Sea Level Rise and Urban Adaptation in Jakarta

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#CLIMATE NO JUSTICE

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 recommendations
   - 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 $c(d)$ for $c'' > 0$ (agent)
- **Defense** g at cost $e(g)$ for $e'' > 0$ (principal)
- Residential value $r(d,g)$ for $r_{dg} > 0$

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

- Moral hazard: 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 $d^*(g^*)$

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

- If g unconstrained via domestic or foreign ability

Over-development without commitment

1. Development d^n
2. Defense $g^n(d^n)$

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

- If g continuous via height, quality, maintenance, or expectation

But 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)
  - Worse with more periods, more locations
  - (Unless migration is not an option)

Equivalent 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

Demand

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

- **Spatial choice:** renters i, locations k
  - Private cost of flooding
  - Moral hazard increasing in flood disutility
  - Moving inland abandons amenities, incurs migration costs
- **Estimation:** linear IV with 2015 population data
  - Rent endogeneity from unobserved amenities
  - Ruggedness as supply shifter
- No dynamics, agglomeration, uncertainty

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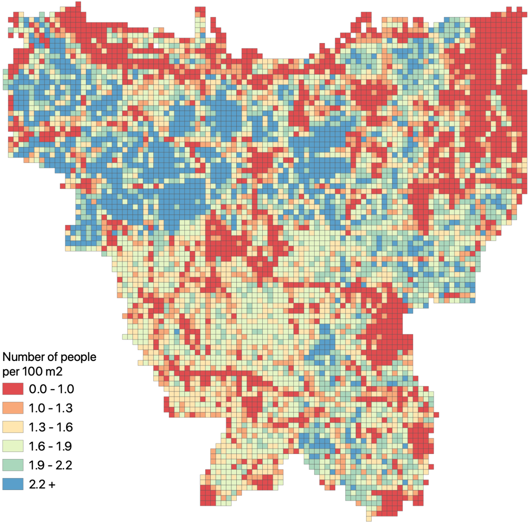
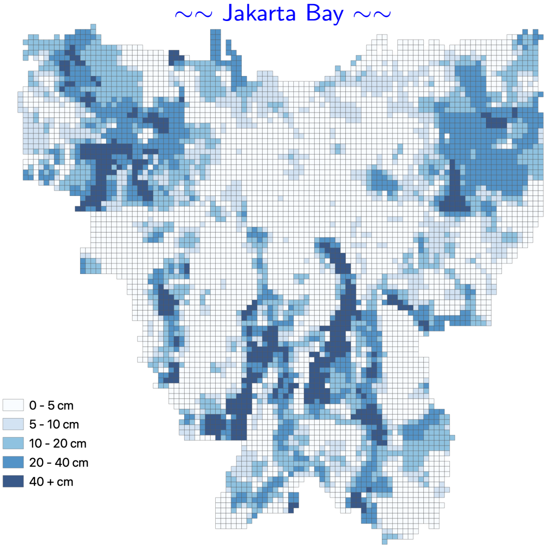
Population (global data)



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	

Supply

$$d_{ikt} \to \sum_{s=0}^{\infty} \mathbb{E}[\alpha r_{kt+s}] - c_{kt}$$

- **Dynamic choice:** landowners i, locations k, time t, state $D_{ikt} \in \{0, 1\}$
  - Private cost of development
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Small, homogeneous landowners

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

- Take rents, costs, and property prices as given
  - 14k developers in Jakarta, 1k with $3.5M annual revenue
  - Constant returns to scale
- Local government coordinates, developers react competitively
  - Market power lessens development
  - But also facilitates coordination

Choices

- Developed plots: sell or hold

$$V_{kt}^1 = \max\{\alpha P_{kt}^1, \tilde{V}_{kt}^1\} \quad (1)$$

$$\tilde{V}_{kt}^1 = \alpha r_{kt} + \beta \mathbb{E}[V_{kt+1}^1] \quad (2)$$

- Empty plots: sell, develop, or hold

$$V_{kt}^0 = \max\{\alpha P_{kt}^0, \tilde{V}_{kt}^0\} \quad (3)$$

$$\tilde{V}_{kt}^0 = \mathbb{E}[\max\{\beta V_{kt+1}^1 - c_{kt} + \varepsilon_{ikt}^1, \ \beta V_{kt+1}^0 + \varepsilon_{ikt}^0\}] \quad (4)$$

