

Sea Level Rise and Urban Adaptation in Jakarta

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March 11, 2024



Jakarta

- By 2050, 35% below sea level (Andreas et al. 2018)
 - Land subsidence + sea level rise
 - Proposed sea wall at up to \$40B
- **How does government intervention complicate adaptation?**

This paper

- **Coastal moral hazard** as defense bails out development
 - If government is time-inconsistent
 - Delays inland migration at high social cost
- **Dynamic spatial model** of development and defense
 - Estimated with granular data for Jakarta

Results

① Severe moral hazard

- Coastal persistence without commitment (5x in 2200)
- Rationalizes high land prices despite future flood risk

② Policy options

- Direct: partial commitment, partial regulation
- Indirect: moving capital, slowing land subsidence

Contributions

- **Adaptation frictions** under endogenous government action
 - Desmet et al. 2021, Barreca et al. 2016, Costinot et al. 2016
 - Kydland & Prescott 1977, Kousky et al. 2006, Boustan et al. 2012
- **Sea level rise damages and policies**
 - Kocornik-Mina et al. 2020, Balboni 2021, Castro-Vincenzi 2022, Fried 2022, Patel 2023
- **Dynamic spatial model** of urban development
 - Kalouptsidi 2014, Hotz & Miller 1993, Arcidiacono & Miller 2011, Murphy 2018
 - Desmet et al. 2018, Caliendo et al. 2019, Kleinman et al. 2023, Bilal & Rossi-Hansberg 2023

Outline

① Theory

② Empirics

③ Policy

Theory

Fundamental trade-offs

- **Spatial:** adapt in-place at coast or migrate inland
- **Dynamic:** incur costs today or damages tomorrow
- **Moral hazard** introduces a market failure
 - Even with one location, one period

Coastal development and defense

- **Development** D at cost $C(D)$ (agent)
- **Defense** G at cost $E(G)$ (principal)
- Residential value $R(D, G)$ for $R_{DG} > 0$

$$\max_D \Pi = \max_D \{R(D, G) - C(D)\}$$

$$\max_G W = \max_G \{R(D, G) - C(D) - E(G)\}$$

- **Moral hazard** via time inconsistency + uninternalized cost

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Agent and principal

- ① “Developers” vs. government
- ② Local vs. national government
- ③ Current vs. future government

First best with commitment

- ① Defense G
- ② Development $D(G)$

$$[\Pi_D] \quad R_D = C_D$$

$$[W_G] \quad R_G = E_G$$

- Same as social planner, who chooses (D, G) directly

Over-development without commitment

- ① Development D
- ② Defense $G(D)$

$$\begin{aligned} [\Pi_D] \quad R_D = C_D &\rightarrow \text{high } G, \text{ high } D \\ [W_G] \quad R_G = E_G &\rightarrow \text{high } D, \text{ high } G \end{aligned}$$

- Weak coordination on high (D, G) , given multiplicity ($R_{DG} > 0$)
 - If G unconstrained via domestic or foreign ability

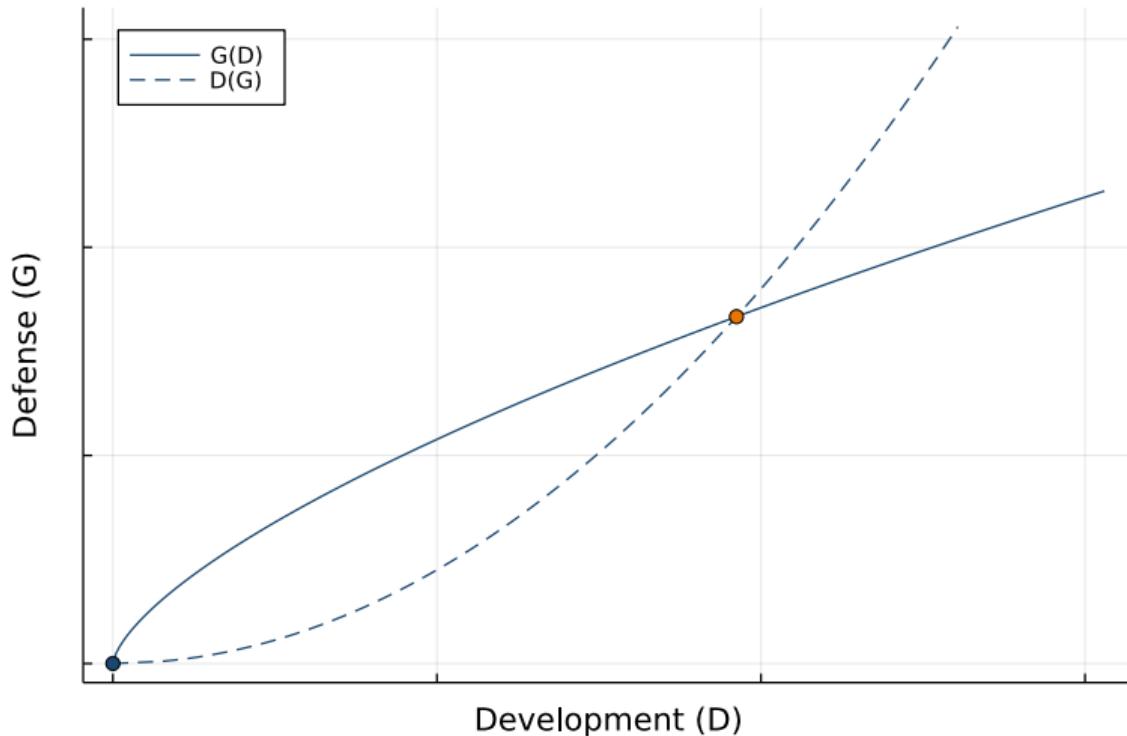
Over-development without commitment

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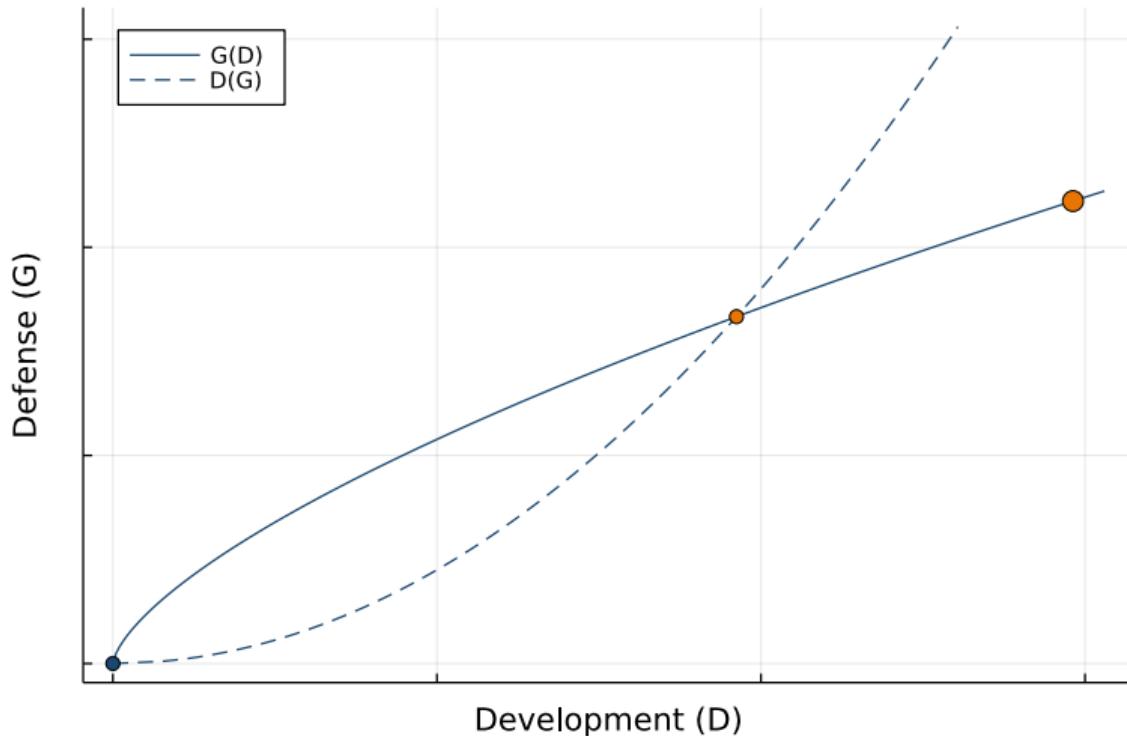
$$\begin{aligned} [\Pi_D] \quad R_D + R_G G_D &= C_D \\ [W_G] \quad R_G &= E_G \end{aligned}$$

- Strong coordination on high $(D, G(D))$, given $G_D > 0$ ($R_{DG} > 0$)
 - If G continuous via height, quality, maintenance, or expectation

Example



Example



Commitment is challenging

- Ex post, principal wants to defend (plus lobbying)
 - Time inconsistency magnifies moral hazard
 - Current government moves before future government
- Coastal defense crowds out inland migration (lock-in)
 - If inland migration is possible

Alternative solutions

- Regulation with tax or quota
 - But still need commitment to costly enforcement
- Local financing rules
 - But even locally, inland taxes subsidize coast
- Mandated insurance
 - But local risk is aggregate, so usually subsidized in practice
- Coasian bargaining
 - But large transfers are challenging and still bad for principal

