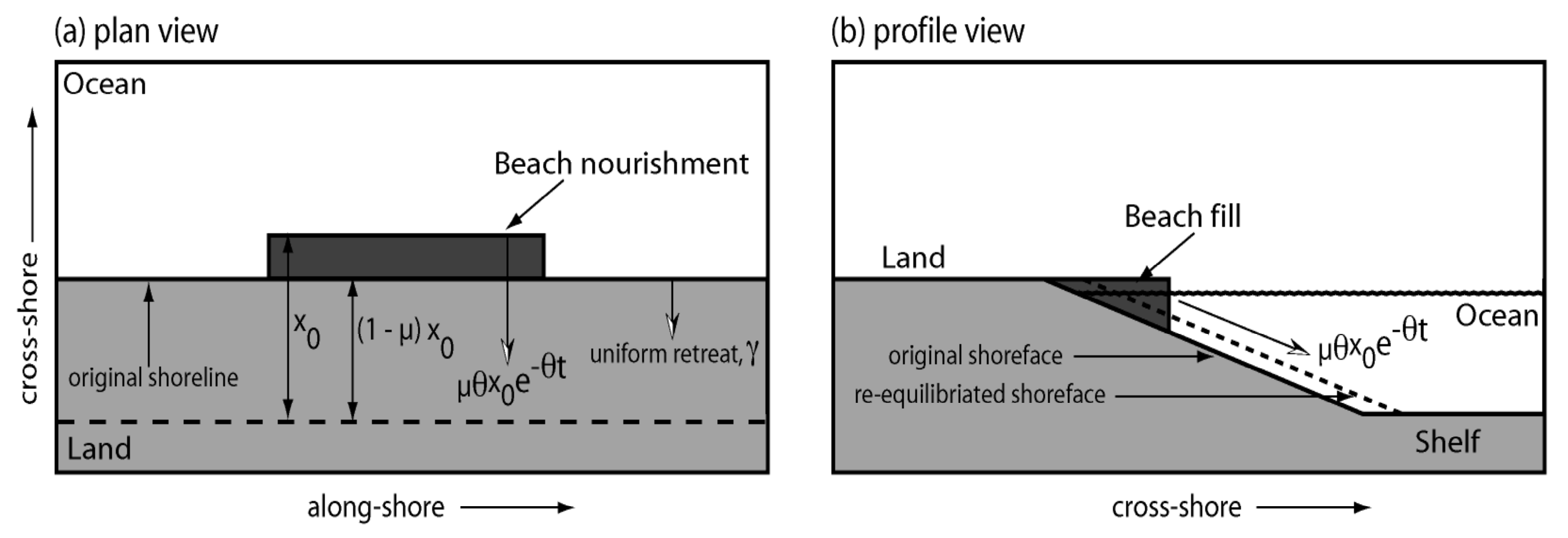

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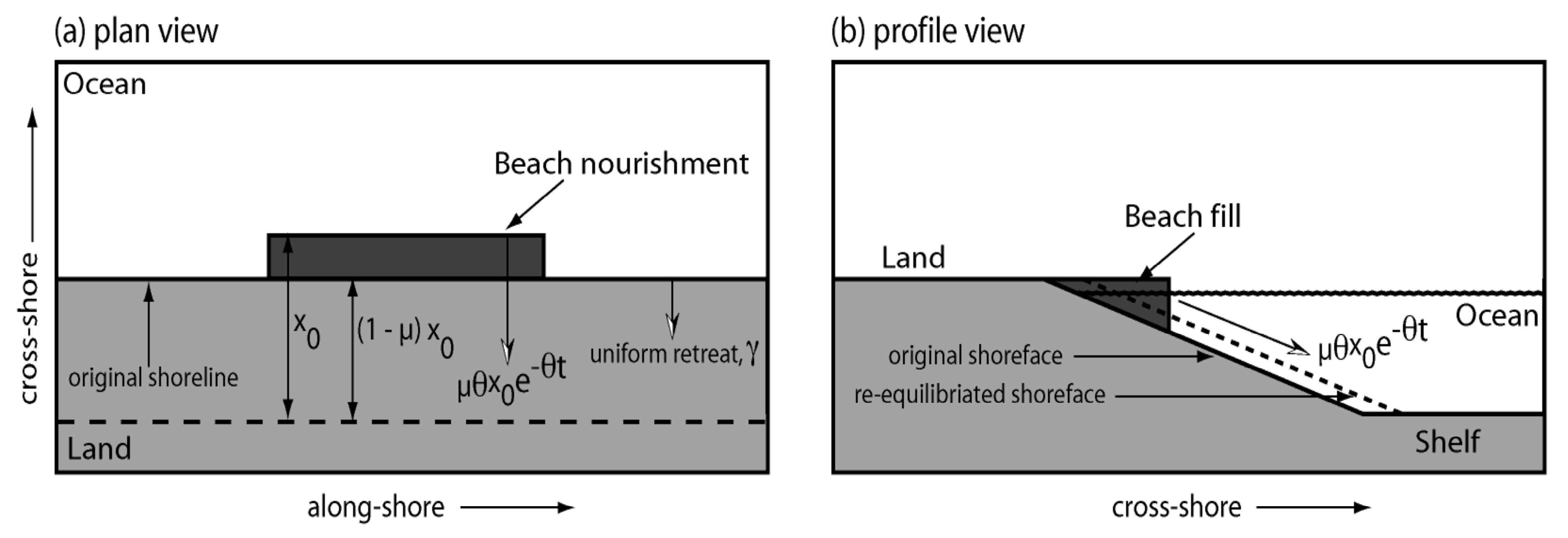

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Rotational/Periodic Nourishment

Optimal Nourishment Interval

Dynamic Policy Simulations

State Equation:

$$\boxed{x(t) = \underbrace{(1-\mu)x_0 - \gamma t}_{} + \underbrace{\mu e^{-\theta t} x_0}_{}}$$

Costs:

$$\boxed{C_i(T_i) = c + \phi[x_i^0 - x_i(T_i)]}$$

Benefits:

$$\boxed{B_i(T_i) = \int_0^{T_i} \delta e^{-\delta t} \alpha [x_i(t)]^\beta \, dt}$$