Choices

- Developed plots: sell or hold

$$
\begin{aligned}
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Equilibrium prices

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- REITs have competitive demand for developed and empty plots
  - Observed prices capture continuation values (Kalouptsidi 2014)
  - Arbitrage by buying assets and collecting rents
  - Flooding decreases rents, which clear $D^{\text{res}}_{kt}(r_{kt}) = D^{\text{dev}}_{kt}(r_{kt})$

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

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- Simple IV estimator
  - Market expectations capitalize into prices
  - Developers respond to prices as if statically
  - Alternatives: full-solution, two-step, Euler CCP

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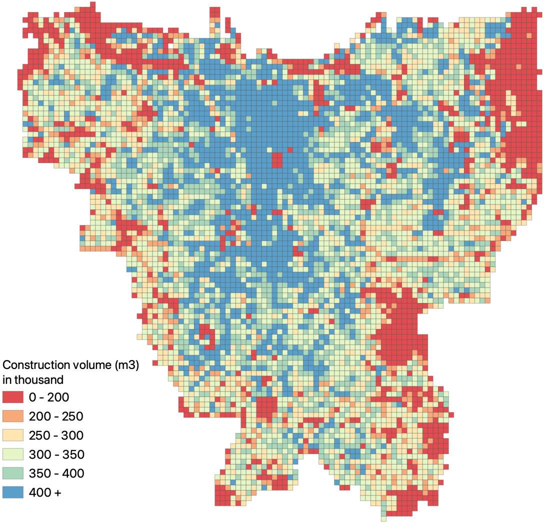
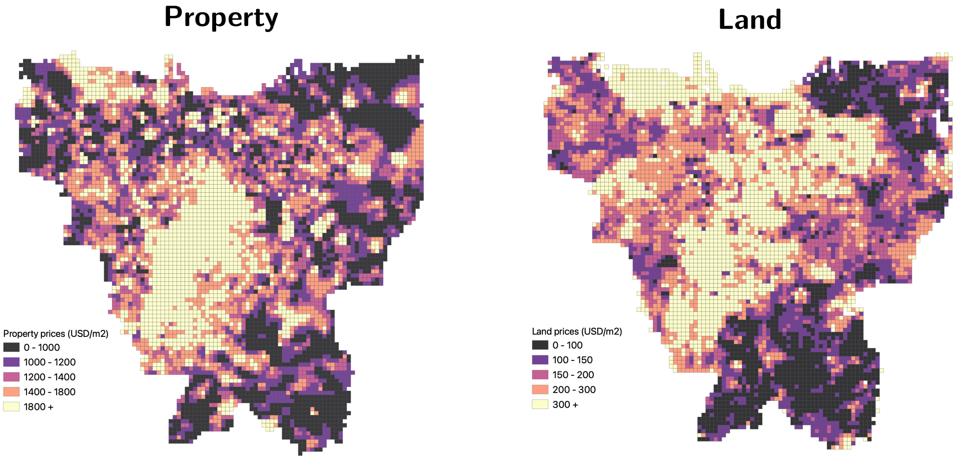
Building construction (global data)