JAKARTA GIANT SEA WALL



PIK 2 terlibat dalam Perencanaan JAKARTA GIANT SEA WALL
Proyek Pemerintah dalam pengembangan daerah pesisir

Profil Proyek NCICD

- Peletakan batu pertama: Oktober 2014
- Target rampung: 2022
- Tahapan pembangunan: 3 (Tahap A, B, dan C)
- Pelaksana: Kementerian PU dan Pemprov DKI
- Biaya investasi: Rp300 triliun
- Reklamasi lahan: 1.000 hektare

Sumber: Kementerian PU-Pera, berbagai sumber, diolah



Target Konstruksi

Tahap A

Konstruksi: 2014-2017
Flood safety: 2030

Tahap B

Konstruksi: 2018-2022
Flood Safety: 2030

Tahap C

Konstruksi: 2022

Empirics

Framework

$$R(D, G), \quad C(D), \quad E(G)$$

- **Development:** spatial demand, dynamic supply
- **Defense:** hydrological model, engineering costs
- **Moral hazard** from model, not data
 - *Potential* impact on adaptation
 - But can rationalize price data

Spatial demand

$$u_{ijk} = \alpha r_k + \phi f_k + x_k \gamma + \varepsilon_k + \tau m_{jk} + \epsilon_{ijk}$$

- Renters i , origins j , destinations k
- **Goal:** flood disutility ϕ
 - Moral hazard increasing in flood elasticity
 - Moving inland abandons amenities, incurs migration costs
 - No dynamics, agglomeration, uncertainty
- **Estimation:** linear IV with 2015 population data
 - Rent endogeneity from unobserved amenities
 - Ruggedness as supply shifter

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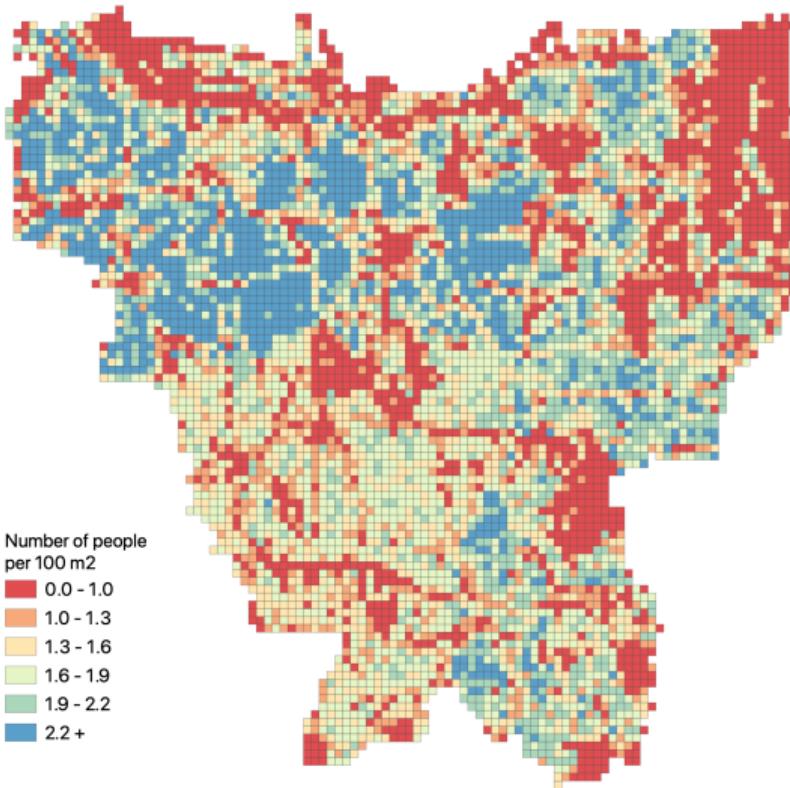
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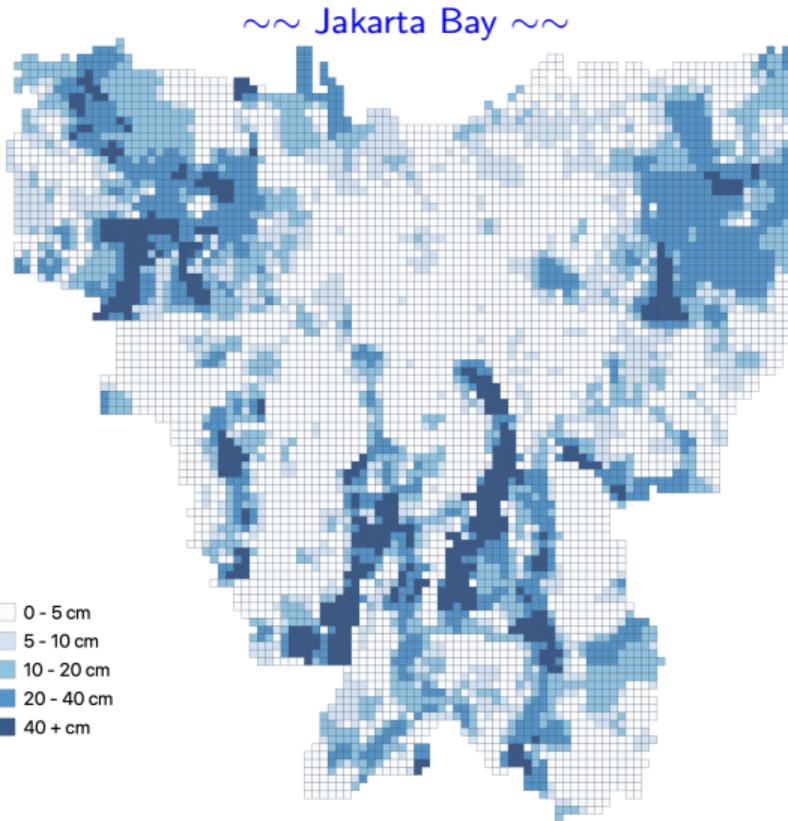
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Population (global data)



Flooding (2013-2020, past → future)



Demand estimates (imply \$0.3B flood damages)

	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	

Dynamic supply

$$c_{kt} \quad \text{vs.} \quad \alpha(r_{kt} + \beta r_{kt+1} + \beta^2 r_{kt+2} + \dots)$$

- Landowners i , locations k , time t , state $D_{ikt} \in \{0, 1\}$
- **Goal:** forward-looking rent utility α
 - Moral hazard increasing in rent elasticity ($\alpha^s \neq \alpha^d$)
 - Moving inland incurs construction costs
 - No market power, agglomeration, quality
- **Estimation** will reduce to linear IV

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Small, homogeneous landowners

$$w_t = \{r_{kt}, c_{kt}, P_{kt}^1, P_{kt}^0\}_k$$

- Take aggregate state as given: rents, costs, and property prices
 - 14k developers in Jakarta, 1k with \$3.5M annual revenue
 - Constant returns to scale
- “Strong coordination” by local government
 - Developers react competitively
 - Market power lessens development
 - But also facilitates coordination

Choices

- **Developed plots:** sell or hold

$$V_{kt}^1 = \max\{\alpha P_{kt}^1, \underbrace{\alpha r_{kt} + \beta \mathbb{E}[V_{kt+1}^1]}_{\tilde{V}_{kt}^1}\}$$

- **Empty plots:** sell, develop, or hold

$$V_{kt}^0 = \max\{\alpha P_{kt}^0, \underbrace{\mathbb{E}[\max\{\beta V_{kt+1}^1 - c_{kt} + \varepsilon_{ikt}^1, \beta V_{kt+1}^0 + \varepsilon_{ikt}^0\}}_{\tilde{V}_{kt}^0}\}$$

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Equilibrium prices

- Rents clear rental markets: $D_{kt}^{\text{res}}(r_t; f_t) = D_{kt}^{\text{dev}}(r_{kt}, r_{kt+1}, \dots)$
- REITs arbitrage property prices
 - Can buy assets and collect rents
 - Observed prices capture continuation values (Kalouptsidi 2014)

$$\begin{aligned} V_{kt}^1 &= \max\{\alpha P_{kt}^1, \tilde{V}_{kt}^1\} & V_{kt}^1 &= \alpha P_{kt}^1 \\ V_{kt}^0 &= \max\{\alpha P_{kt}^0, \tilde{V}_{kt}^0\} & V_{kt}^0 &= \alpha P_{kt}^0 \end{aligned}$$

$$P_{kt}^1 = \sum_{t'=0}^{\infty} \beta^{t'} \mathbb{E}[r_{kt+t'}], \quad P_{kt}^0 = \frac{1}{\alpha} \log \left(\exp(\beta V_{kt+1}^1 - c_{kt}) + \exp(\beta V_{kt+1}^0) \right)$$

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Logit inversion

$$\tilde{V}_{kt}^0 = \mathbb{E}[\max\{\beta V_{kt+1}^1 - c_{kt} + \varepsilon_{ikt}^1, \beta V_{kt+1}^0 + \varepsilon_{ikt}^0\}]$$

$$\begin{aligned}\ln \pi_{kt}^1 - \ln \pi_{kt}^0 &= \beta \mathbb{E}[V_{kt+1}^1 - V_{kt+1}^0] - c_{kt} \\ &= \alpha \beta \mathbb{E}[P_{kt+1}^1 - P_{kt+1}^0] - c_{kt} \\ &= \alpha \beta (P_{kt}^1 - P_{kt}^0) - c_{kt}\end{aligned}$$

