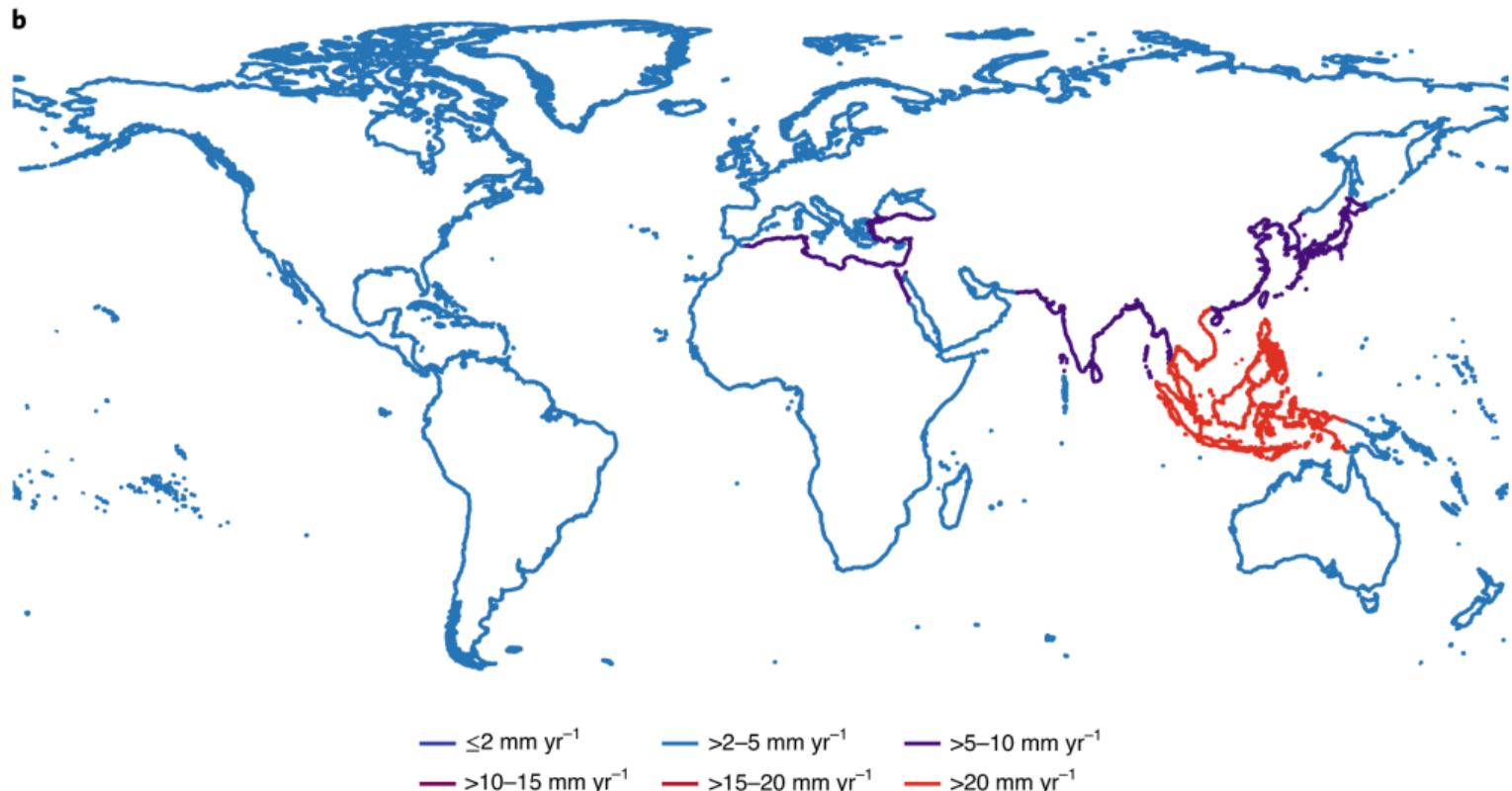


Sea Level Rise and Urban Adaptation in Jakarta

Allan Hsiao
Princeton University

May 9, 2023

Sea levels are rising globally (Nicholls et al. 2021)





Motivation

- **Sea level rise threatens 1B people by 2050** (IPCC 2019)
- Jakarta will be 35% below sea level by 2050 (Andreas et al. 2018)
 - World's second largest city at 31M (first by 2030)
 - Proposed sea wall at up to \$40B
- **How does government intervention complicate long-run adaptation?**

This paper

- **Dynamic spatial model** of coastal development and defense
 - Estimated with granular spatial data for Jakarta
- Long-run adaptation requires moving inland, but
 - ① Moral hazard from government intervention
 - ② Persistence from durable capital
- **Result:** limited adaptation without government commitment

Contributions

- **Adaptation frictions under endogenous government intervention**
 - Kydland & Prescott 1977, Desmet et al. 2021, Balboni 2021, Castro-Vicenzi 2022, Jia et al. 2022, Peltzman 1975, Kousky et al. 2006, Boustan et al. 2012, Annan & Schlenker 2015, Kousky et al. 2018, Baylis & Boomhower 2022, Fried 2022, Coate 1995, Mulder 2022, Wagner 2022
 - Rationalize: Kocornik-Mina et al. 2020, Hino & Burke 2021, Bakkenes & Barrage 2022
- **Dynamic spatial model of urban development**
 - Kalouptsidi 2014, Hopenhayn 1992, Ericson & Pakes 1995, Hotz & Miller 1993, Arcidiacono & Miller 2011, Scott 2013, Desmet et al. 2018, Caliendo et al. 2019, Kleinman et al. 2022
- **Sea level rise damages for Jakarta**
 - Budiyono et al. 2015, Takagi et al. 2016, Wijayanti et al. 2017, Andreas et al. 2018