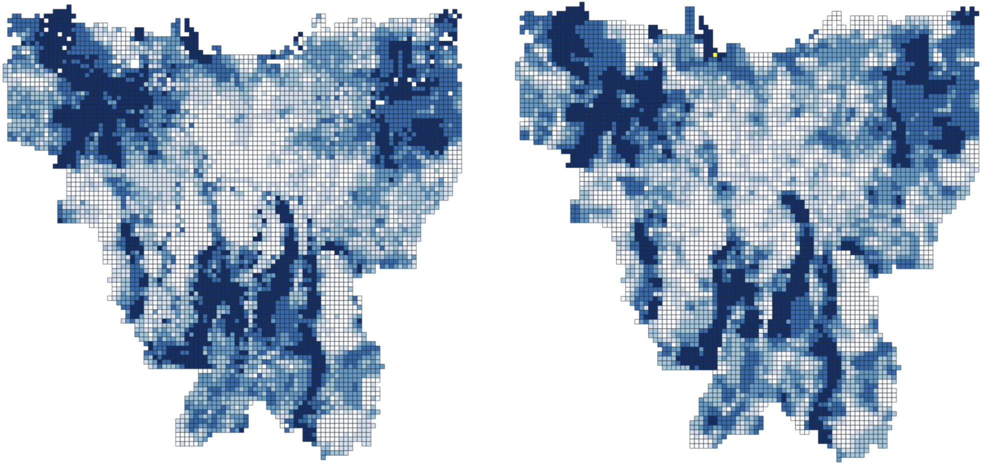
Real estate prices (urban data)



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)

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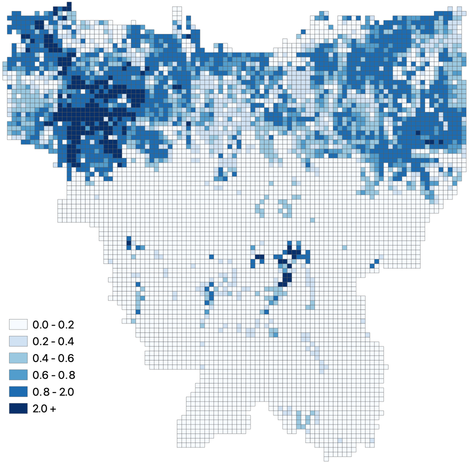
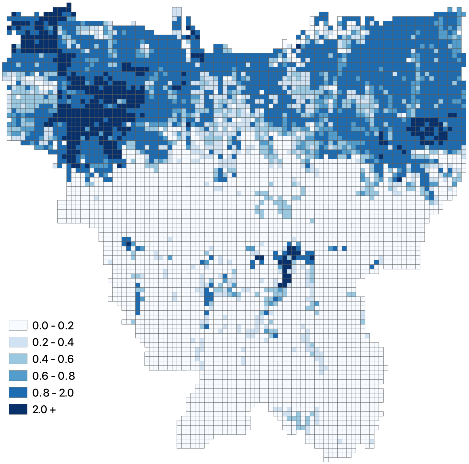