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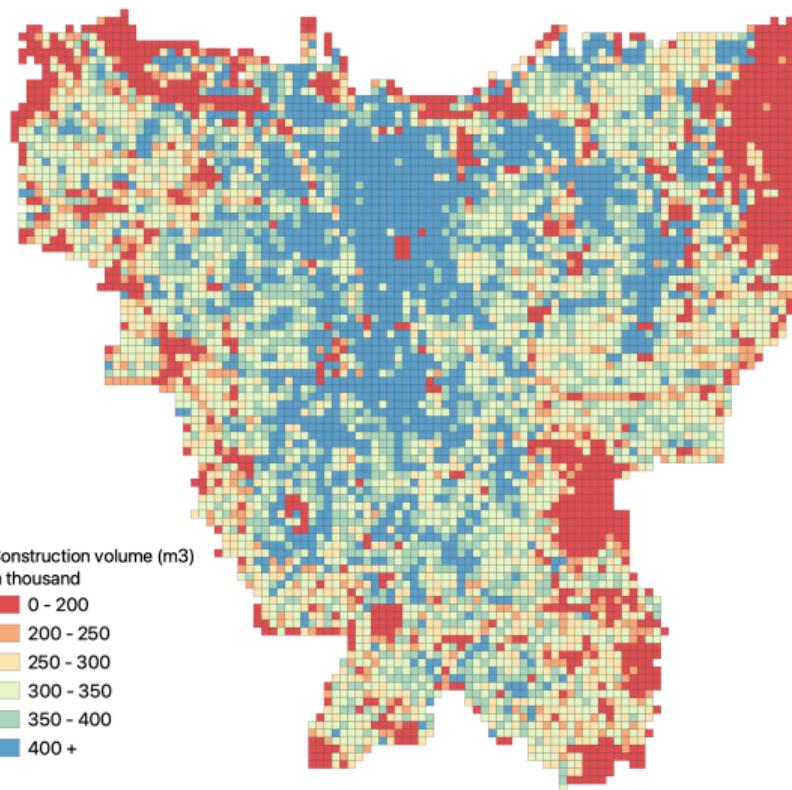
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Estimation

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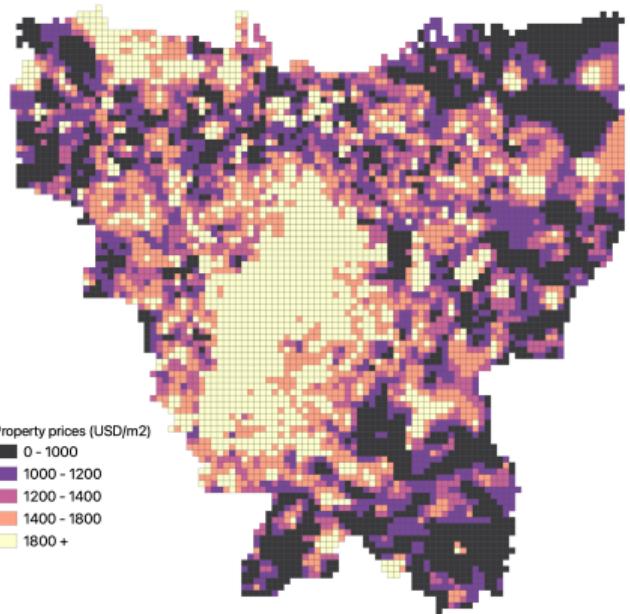
- **Estimation:** linear IV with 2015 construction data
 - Rent endogeneity from unobserved costs
 - Residential amenities as demand shifter
- Policy-invariant with respect to commitment
 - Market expectations capitalize into prices flexibly
 - Developers respond to prices as if statically
 - Can invert to infer commitment
- Alternatives: full-solution, two-step, Euler CCP

Building construction (global data)

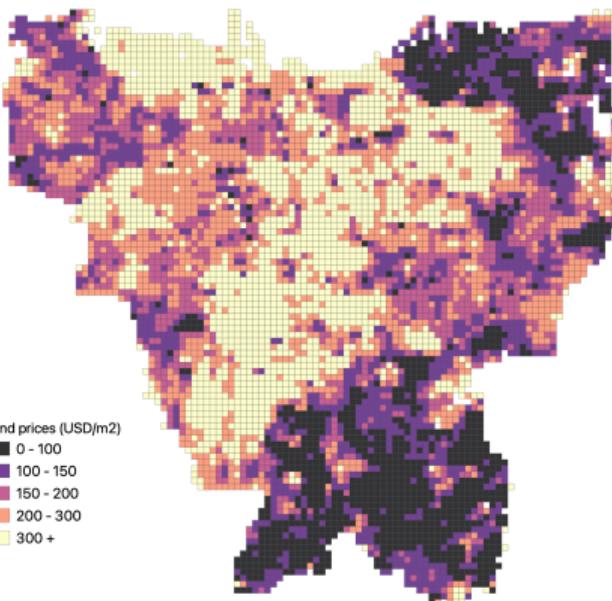


Real estate prices (urban data)

Property



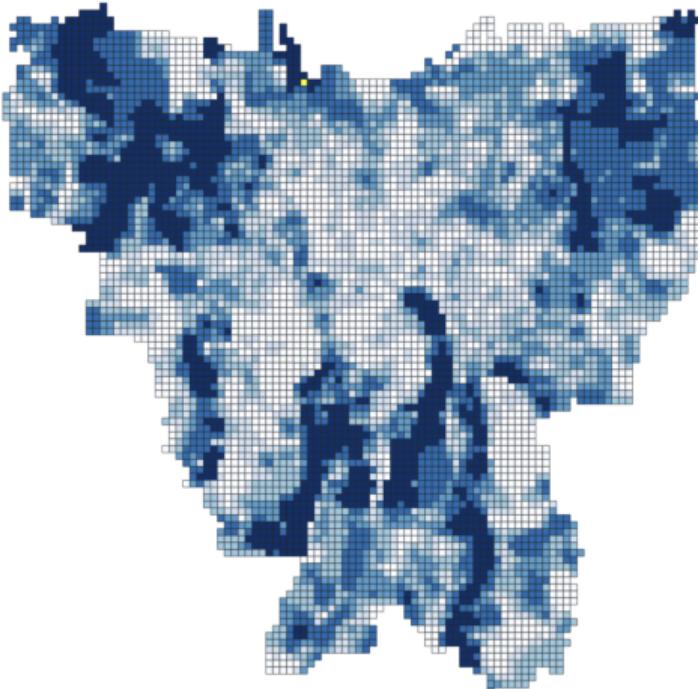
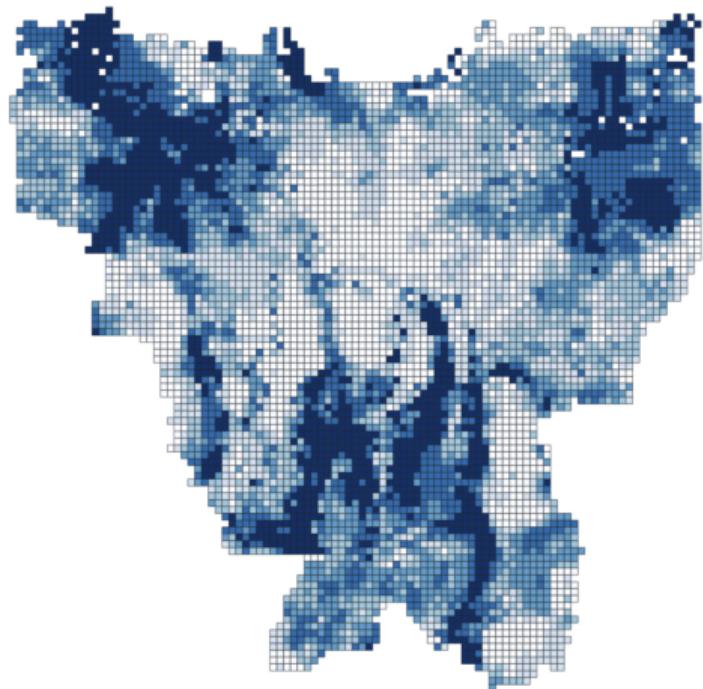
Land