Outline

- ① Theory
- ② Empirics
- ③ Counterfactuals

Theory

Coastal development and defense

① **Development** d at cost $c(d)$ for $c'' > 0$

② **Defense** g at cost $e(g)$ for $e'' > 0$

③ Residential value $r(d, g)$ for $r_{dg} > 0$

- g maximizes $W_g = r(d, g) - c(d) - e(g)$
- d maximizes $W_d = r(d, g) - c(d)$
- Interpretation
 - Current vs. future government
 - Local vs. national government
 - Coastal residents/developers vs. government

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Commitment (first best)

- ① Commitment $g^* > 0$
- ② Response $d^*(g^*) > 0$

$$\begin{aligned}[d^*] \quad r'(d) &= c'(d) \\ [g^*] \quad r'(g) &= e'(g)\end{aligned}$$

- But defense optimal ex post + lobbying ex post (rezoning, NFIP 2.0)

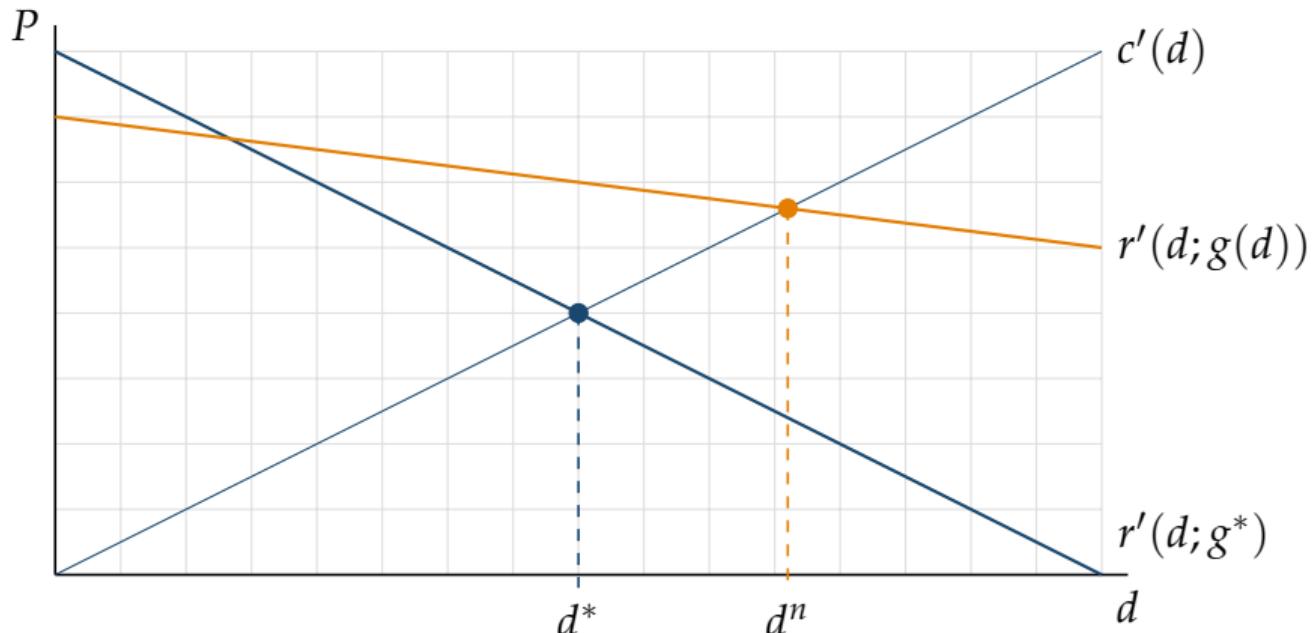
No commitment

- ① Development $d^n > d^*$
- ② Response $g^n(d^n) > g^*$

$$\begin{aligned}[d^n] \quad r'(d) + r'(g) g'(d) &= c'(d) \\ [g^n] \quad r'(g) &= e'(g)\end{aligned}$$

- Time inconsistency: static gain, dynamic cost ($g'(d) > 0$)
- Moral hazard: coastal lock-in, delayed adaptation ($g'(d)$ magnifier)

Over-development without commitment



Empirics

Empirical framework

$$W = r(d, g) - c(d) - e(g)$$

- $\tilde{r}(d, f(g))$: **spatial model** of residential demand
- $f(g)$: **hydrological model** of flood risk
- $c(d)$: **dynamic model** of developer supply
- $e(g)$: **engineering estimates**