Choose T* that maximizes the infinite stream of net benefits

Dynamic Policy Simulations

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Baseline
Property Value

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Benefits:

$$B_i(T_i) = \int_0^{T_i} \delta e^{-\delta t} \underset{\text{Baseline Property Value}}{\alpha} [\underset{\text{Width}}{x_i(t)}]^\beta \, dt$$

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Baseline Property Value

Width

Hedonic Beach Value

Choose T* that maximizes the infinite stream of net benefits

T* ⇨

Decreases with higher erosion rate
Decreases with higher baseline property values
Can decrease with higher cost of sand

Simulation Results

Description	Atlantic Beach	Carolina Beach	Emerald Isle	Indian Beach	Kure Beach	Wrightsville Beach
Observations	216	212	191	149	122	90
Mean Property Value (1000s of 2004 $)	337.95	353.26	482.88	438.45	544.12	676.48
Mean Predicted Value (TSLS)	322.35	337.4	468.36	410.58	543.56	723.44
Baseline Value 1 (beta = 0.2) $A_1 = V/(x^{\beta_{OLS}})$	143.65	147.34	205.85	176.28	224.99	274.05
Baseline Values 2 (beta = 0.48) $A_2 = V/(x^{\beta_{IV}})$	38.29	37.95	54.97	43.05	57.19	67.52
Mean Width	91.94	101.37	92.45	126.83	107.16	120.11
Year of First Nourishment	1973	1955	1984	2001	1997	1939
Most Recent Nourishment	2005	2004	2005	2004	2004	2006
Observed Number of Nourishments	6	28	14	2	3	23
Observed Rotation Length	**5.33**	**1.75**	**1.50**	**1.50**	**2.33**	**2.22**
Optimal Rotation w/OLS (beta = 0.2)	4.53	4.48	3.78	4.09	3.61	3.26
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Decrease (%) in Discounted Net Value with increased erosion rate and variable costs of nourishment sand

---

Baseline Erosion rate = 2ft/year

Variable costs = $300 per ft of cross-shore build out

Scenario		**% Decrease in Net Value**		
		Baseline Property Value		
% Increase in Cost of sand	% Increase in Erosion rate	40000 (Carolina Beach)	60000 (Emerald Isle)	70000 (Wrightsville)
50%	50%	7.8	5.0	4.3
100%	100%	17.1	11.1	9.4
200%	100%	29.4	18.9	16.0
300%	200%	56.3	36.1	30.7

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Long-run value of net benefits decreases by over 56%

Conclusion

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- Instrumenting for beach corrects endogeneity and attenuation bias
- Optimal nourishment frequency using the TSLS value of width closer to observed frequency
- Concerns about the long-run feasibility of beach nourishment

Thank You!

Additional Slides

Limitations & Future Work

- Lack of spatially refined data on nourishment
- Number of nourishment projects low
- Stationarity assumed in the optimal nourishment decision model

- Sand use as a common pool resource problem
- Spatial model incorporating the diffusion of nourishment sand

BIAS CORRECTION UNDER IV

- Direction of bias?

- Beach Dynamics with Nourishment

- Measument error

BIAS CORRECTION UNDER IV

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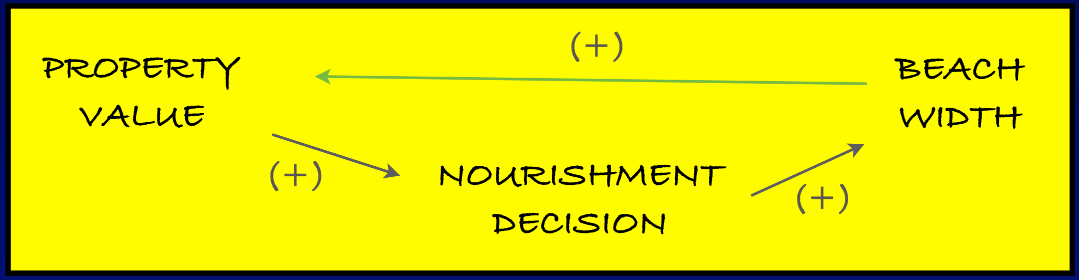
$$\boxed{\beta_{IV} < \beta_{OLS}}$$



PROPERTY VALUE

(+)

BEACH WIDTH

(+)

NOURISHMENT DECISION

(+)

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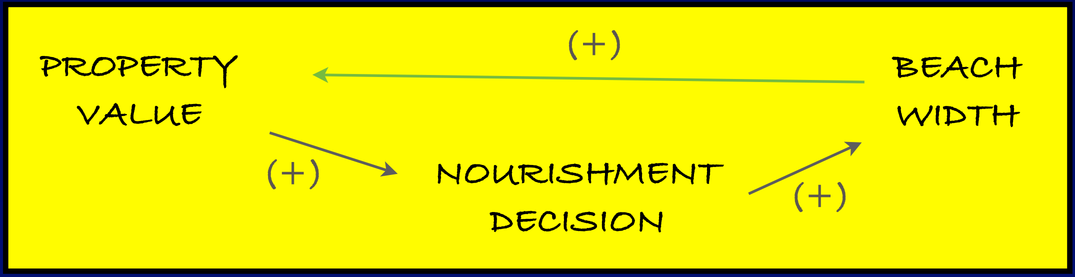