Supply estimates

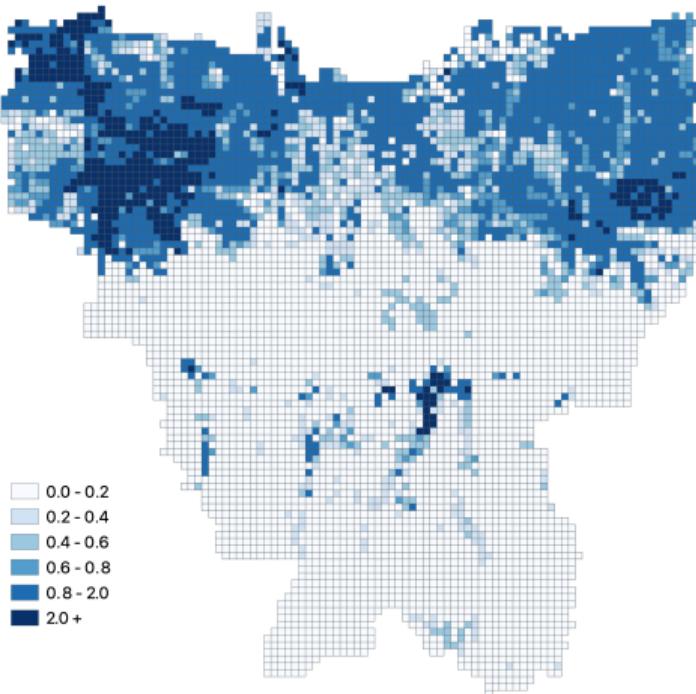
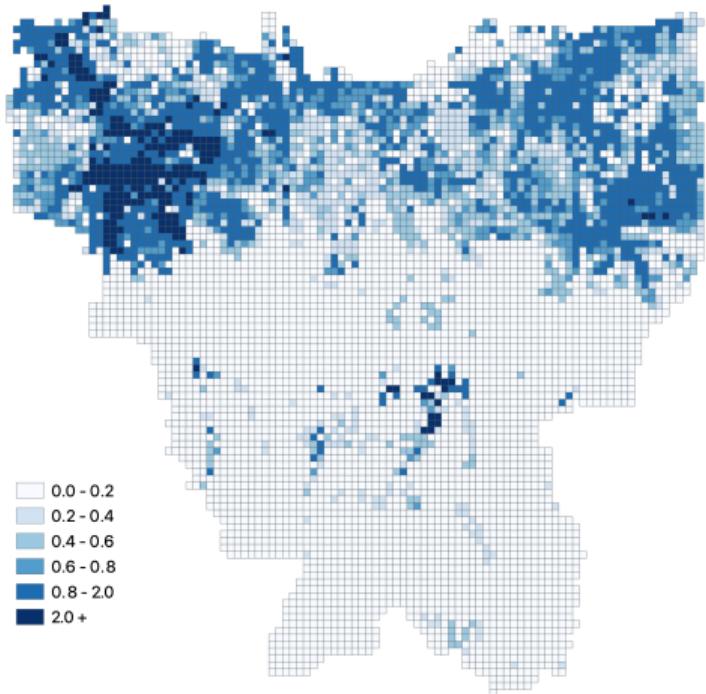
	IV		First stage	
	Estimate	SE	Estimate	SE
Prices	0.171***	(0.041)		
Residential amenities			0.182***	(0.043)
Flooding	0.064	(0.044)	-0.842***	(0.216)
Ruggedness	-0.143***	(0.054)	1.268***	(0.103)
District FE	x		x	
Observations	5,780		5,780	
F-statistic			18.14	

Flooding (under SLR + subsidence)



Predicted vs. observed monthly flooding (2013-2020)

Flooding (under SLR + subsidence)



3m vs. 5m sea wall

Sea wall costs

$$E(G) = \underbrace{10.67 * G * 60}_{\text{onshore}} + \underbrace{10.78 * (2G + 16) * 32}_{\text{offshore}} \quad (\$1M)$$

- \$9.5B for 3m wall, \$12B for 5m wall
 - Matches official estimates from 2014 and 2020
 - Simple linear model (Lenk et al. 2017)

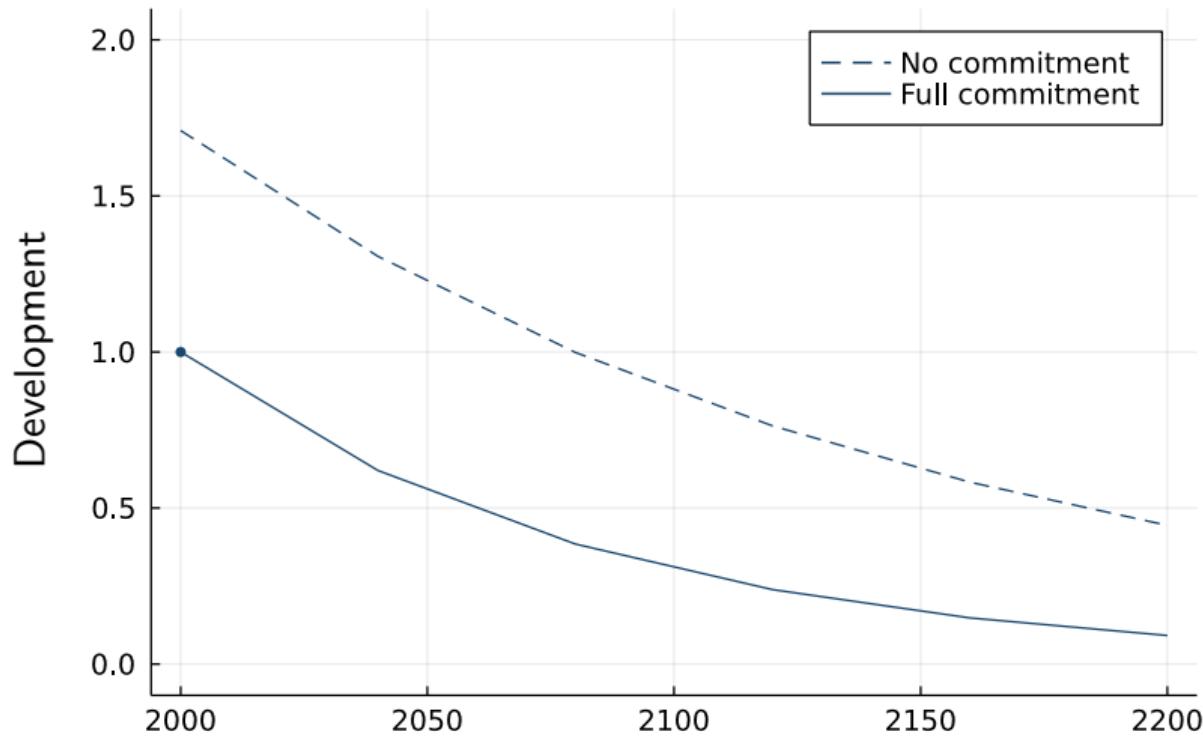
Counterfactuals

Solving the model

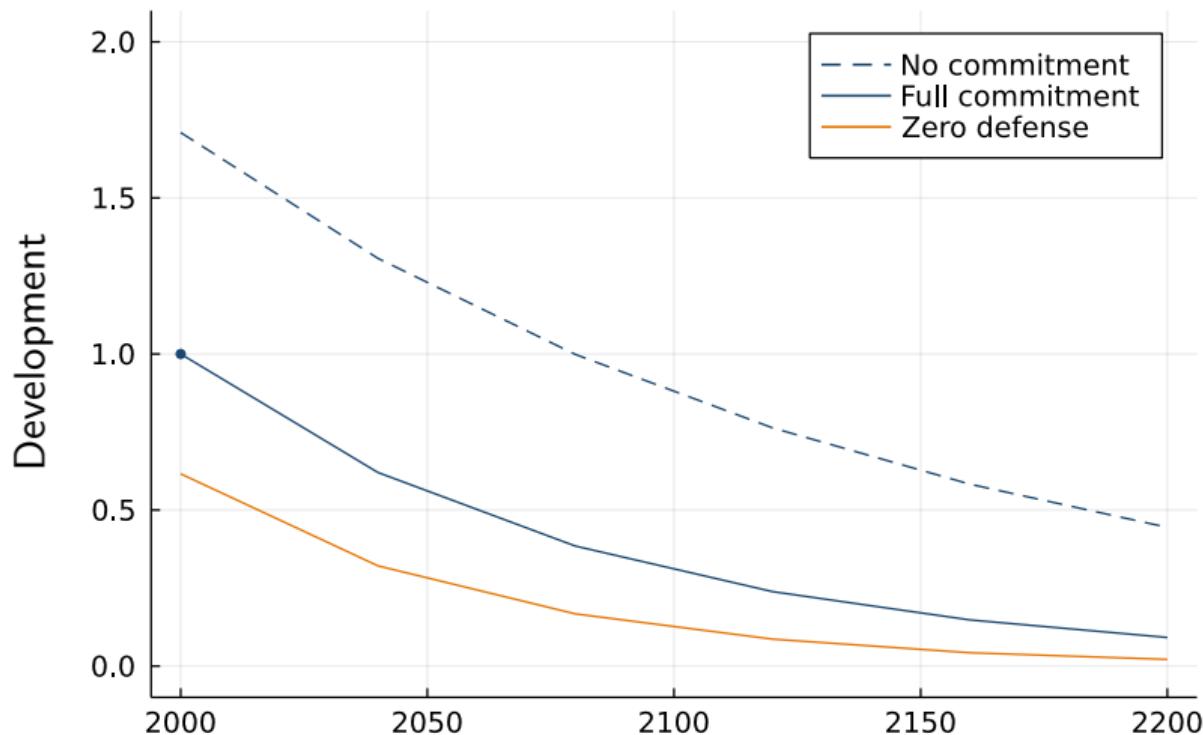
$$D^*(G) = \arg \max \Pi(D; G)$$
$$[G^*(D) = \arg \max W(G; D)]$$

- Solving across locations and periods
 - In spatial equilibrium, by backward induction
 - Need expectational assumptions
- Sea wall construction every 40 years
 - Typical lifespan of 30 to 50 years