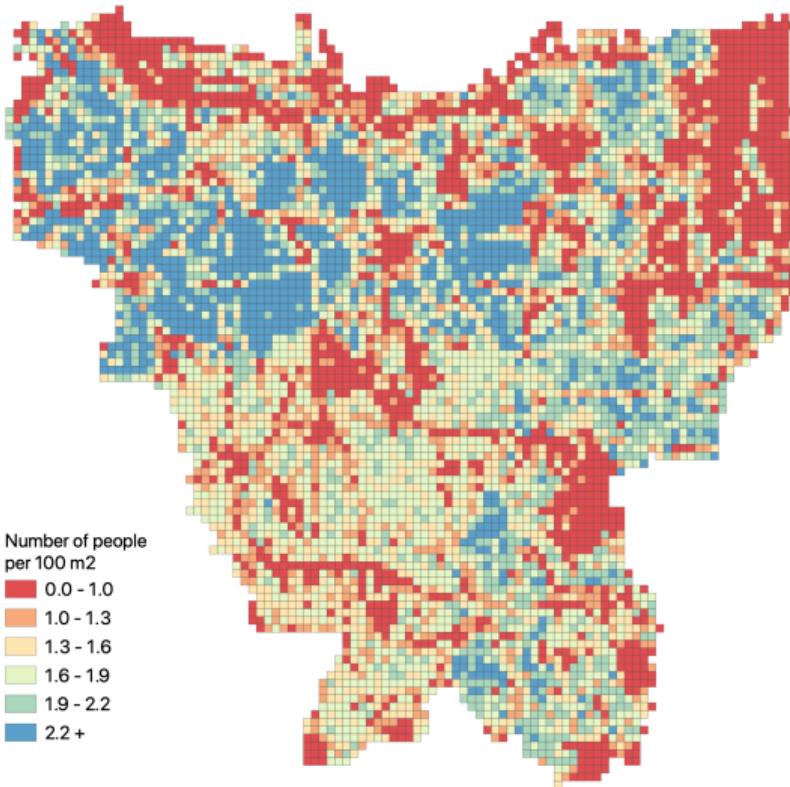
Demand from residents

$$U_{ijk} = \underbrace{\alpha r_k + \phi f_k + x_k \gamma + \varepsilon_k}_{\delta_k} + \tau m_{jk} + \epsilon_{ijk}$$

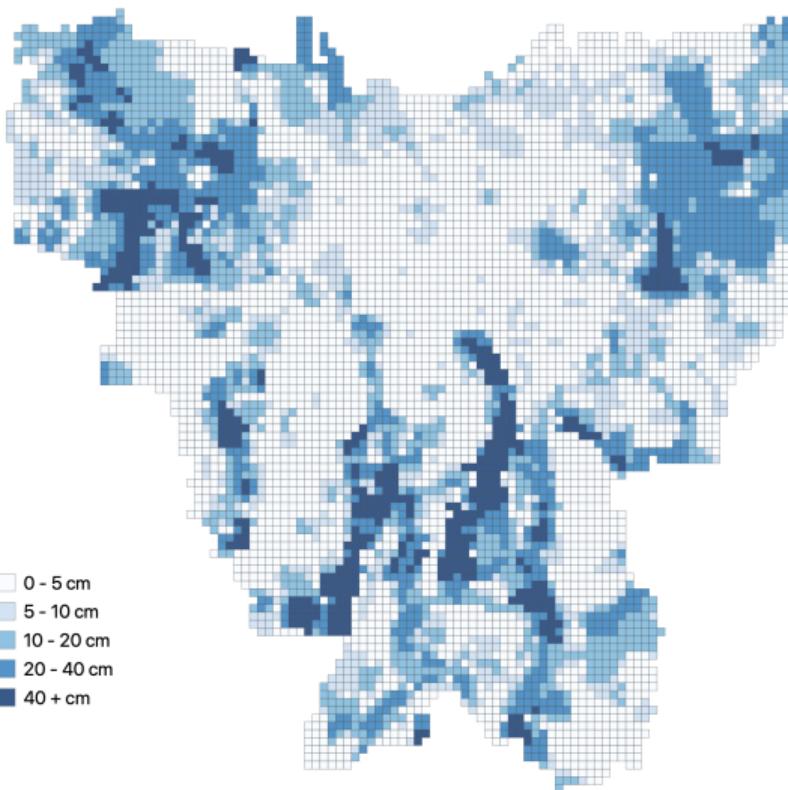
- **Spatial model** of residential choice (individual i , origin j , destination k)
 - Resident renters consider rents, flooding, amenities, distances, logit shocks
 - Moving inland abandons high-amenity places and incurs migration costs
- **Estimation** with 2020 population shares and instruments (BLP 1995)
 - Price endogeneity from correlation of rents and unobserved amenities
 - IV with ruggedness as supply shifter

Details

Population (global data)



Flooding (2013-2020, past → future)



Demand estimates

	IV		First stage	
	Estimate	SE	Estimate	SE
Rents	-0.032***	(0.004)		
Ruggedness			12.20***	(1.176)
Flooding	-0.490***	(0.097)	-15.53***	(2.485)
Residential amenities	0.110***	(0.018)	1.540***	(0.469)
District FE	x		x	
Observations	5,780		5,780	
F-statistic			108	

Supply from developers

$$V_{kt}(D, L) = r_{kt}(D) + \mathbb{E}[\max_{d \in \{0,1\}} \{v_{kt}^d(D, L) + \epsilon_{ikt}^d\}]$$

$$v_{kt}^1(D, L) = -c_{kt}(x, \varepsilon) + \beta \mathbb{E}[V_{kt+1}(D + 1, L - 1)]$$

$$v_{kt}^0(D, L) = \beta \mathbb{E}[V_{kt+1}(D, L)]$$

- **Dynamic model** of developer choice (individual i , location k , time t)
 - Developer landlords consider rents, costs, logit shocks (development D , land L)
 - Moving inland abandons high-rent places and incurs construction costs
- **Estimation:** data as continuation values (Kalouptsidi 2014)
 - Price endogeneity from correlation of rents and unobserved costs
 - IV with residential amenities as demand shifters