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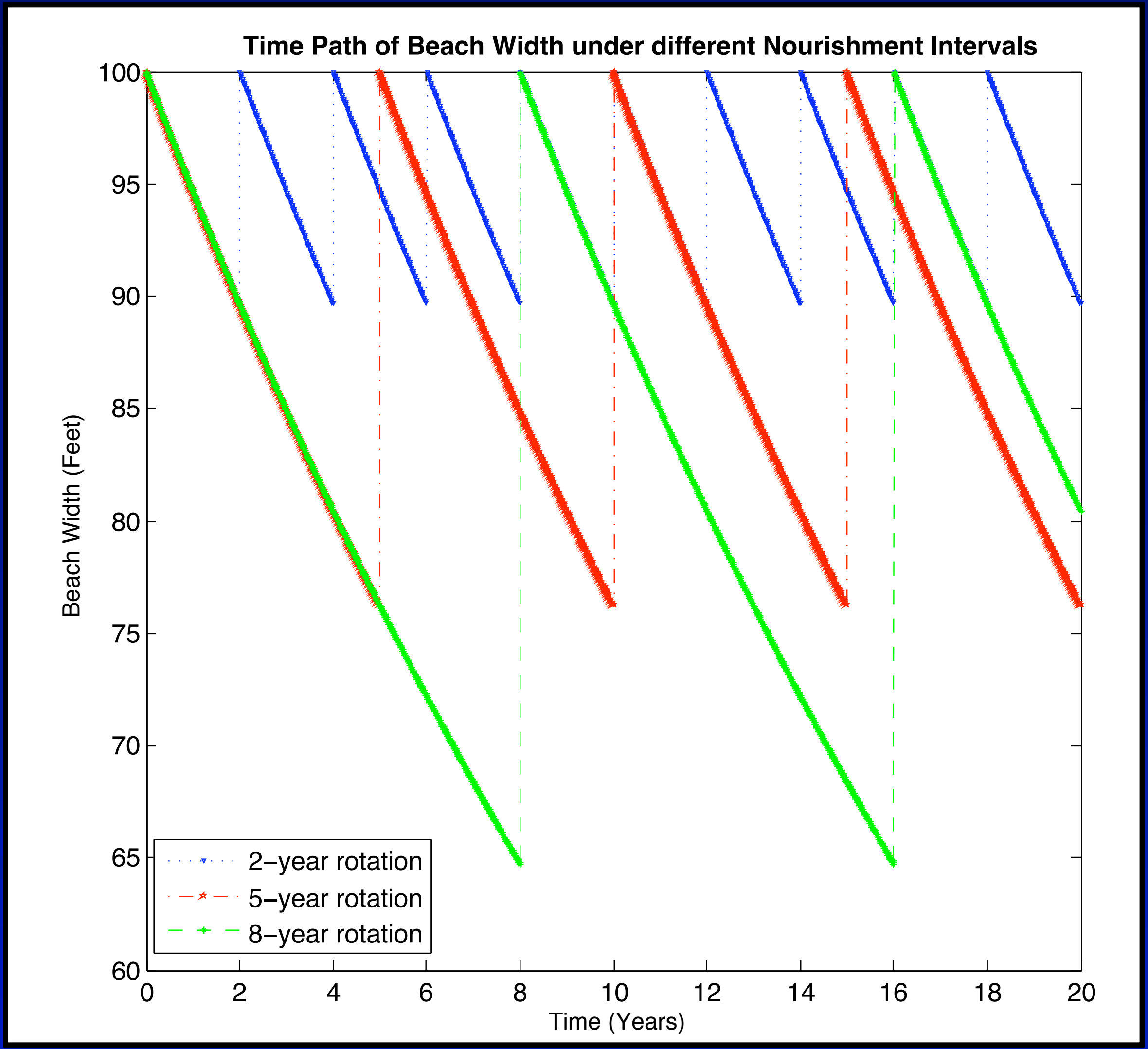

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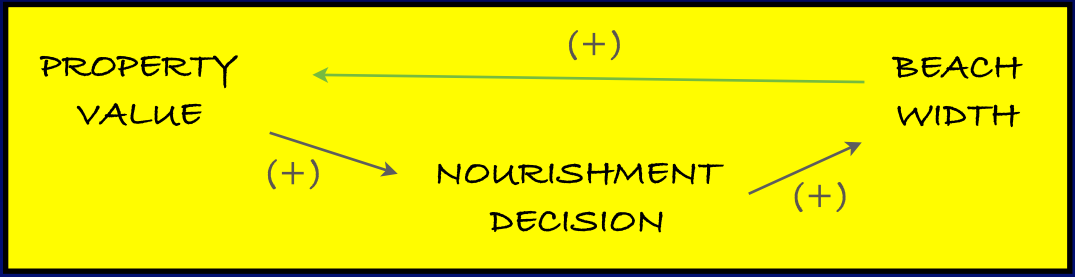
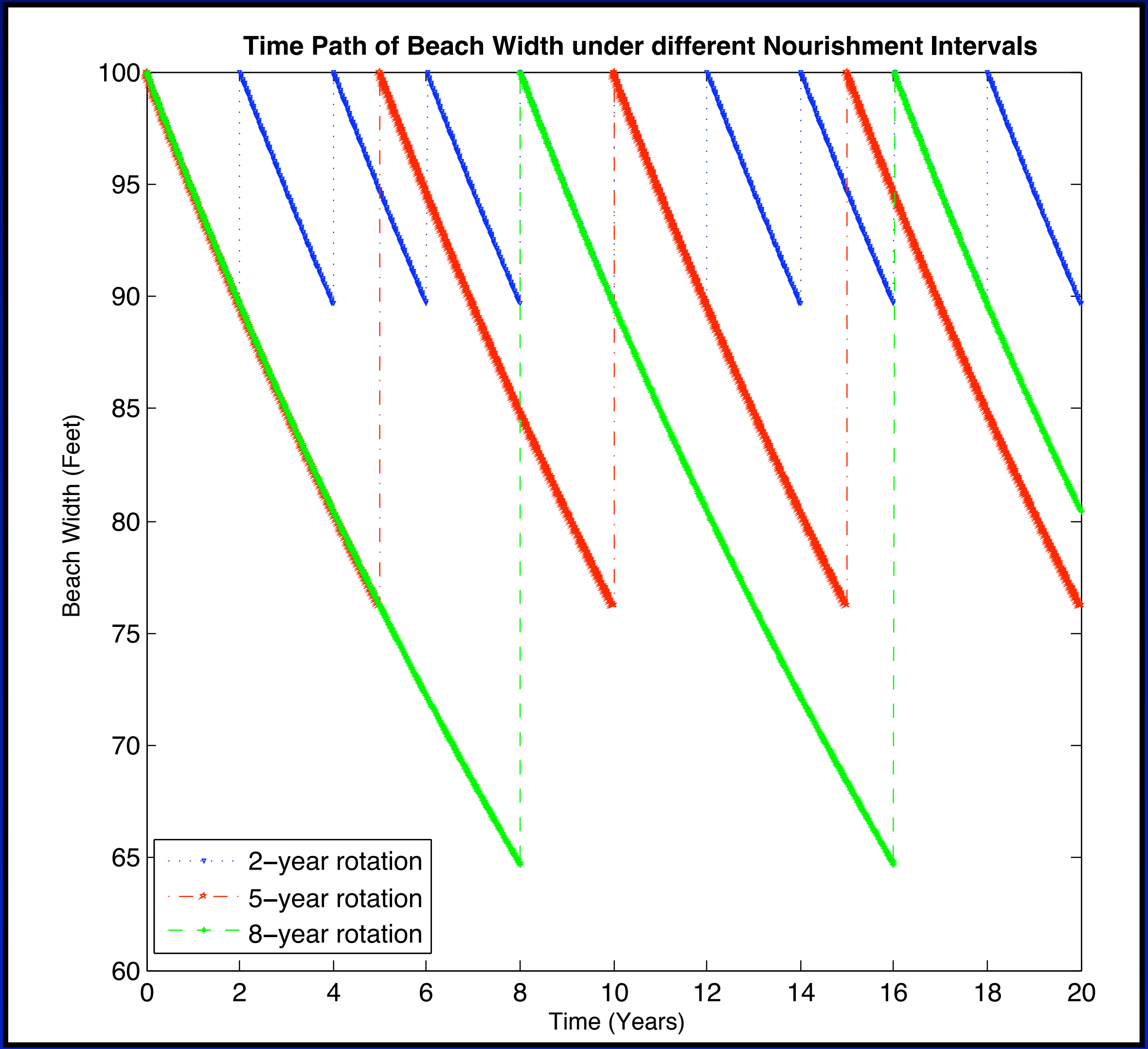