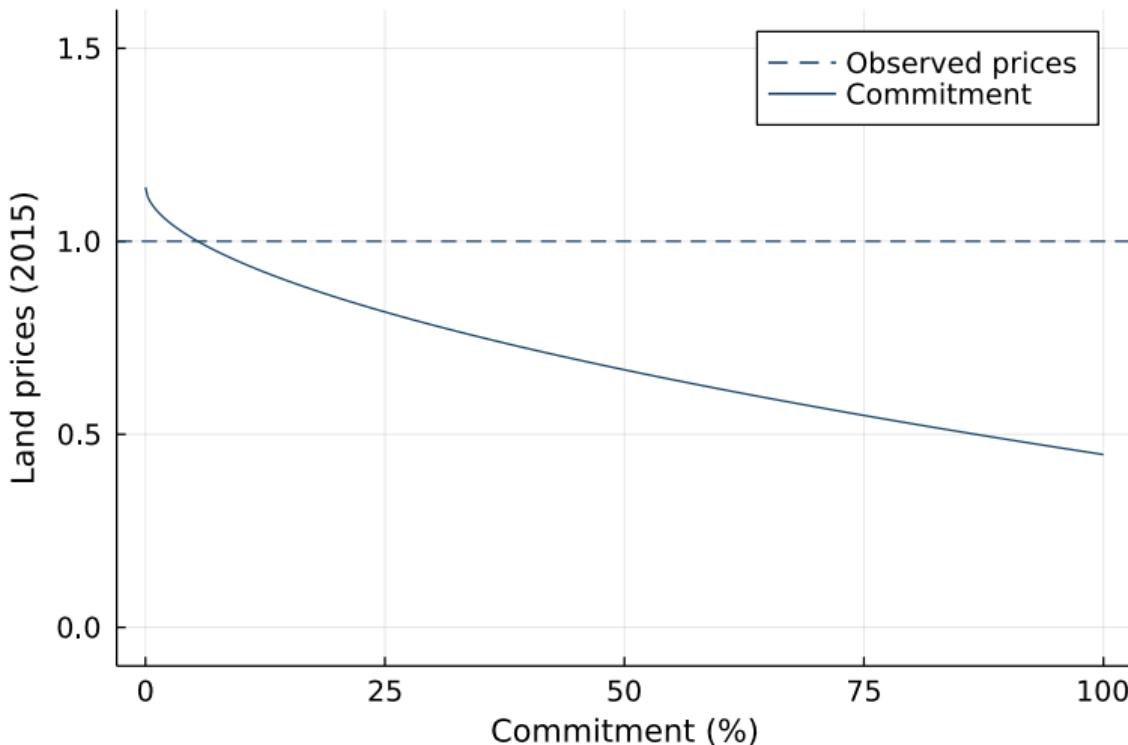
Moral hazard delays adaptation



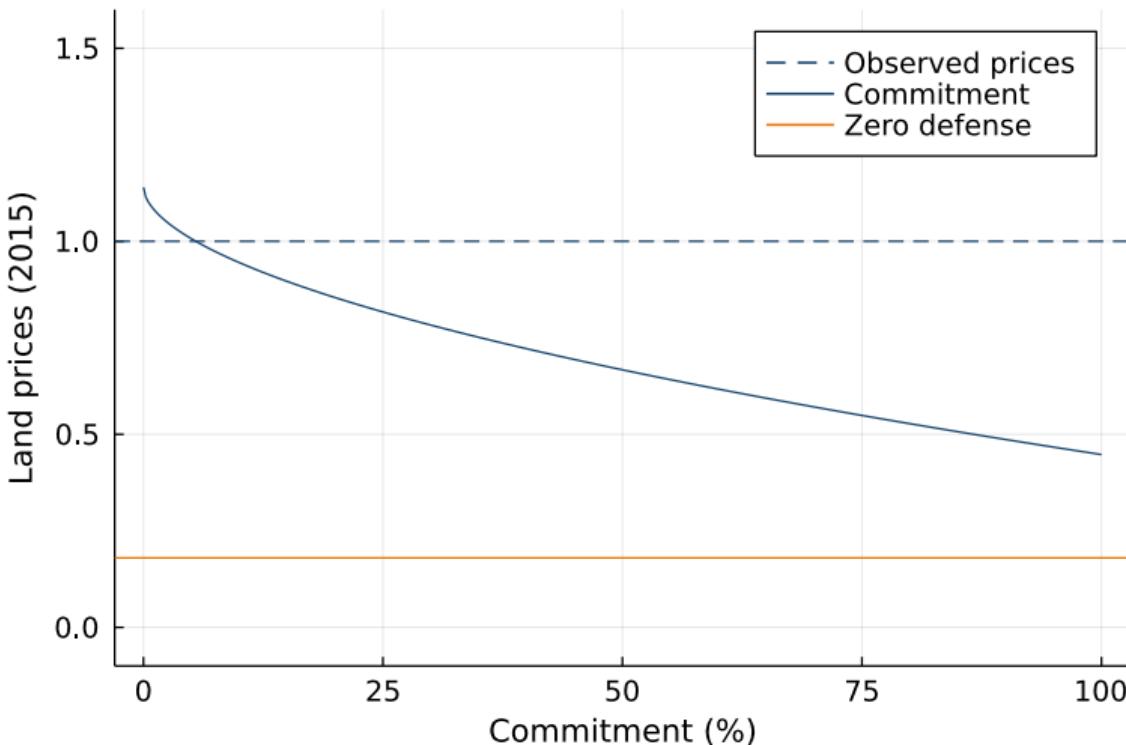
Moral hazard delays adaptation (55% loss)



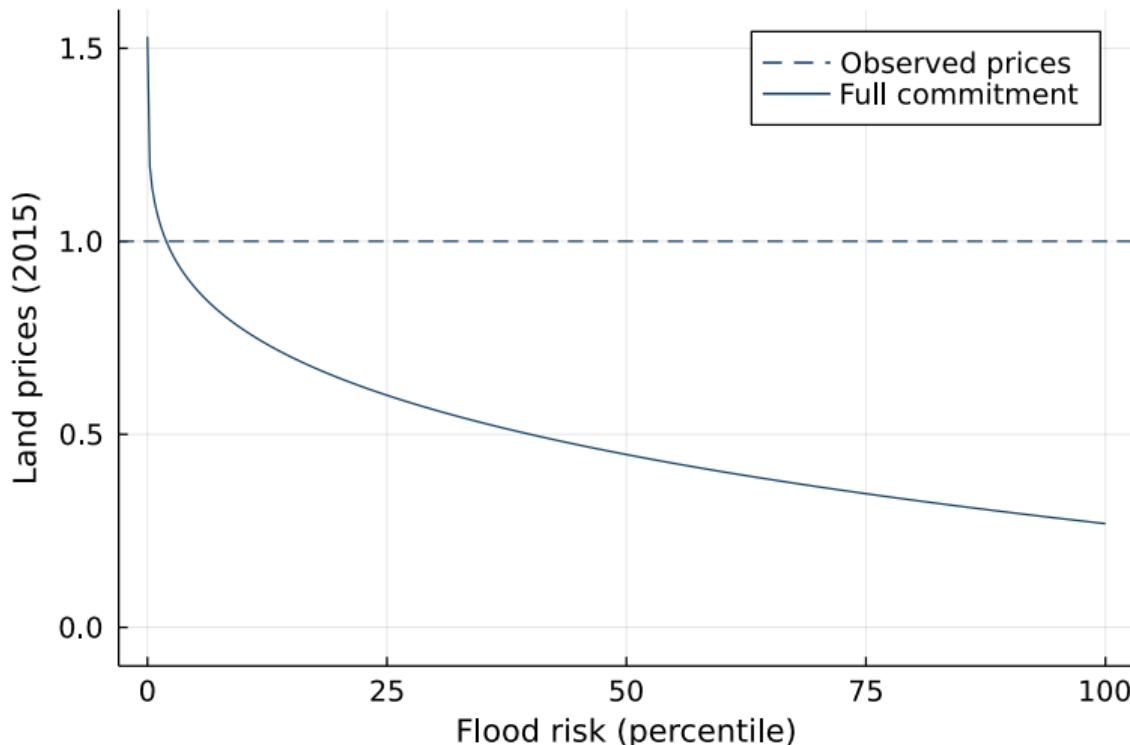
Moral hazard can rationalize observed prices