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Data as continuation values

$$V_{kt}(D, L) = \alpha P_{kt}^D D + \alpha P_{kt}^L L \quad (*)$$

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- Simple IV estimation (fast, transparent)
 - Need efficient real estate market ($P \rightarrow V$, frictions as ε)
 - Flexible expectations without finite dependence (P as market offer)

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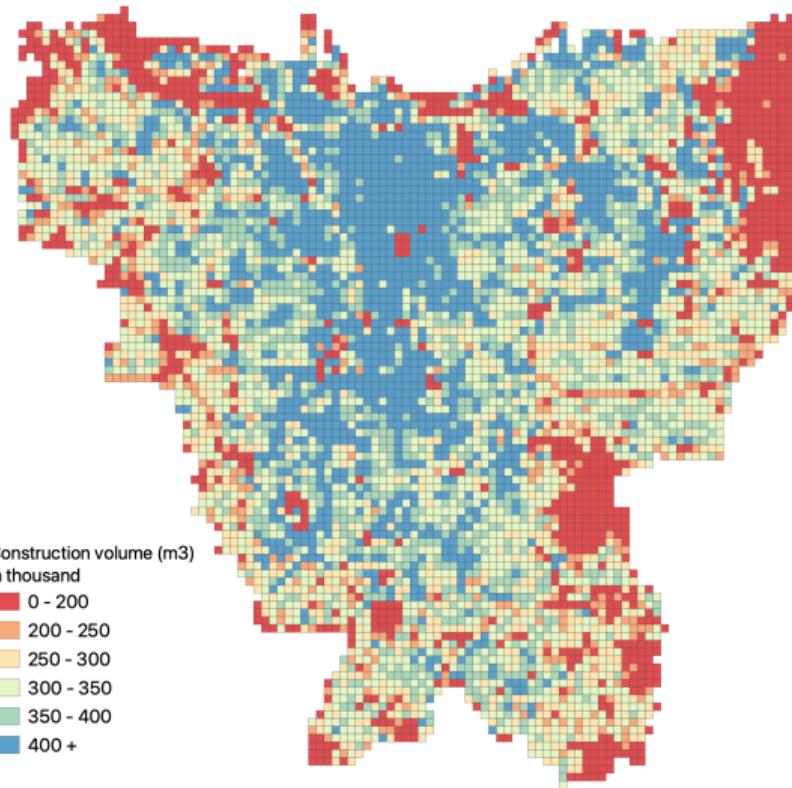
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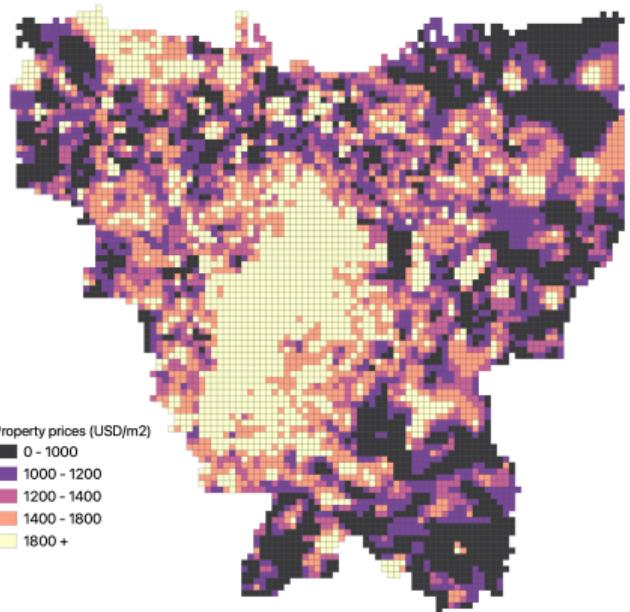
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Building construction (global data)

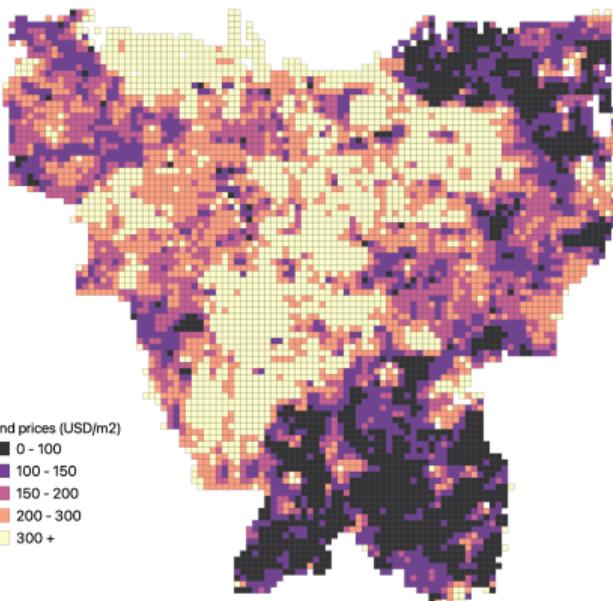


Real estate prices (urban data)

Property



Land



Supply estimates

	IV		First stage	
	Estimate	SE	Estimate	SE
Prices	0.171***	(0.041)		
Residential amenities			0.182***	(0.043)
Flooding	0.064	(0.044)	-0.842***	(0.216)
Ruggedness	-0.143***	(0.054)	1.268***	(0.103)
District FE	x		x	
Observations	5,780		5,780	
F-statistic			18.14	

Government

- Commitment and objective by assumption
- Hydrological model of flood risk
- Engineering estimates of costs
- Equilibrium rents