PROPERTY VALUE
(+)
BEACH WIDTH
(+)
NOURISHMENT DECISION
(+)

- Beach Dynamics with Nourishment

  Direction of bias unclear

- Measument error



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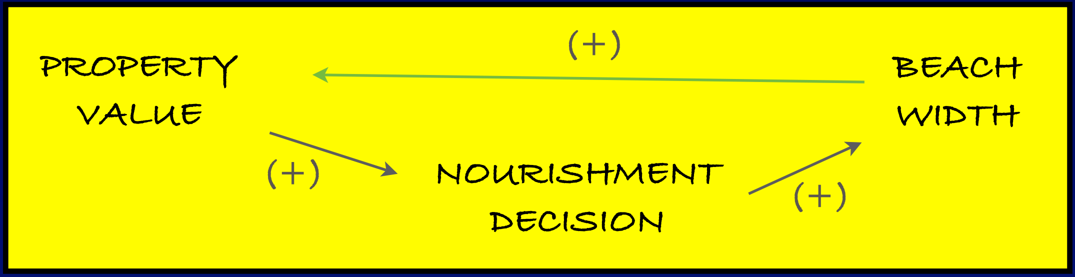

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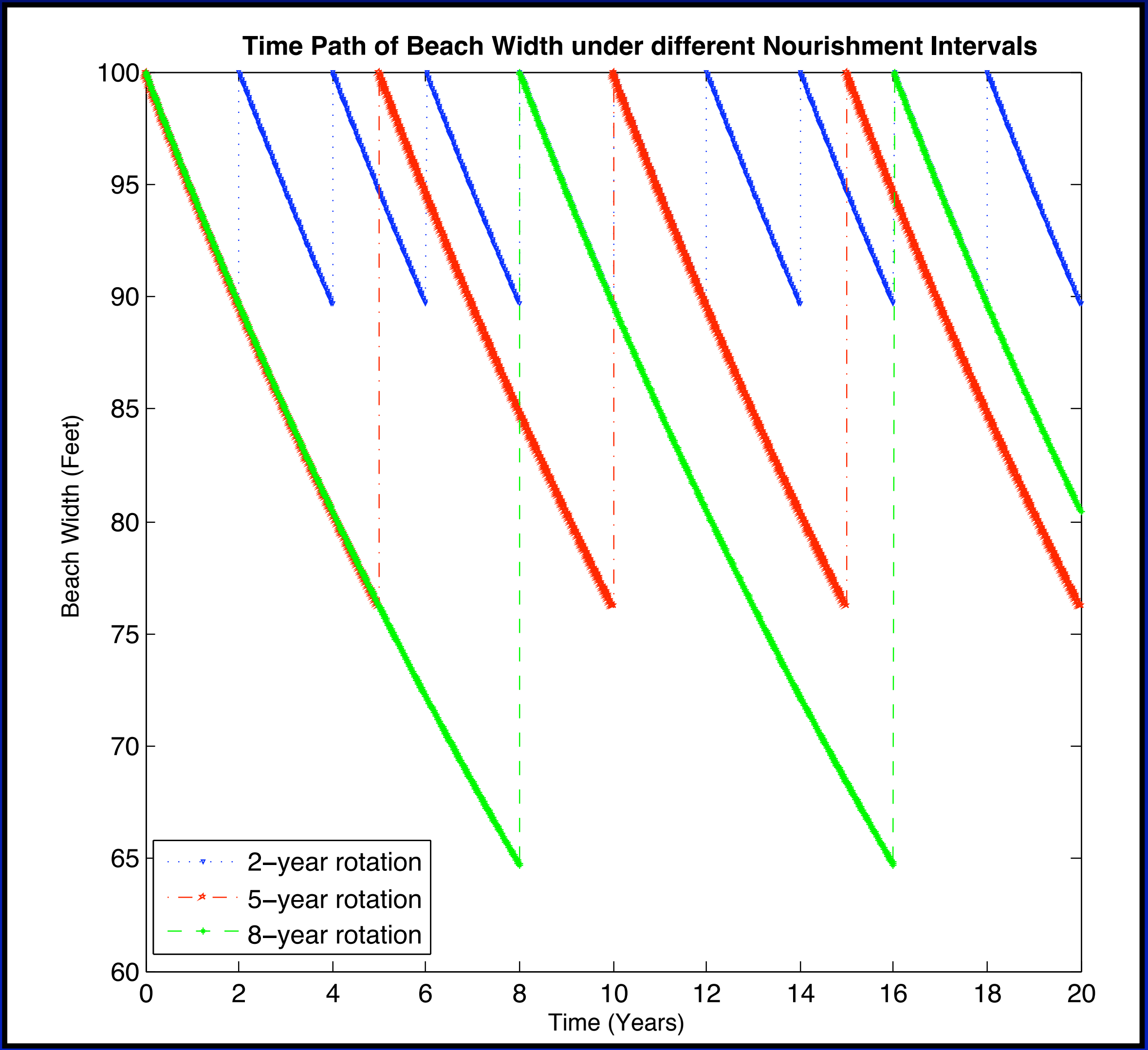