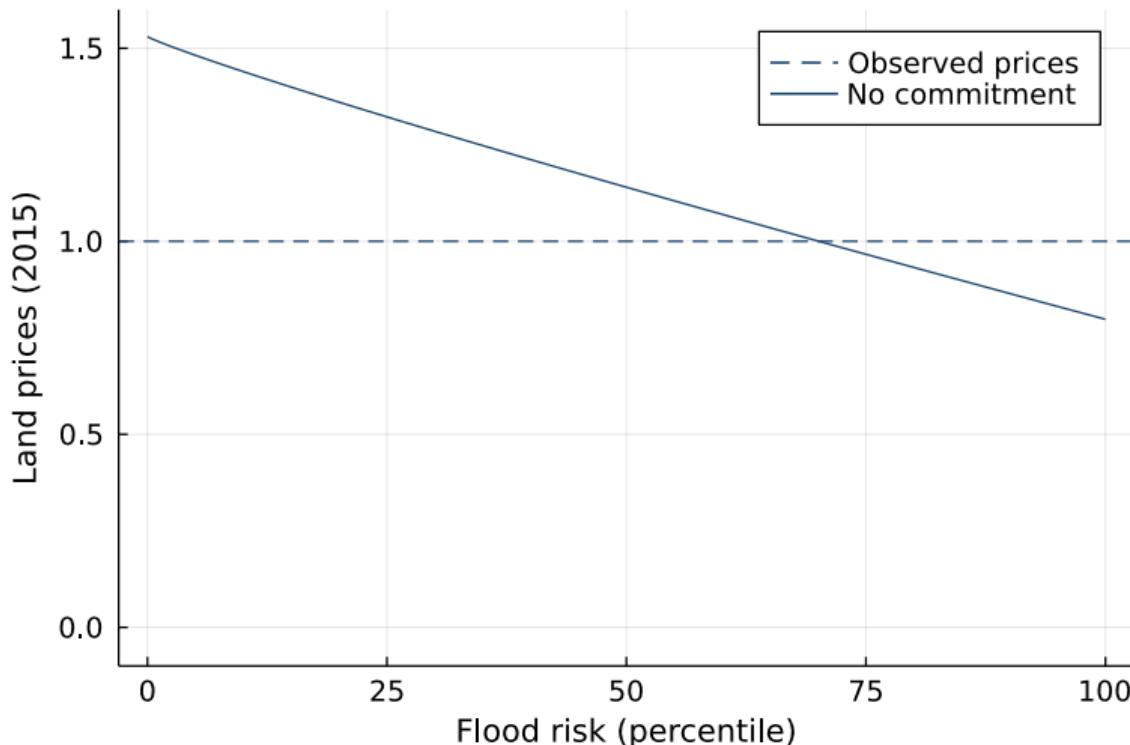
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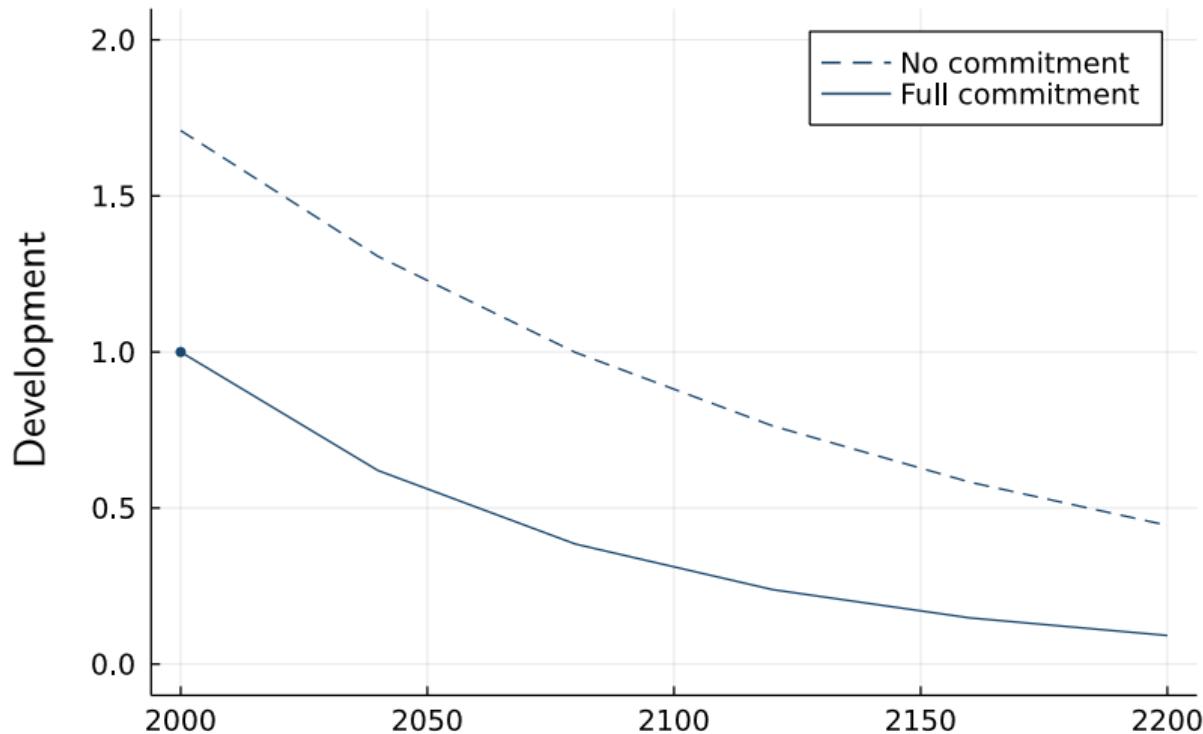
Flood risk cannot rationalize observed prices



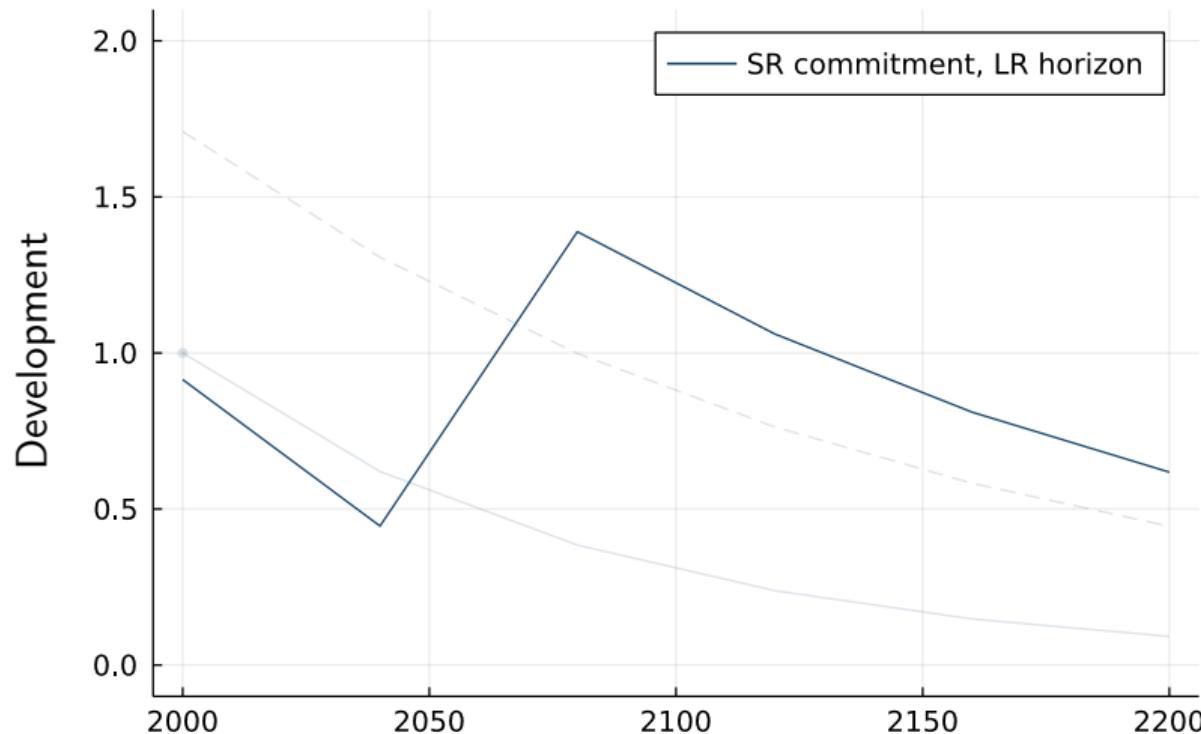
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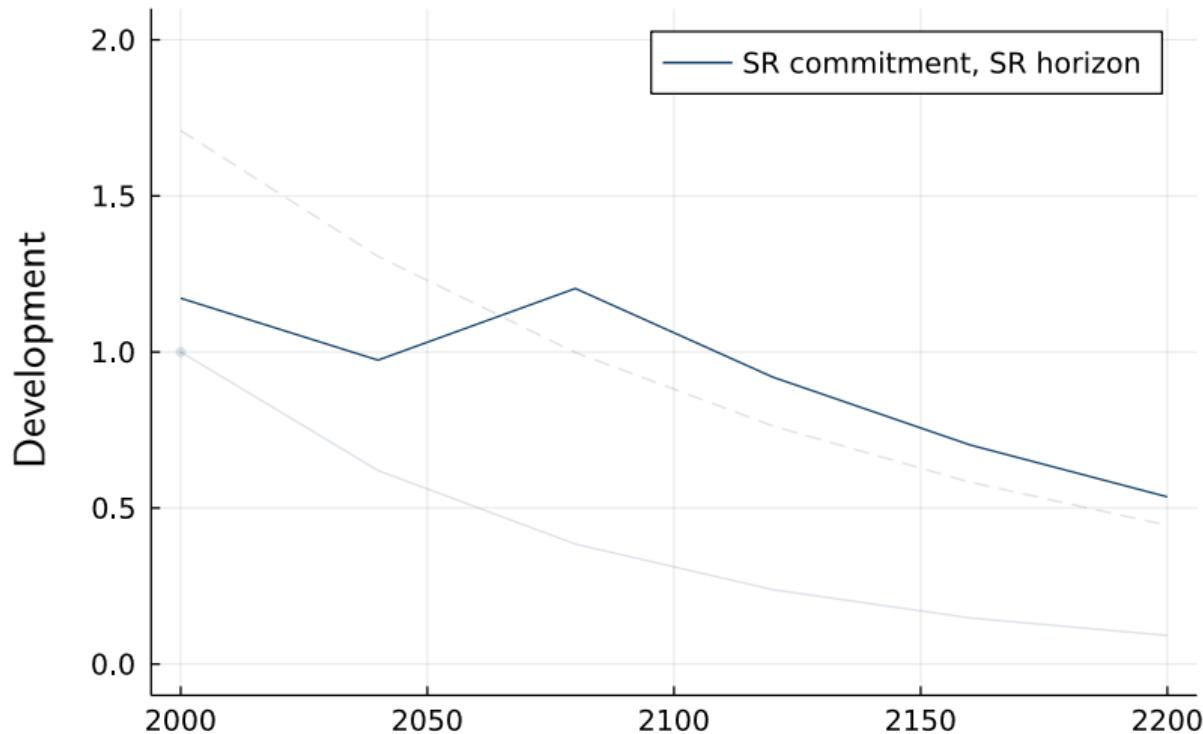
Partial commitment helps, subject to politics (53% vs. 63% loss)