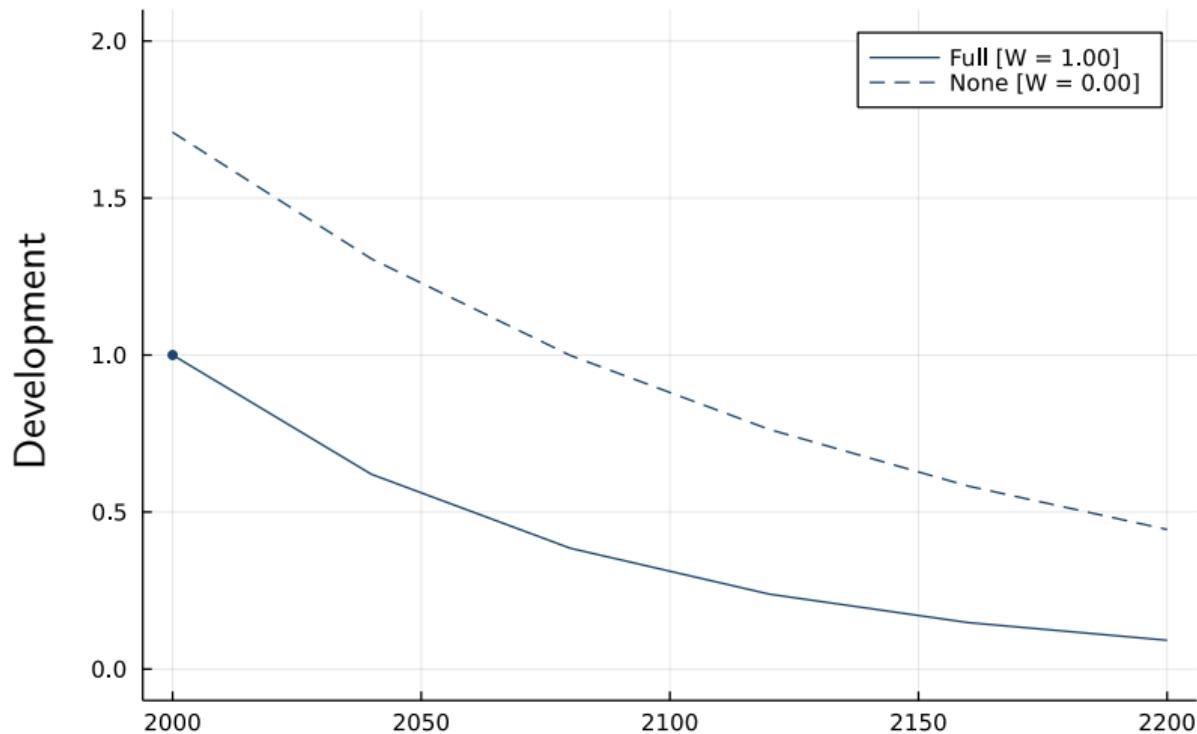
Counterfactuals

Model components

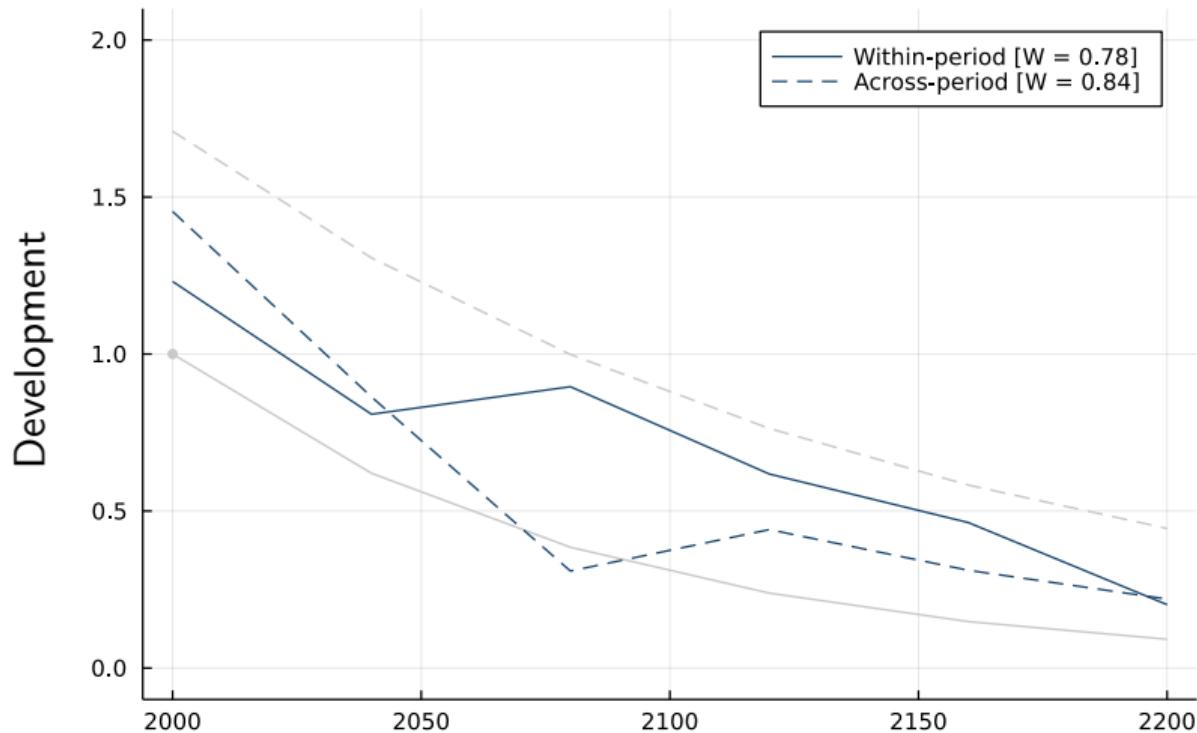
Defense g → flooding s by **hydrological** model
→ rents r by **demand** model
→ development d by **supply** model

- Need more assumptions to solve model
- **What is the potential magnitude of the moral hazard problem?**
 - Not: How much has moral hazard driven historical development?