BIAS CORRECTION UNDER IV

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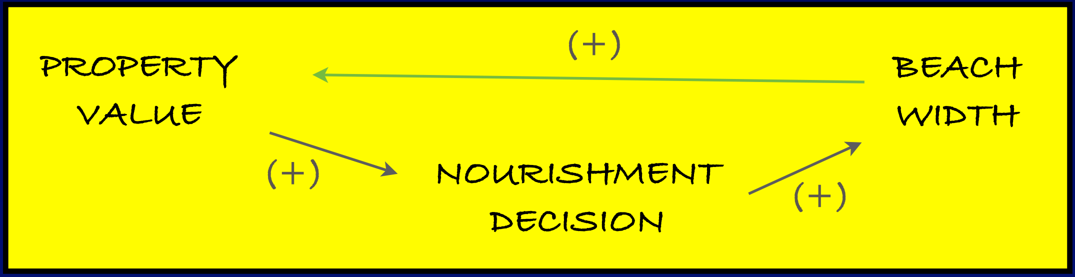

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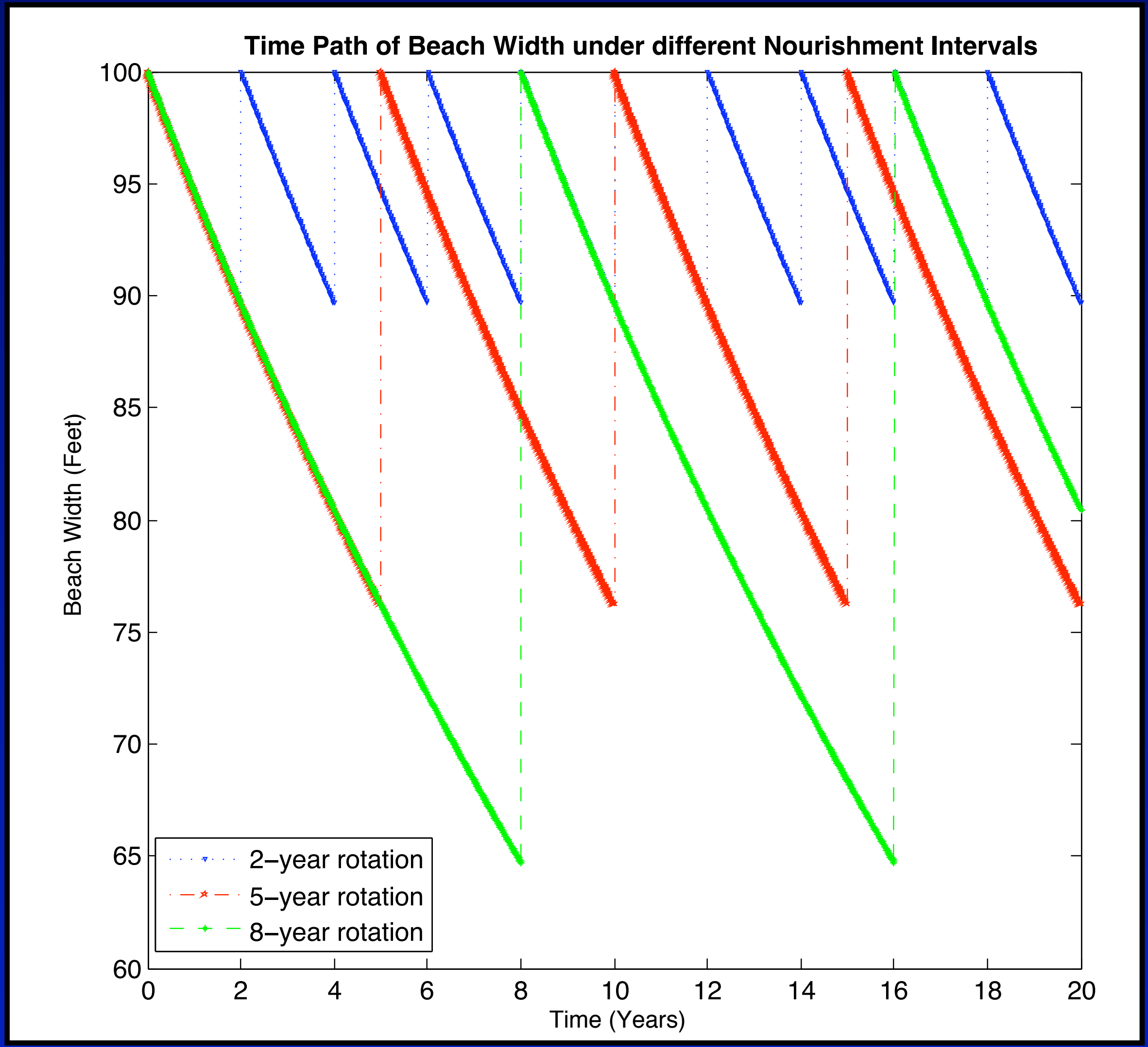
Combination?