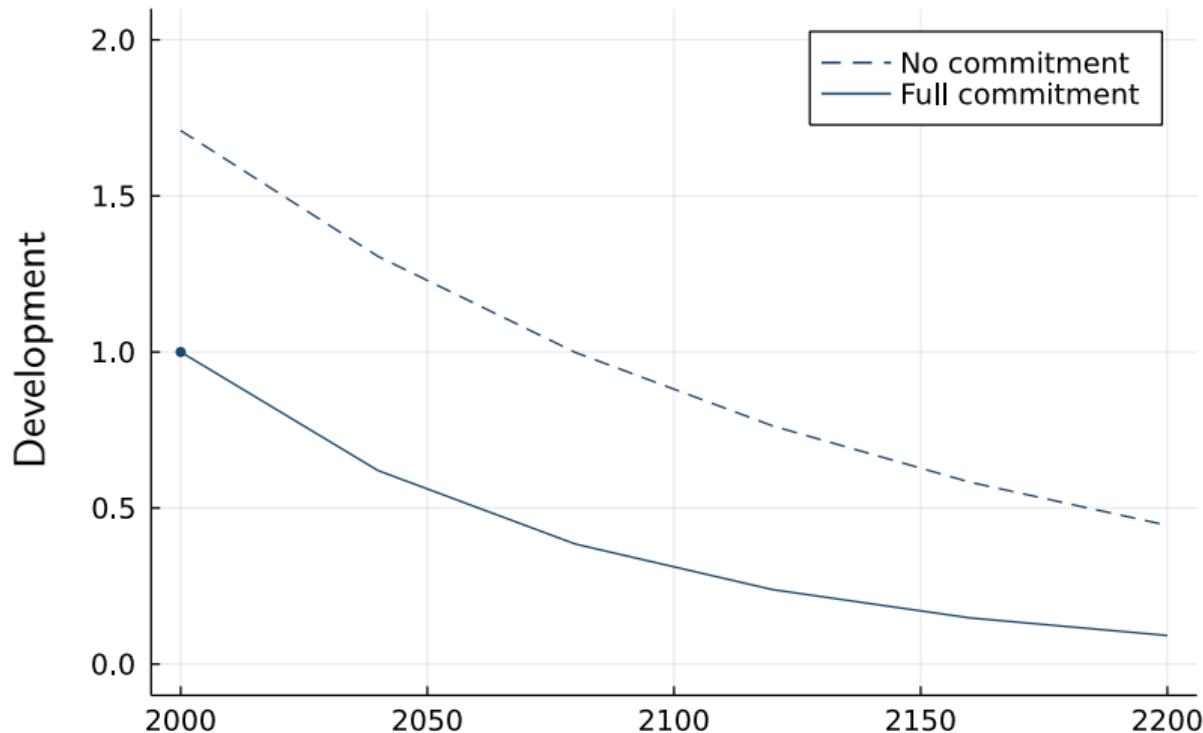
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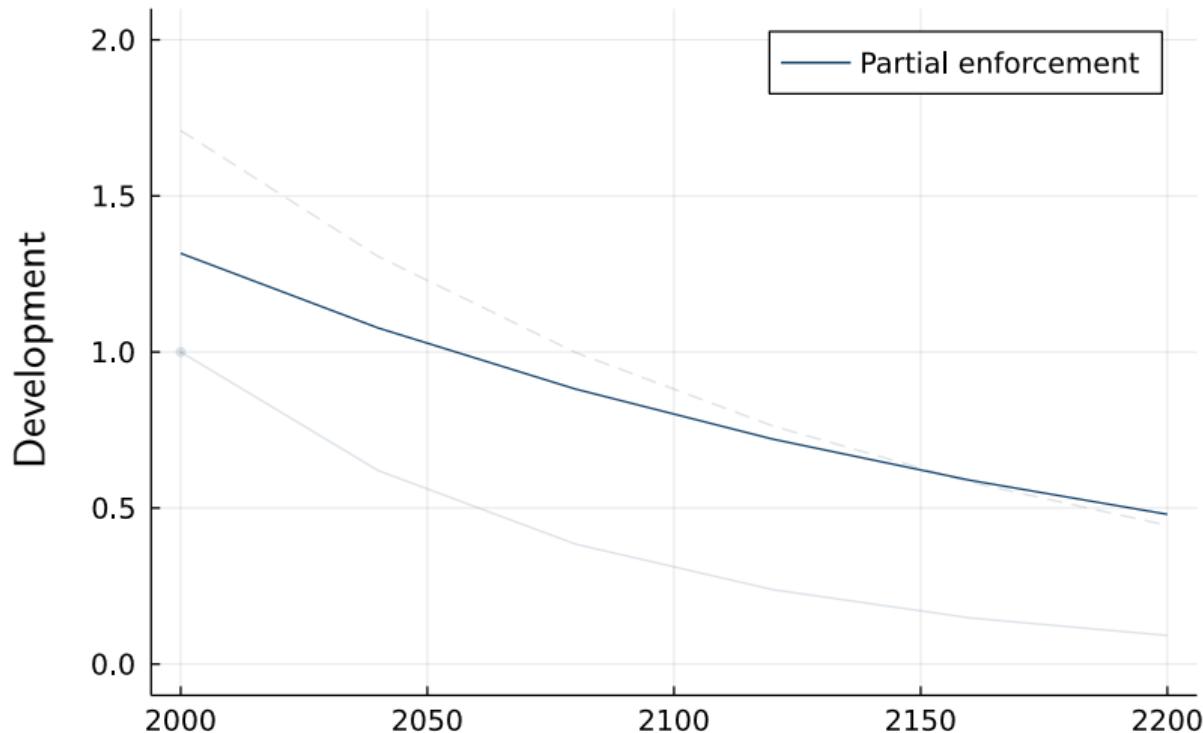
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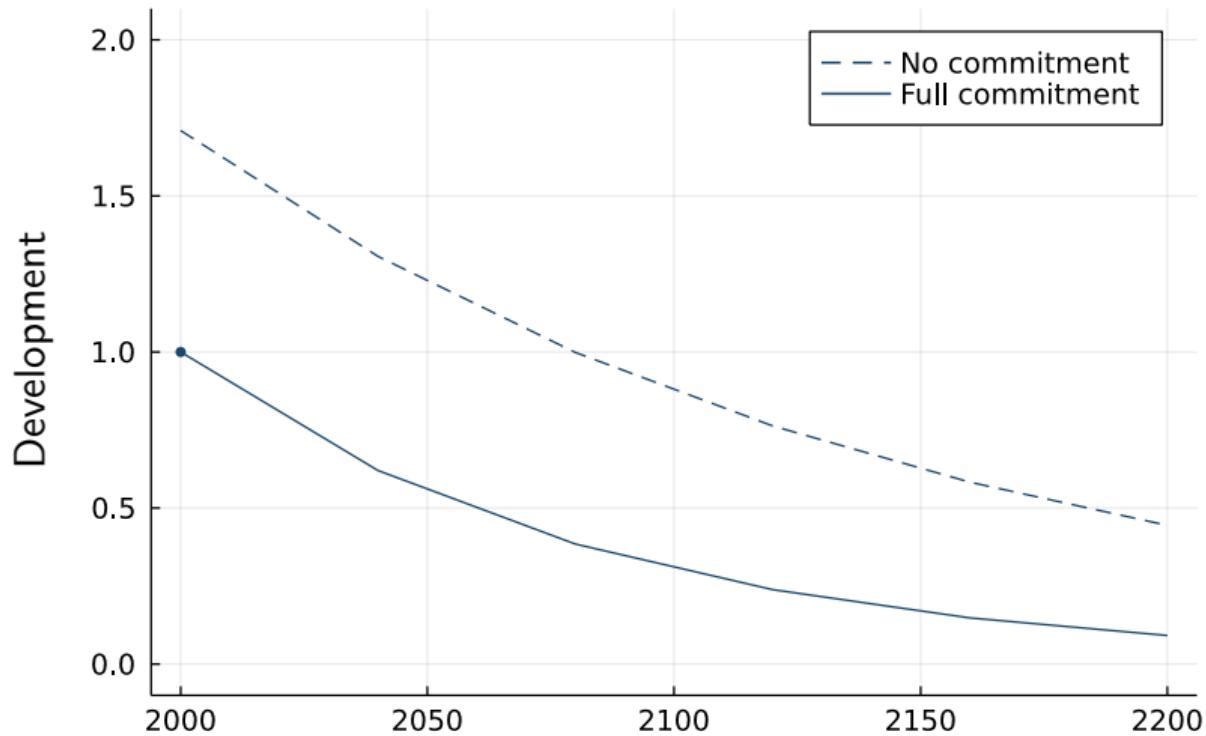
Partial enforcement helps, if consistent (79% loss)