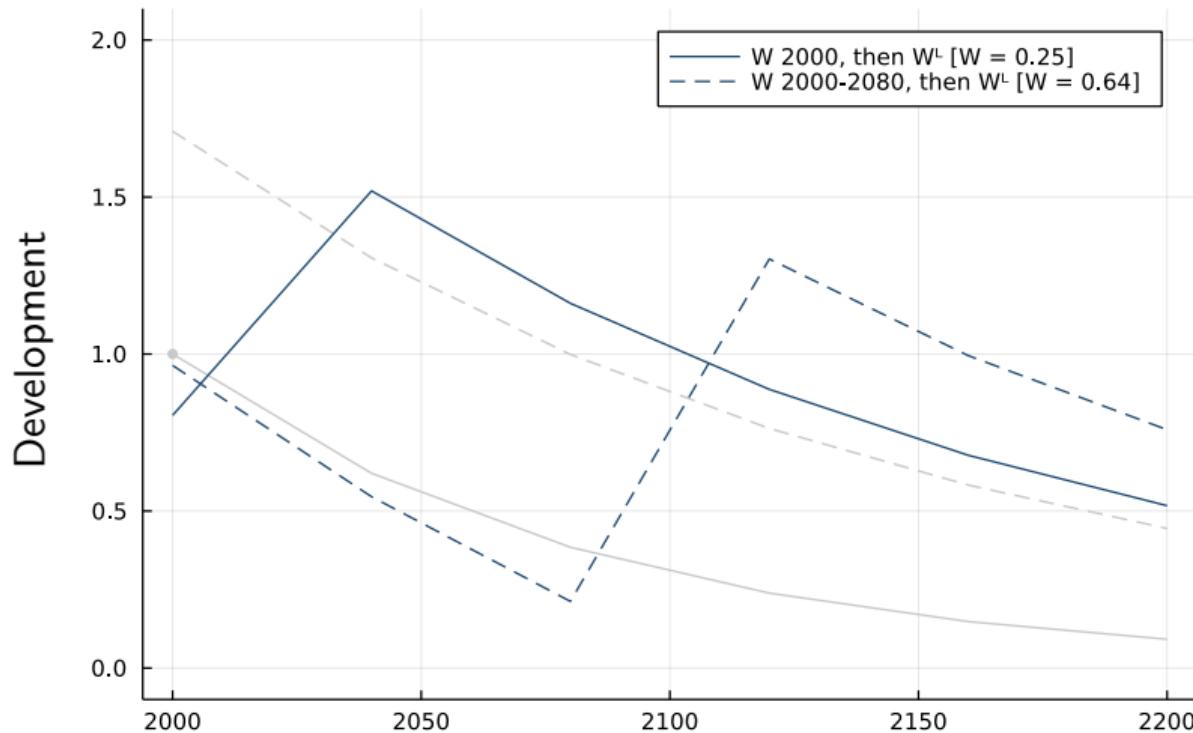
Full vs. no commitment



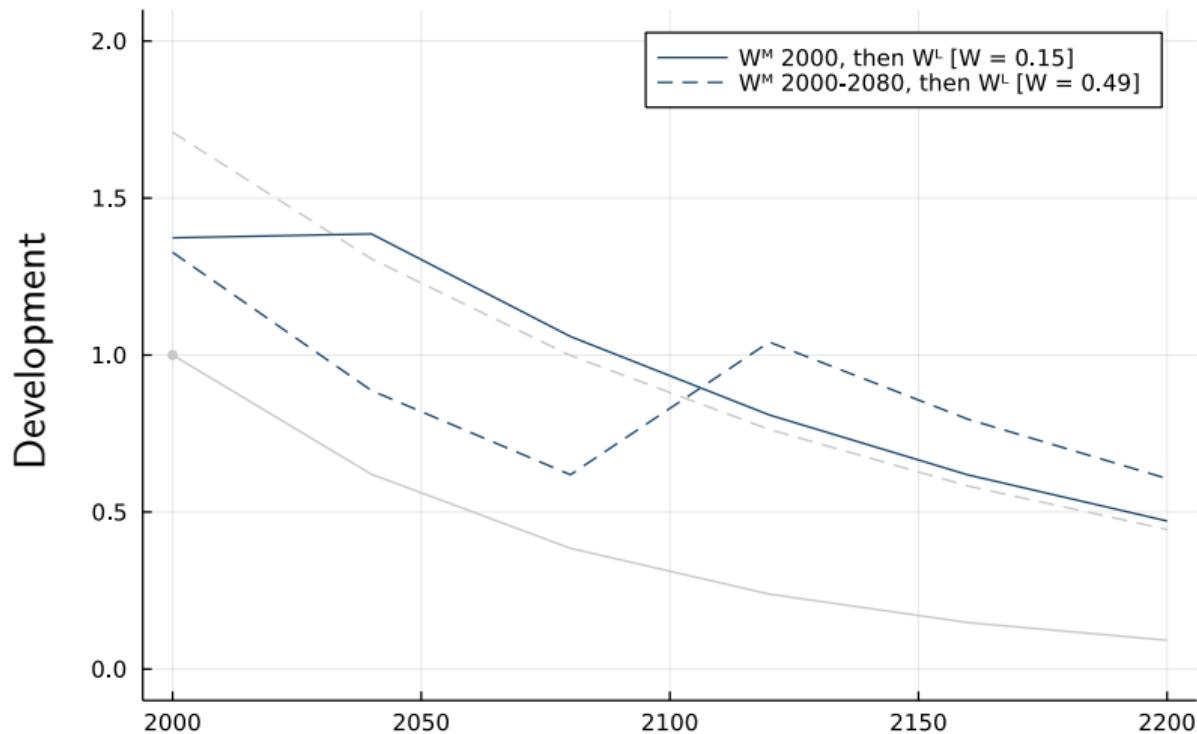
Within- vs. across-period commitment



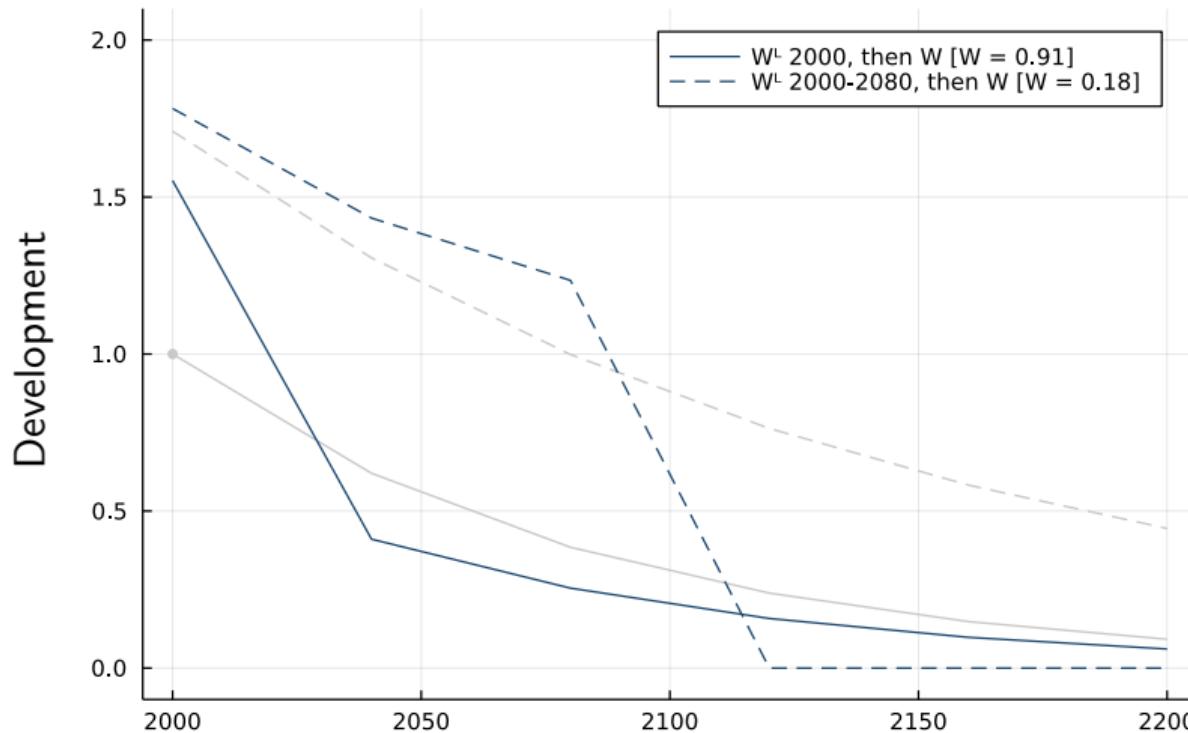
Limited commitment: forward-looking



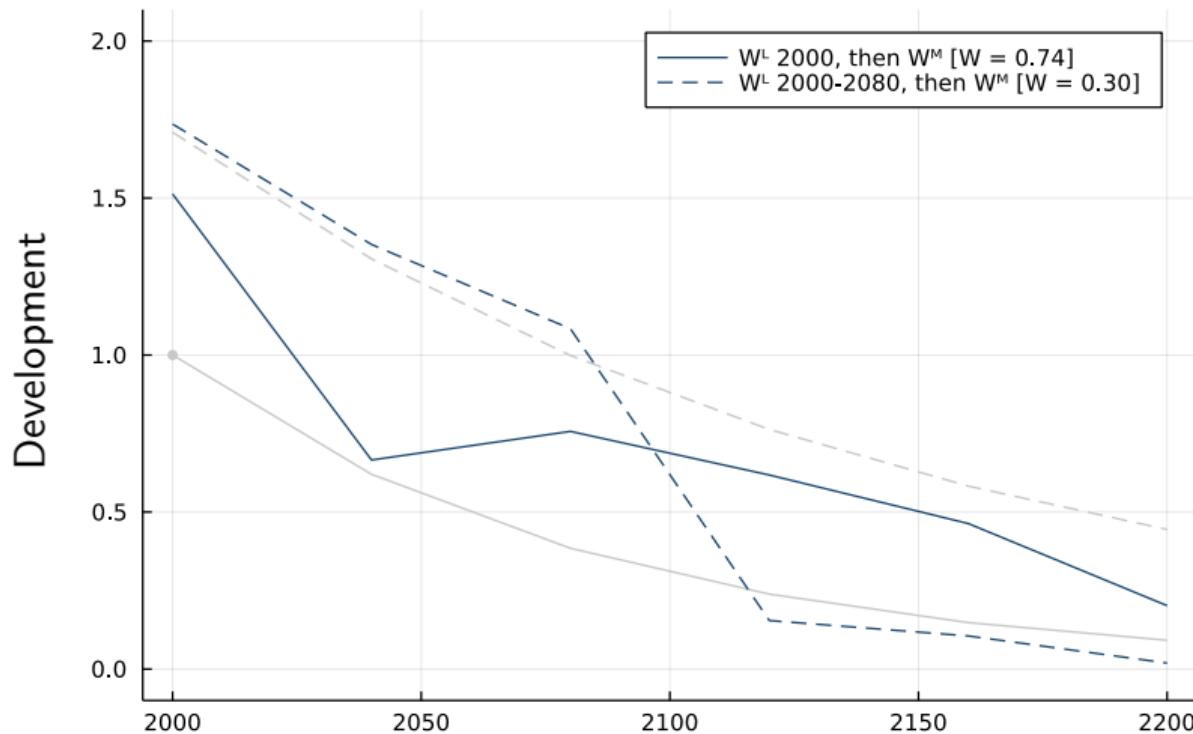
Limited commitment: political myopia



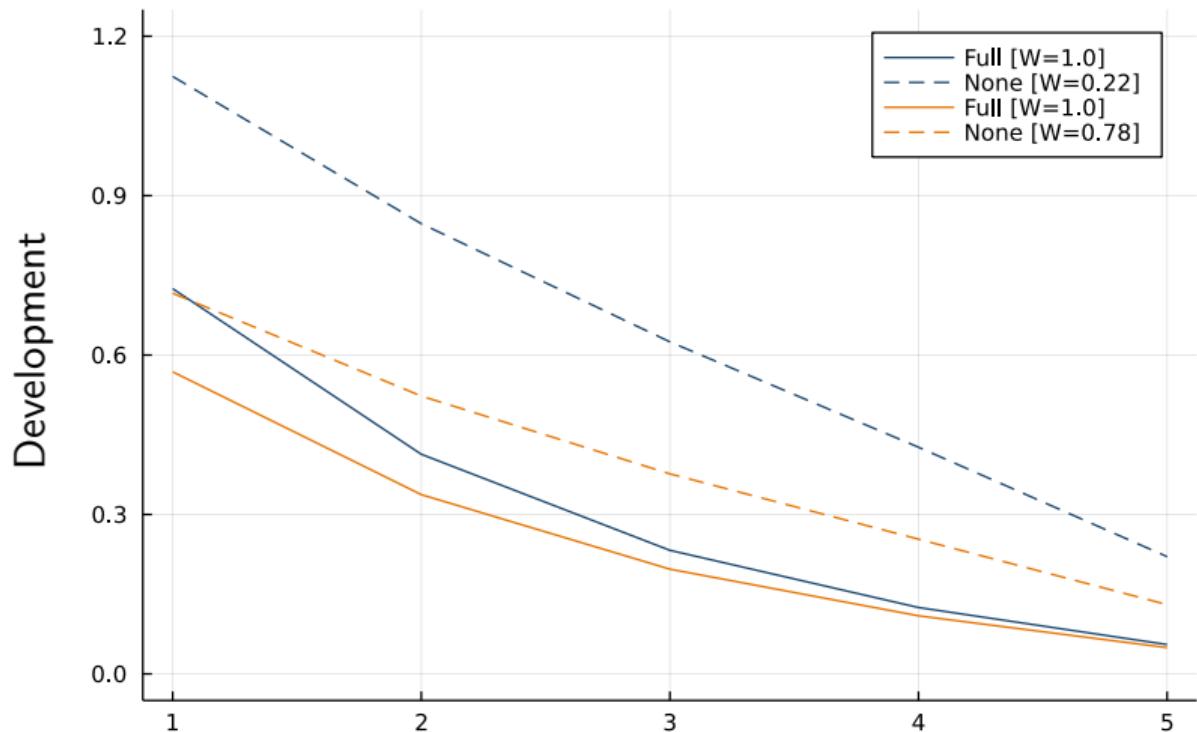
Limited non-commitment: forward-looking



Limited non-commitment: political myopia



Reducing coastal demand



Policy implications

① Political economy matters

- Politics hinder adaptation and exacerbate damages
- Consider political feasibility even if less efficient

② Long-term policy needed

- Short-term policy worsens lock-in and delays adaptation

③ Integrated policy with sea wall + reduced coastal demand

- Encourage vs. punish, indirect vs. direct
- Migration subsidies, inland investments, new capital
- Reduced land subsidence, imperfect coastal regulation

Extensions and robustness

- Political lobbying
 - Uncertain flooding
 - Endogenous amenities
 - Depreciating development
-
- Discount factor
 - Demand and supply elasticities
 - Horizon and timing

Conclusion

Summary

- **Moral hazard impedes adaptation** to climate change
- **Jakarta** foreshadows sea level rise that threatens 1B people by 2050

1	Miami	6	Mumbai
2	Guangzhou	7	Tianjin
3	New York City	8	Tokyo
4	Kolkata	9	Hong Kong
5	Shanghai	10	Bangkok

Hanson et al. (2011)