Montecarlo Simulation: Hedonic Model

- Hedonic Price Function: $V = e^{-\delta t}\alpha[x(t)]^{\beta}$

- Estimated: $\ln(V_{ij}) = -\delta t_{ij} + a\ln(\alpha) + \beta\ln(x_{ij}) + \varepsilon_{ij}$

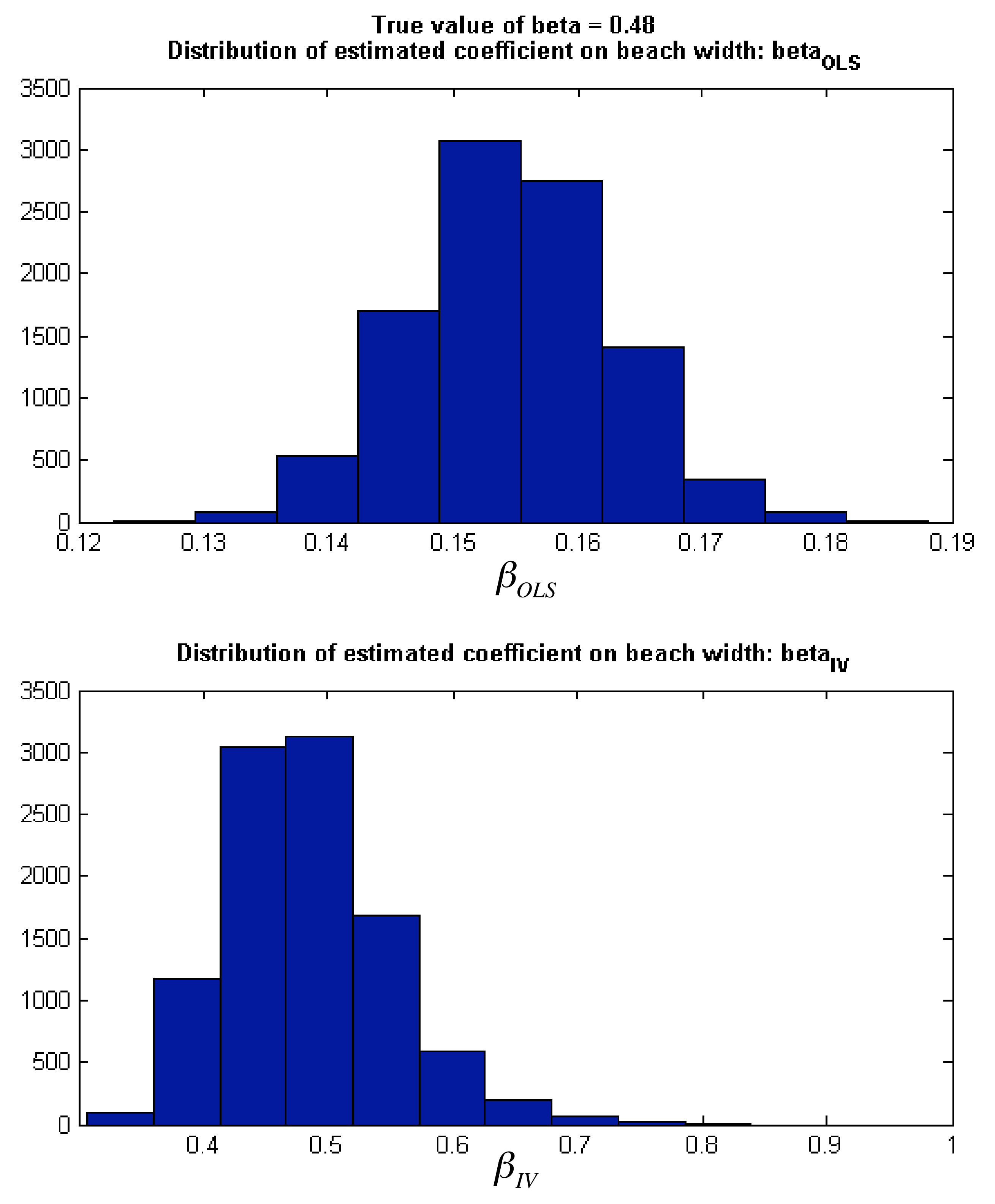
-

	Estimated Parameter		
Model	δ^0 **= -0.06**	a^0 **= 1.00**	β^0 **= 0.48**
OLS	$\overline{\delta}_{OLS}$ = -0.046	$\overline{a}_{OLS}$ = 1.319	$\overline{\beta}_{OLS}$ = 0.155
TSLS	$\overline{\delta}_{IV}$ = -0.060	$\overline{a}_{IV}$ = 0.991	$\overline{\beta}_{IV}$ = 0.489