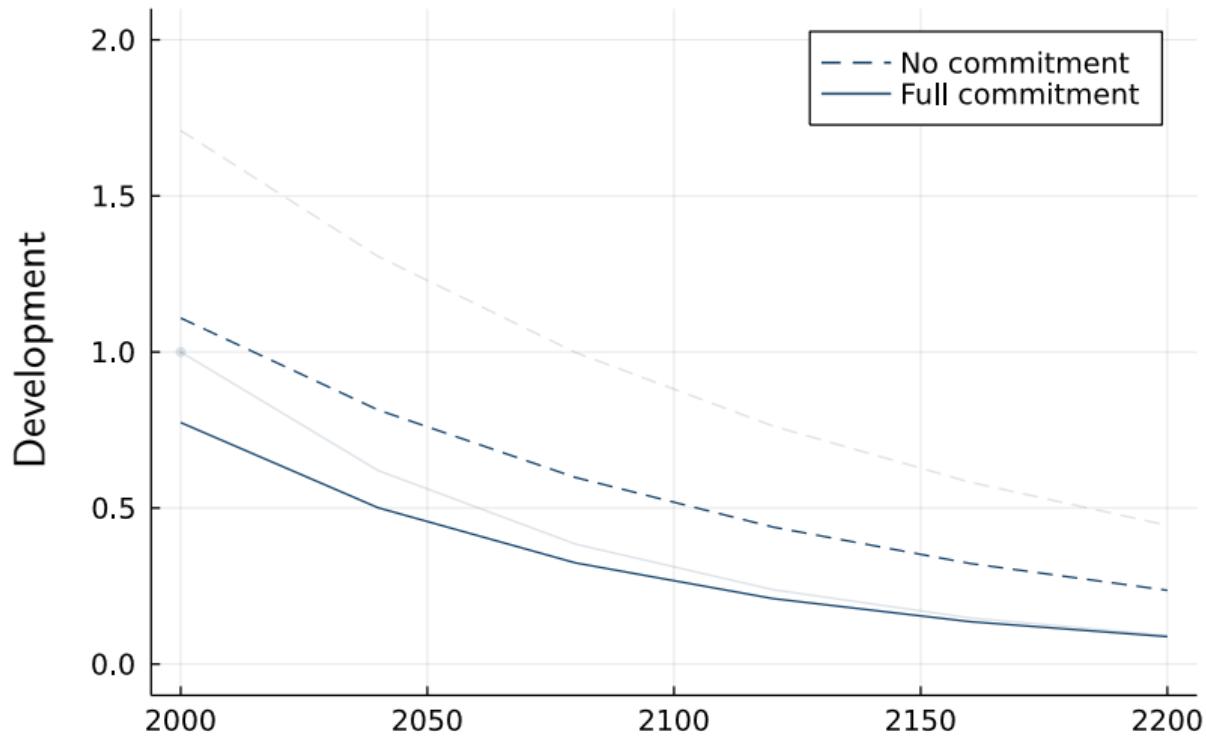
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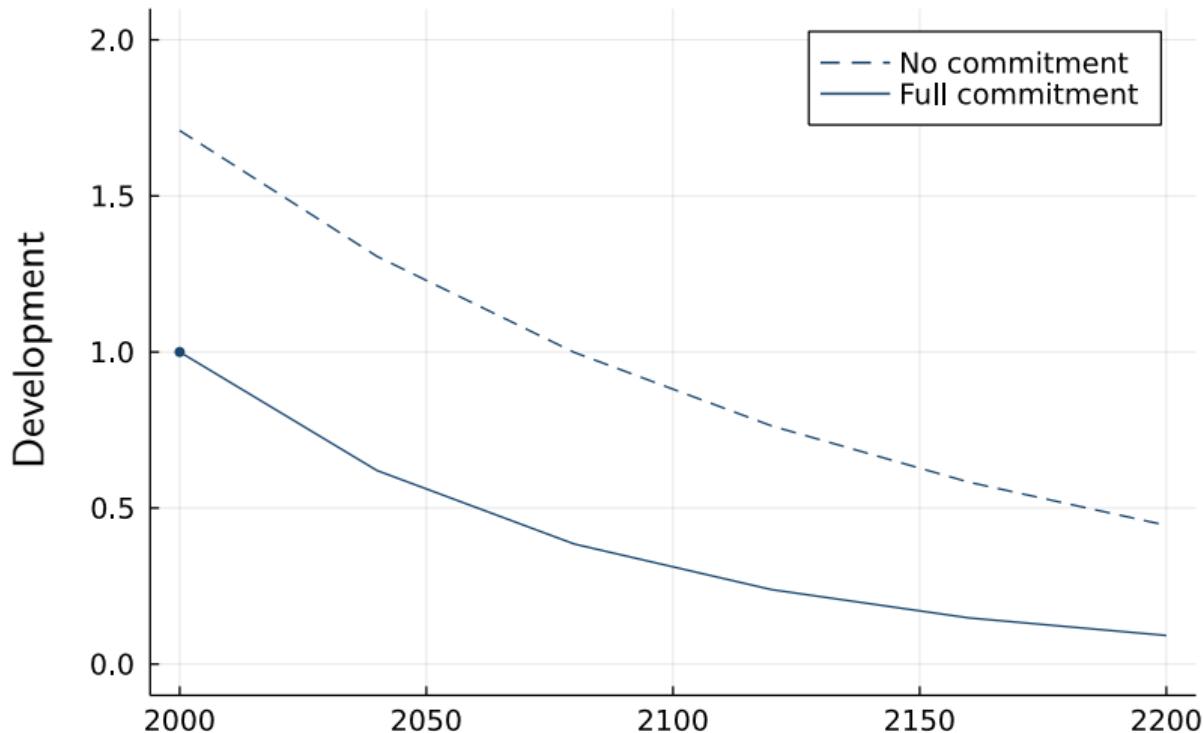
Moving the capital reduces moral hazard (26% loss)



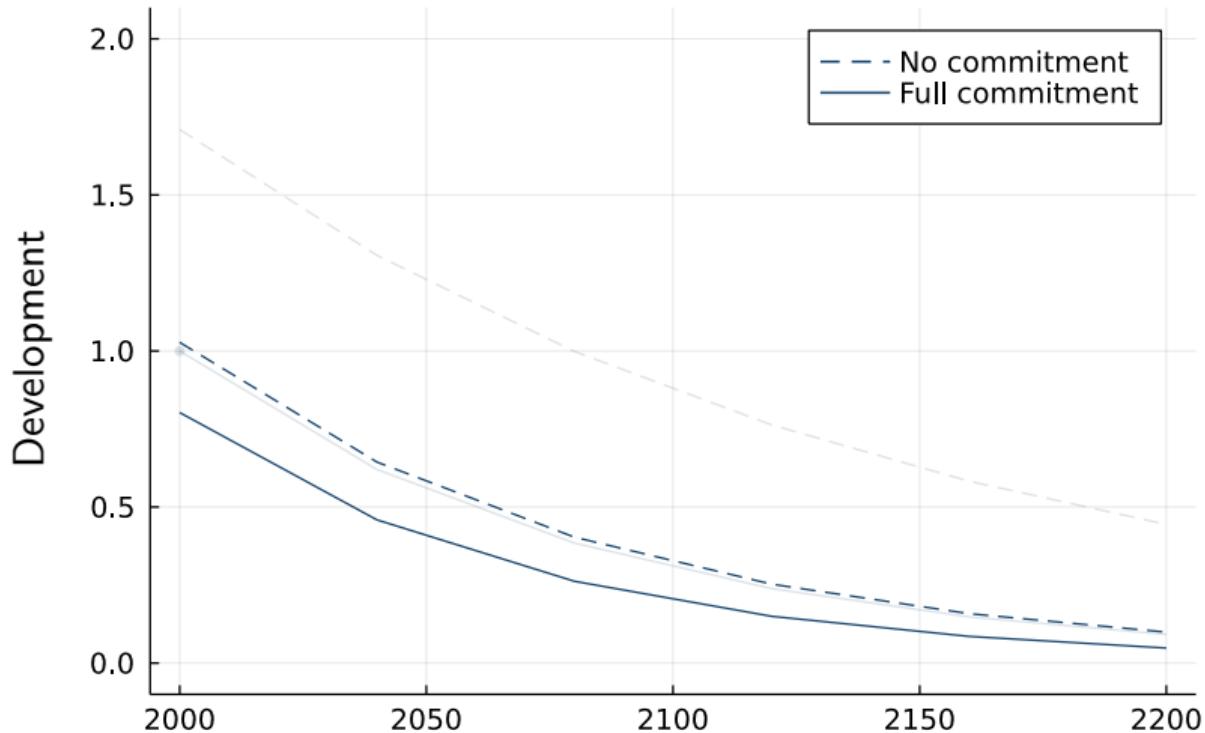
Moving the capital reduces moral hazard (26% loss)



Slowing subsidence reduces moral hazard (6% loss)



Slowing subsidence reduces moral hazard (6% loss)



Policy recommendations

① Partial commitment

- Persistence: benefits of short-run policy
- Anticipation: benefits of phased-in policy

② Indirect policy

- Moving capital, as is already happening
- Less efficient, but more politically feasible

Conclusion

Summary

- **Moral hazard can impede climate adaptation**
- Jakarta foreshadows the future for other coastal cities

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)