Parameters

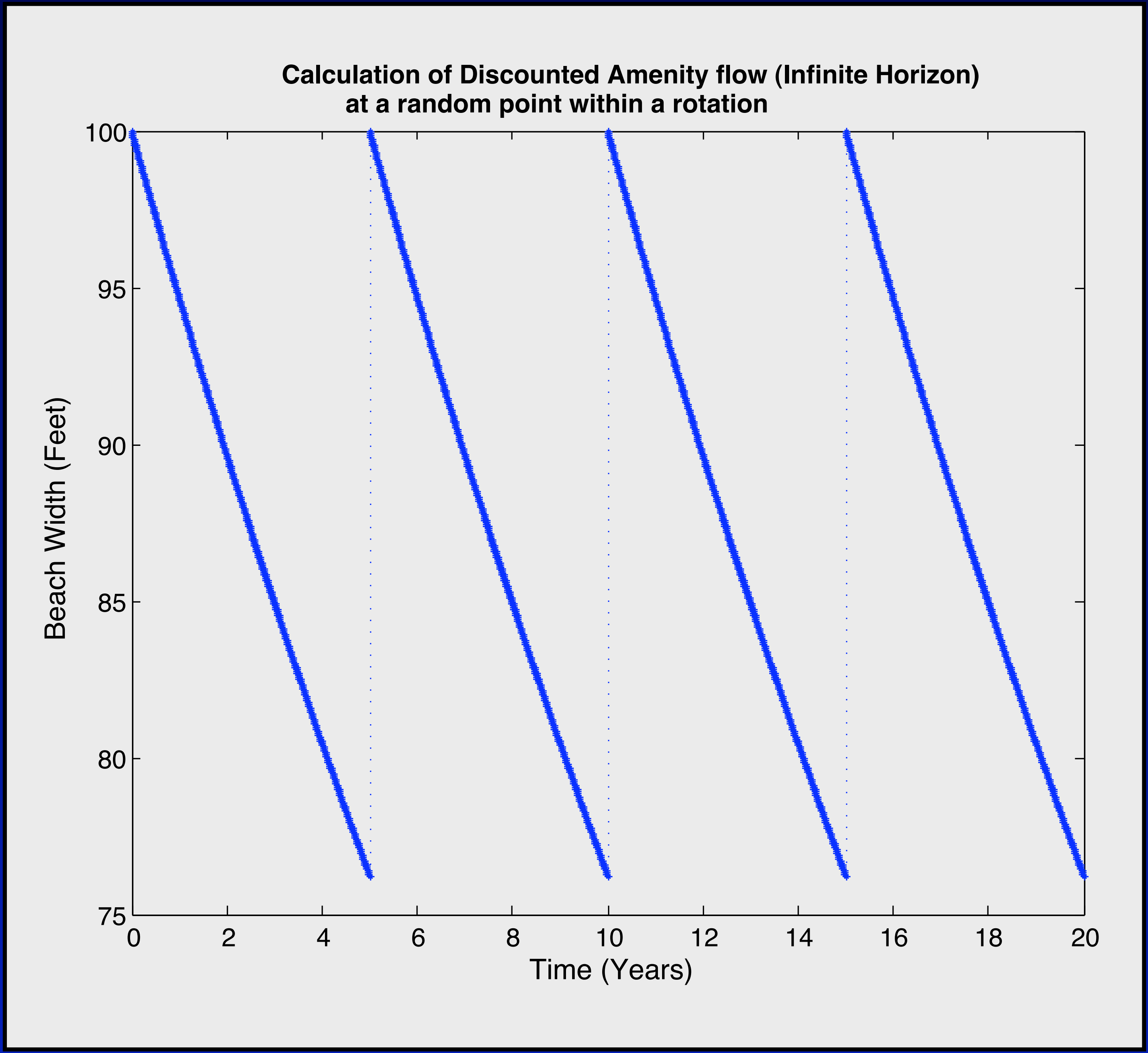
Parameter	Value	Description
δ	0.06	Discount factor
γ	2	Baseline Erosion (Feet/year)
θ	0.10	Exponential Erosion Rate
μ	0.35	Portion of the beach that is nourished
x_0	100	Initial Width (Feet)
c	2	Fixed Cost (Scale: 1000$)
ϕ	0.3	Variable Cost per foot of cross-shore build out (Scale: 1000s $)
α	100	Baseline Property Values (Scale: 1000s $)
β	0.19 0.48	Hedonic Value of beach width

Distribution of Estimated beta under OLS and TSLS



- Number of simulation runs = 10000
- Each Run:
- Draw A ~ U(50,250) - Base Value
- Draw gamma $\gamma_j \sim U(1,10); j \in [1,25]$ (erosion rates)
- Calculate Optimal Rotation T_{ij}* for each (A, gamma)
- Draw random sample of 100 time points within each rotation for each j
- Calculate width (x_{ij}) and value (V_{ij})
- Estimate hedonic price function

Calculation of Discounted Amenity Flow within a rotation



Benefits from a single rotation

$$B(t_{ij}) = \int_{t_{ij}}^{T_j^*} e^{-\delta t_{ij}} \delta\alpha[x_j(s)]^\beta \, ds + e^{-\delta T_j^*} \int_0^{t_{ij}} e^{-\delta t_{ij}} \delta\alpha[x_j(s)]^\beta \, ds$$

Cumulative Value

$$V_{ij} = \frac{B(t_{ij})}{1 - e^{-\delta T_j^*}}$$

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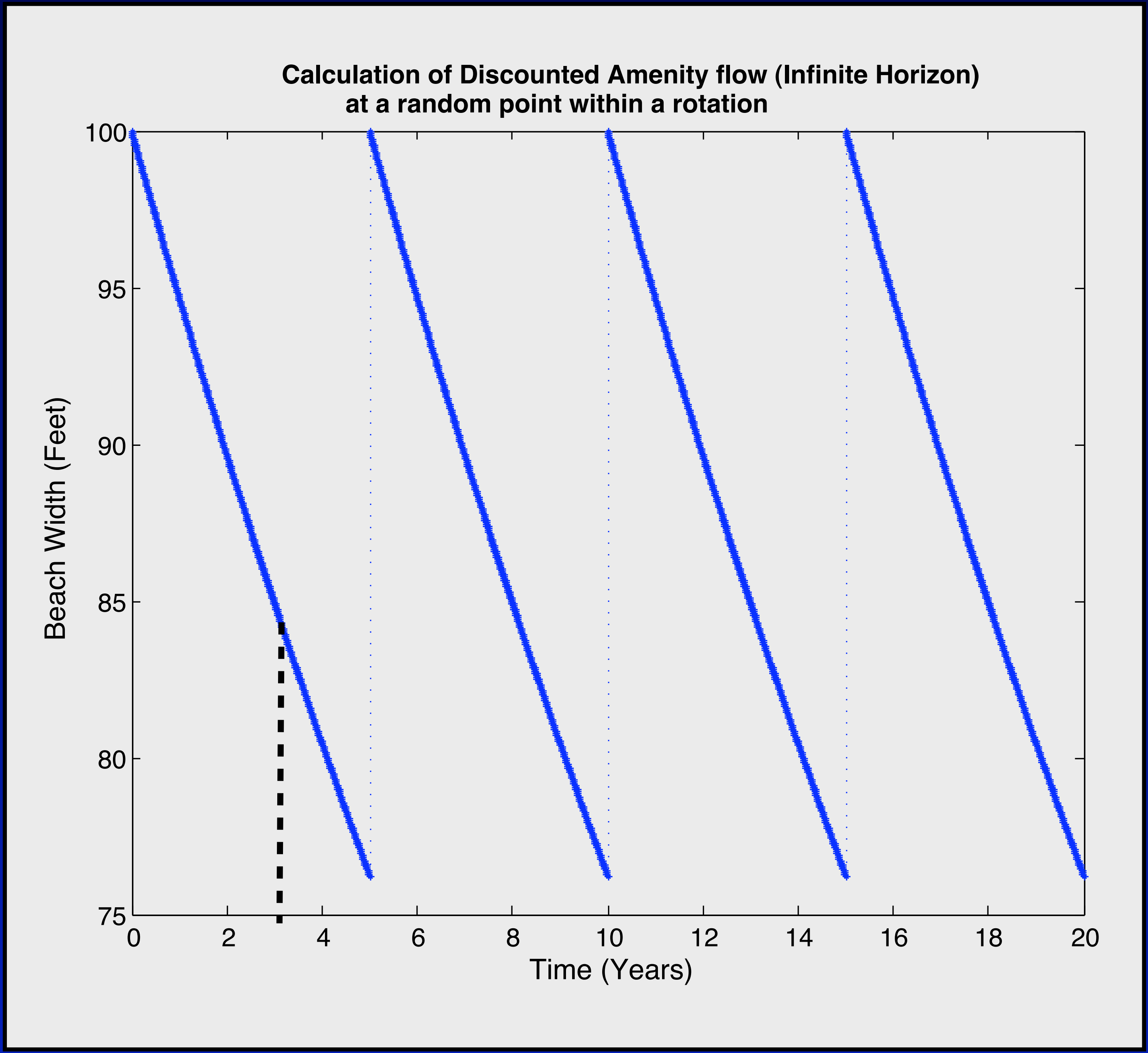

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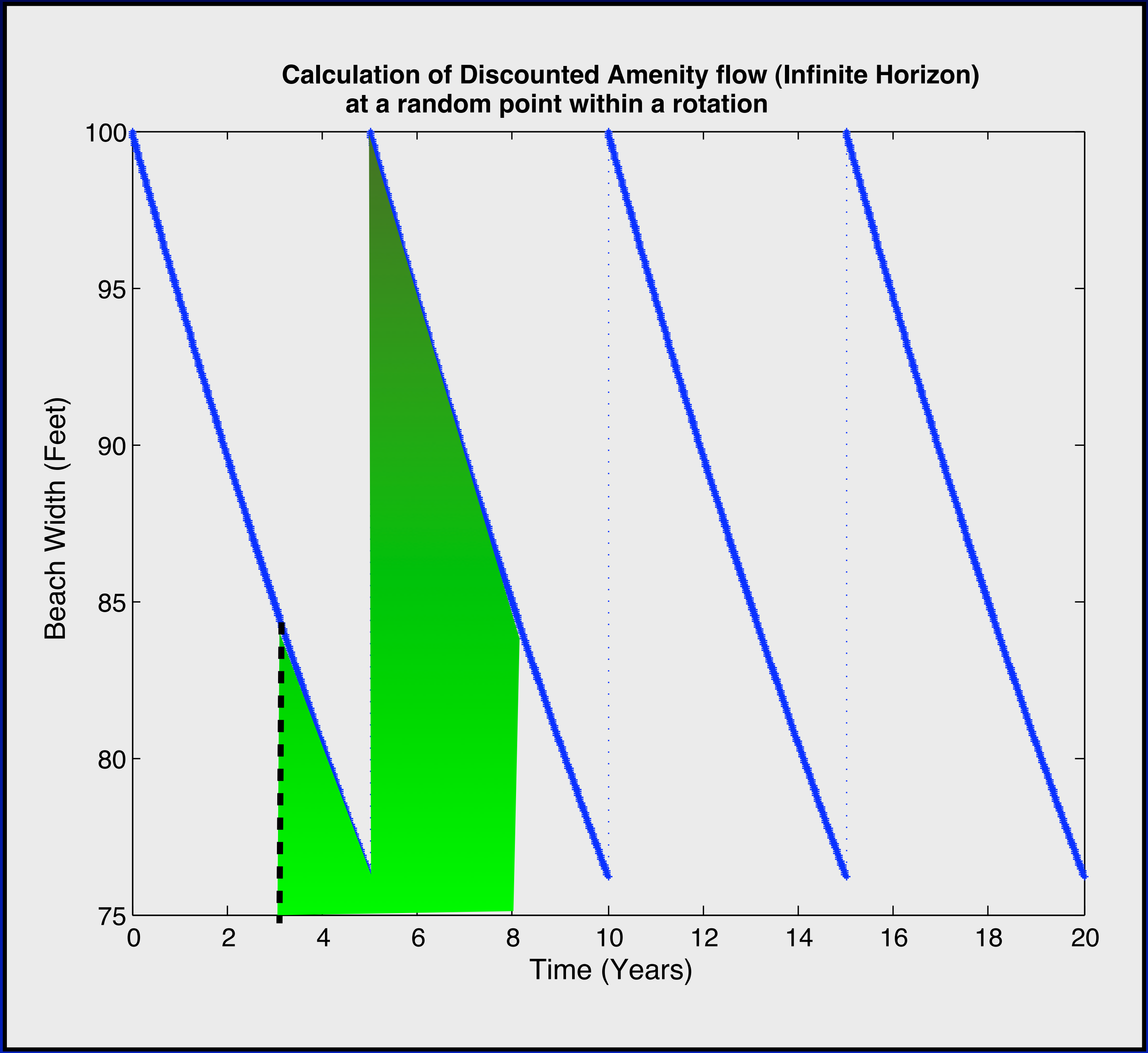

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Results LOCATION-SPECIFIC FIXED EFFECTS

	1	**2**	**3**	**4**
VARIABLES	OLS (Semi-log)	OLS (Double-log)	TSLS (Semi-log)	TSLS (Double-log)
Atlantic Beach			0.223***	0.217***
Carolina Beach			0.12*	0.05
Emerald Isle			0.310***	0.309***
Indian Beach / Pine Knoll Shores			0.174*	0.253**
Kure Beach			0.248***	0.242***
Nags Head			-0.321***	-0.286***
Wrightsville Beach			0.562***	0.607***
Nourish (=1 if ever nourished)	0.471***	0.452***		