3m vs. 5m sea wall

Sea wall costs

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

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

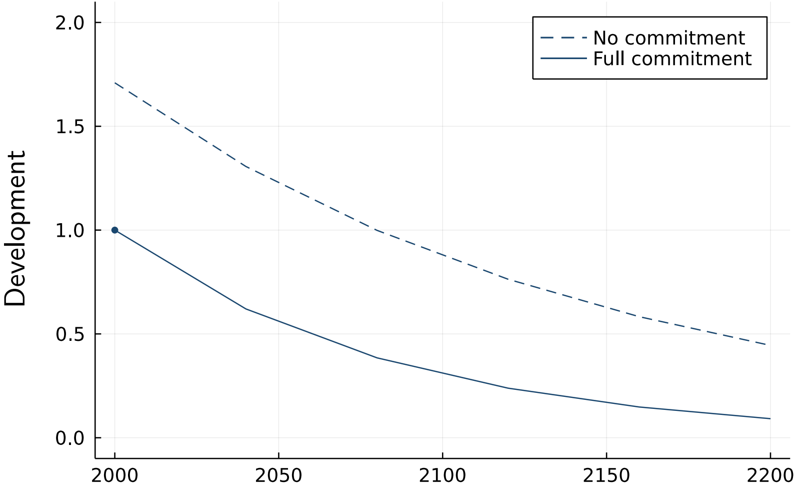
Counterfactuals

Solving the model

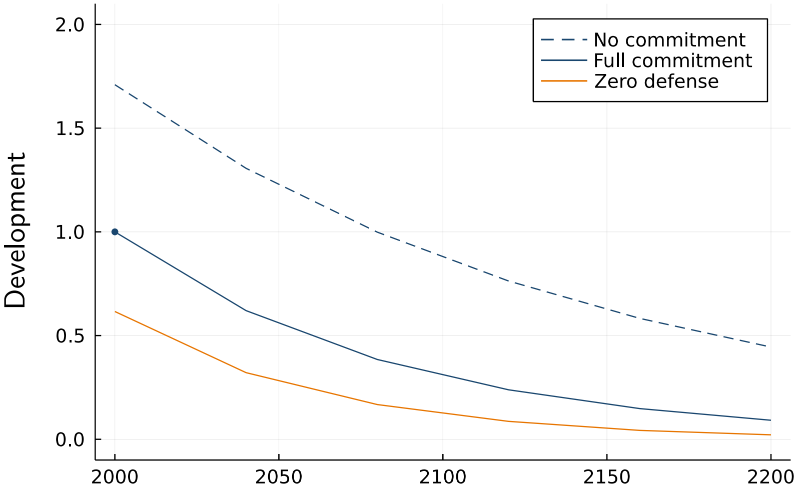
$$d^*(g) = \arg\max \{r(d;g) - c(d)\}$$
$$[g^*(d) = \arg\max \{r(g;d) - c(d) - e(g)\}]$$

- 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

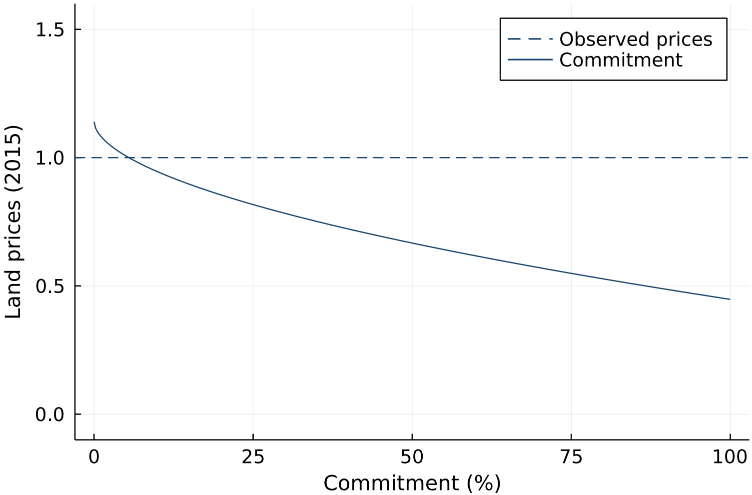
Moral hazard delays adaptation



Moral hazard delays adaptation (55% loss)



Moral hazard can rationalize observed prices



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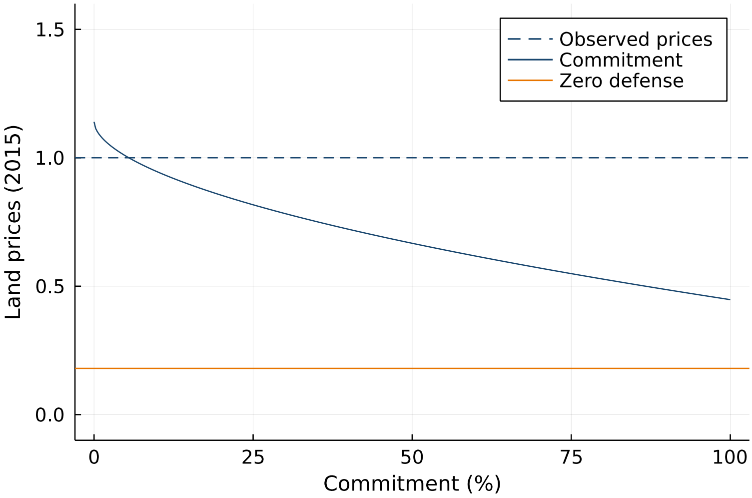
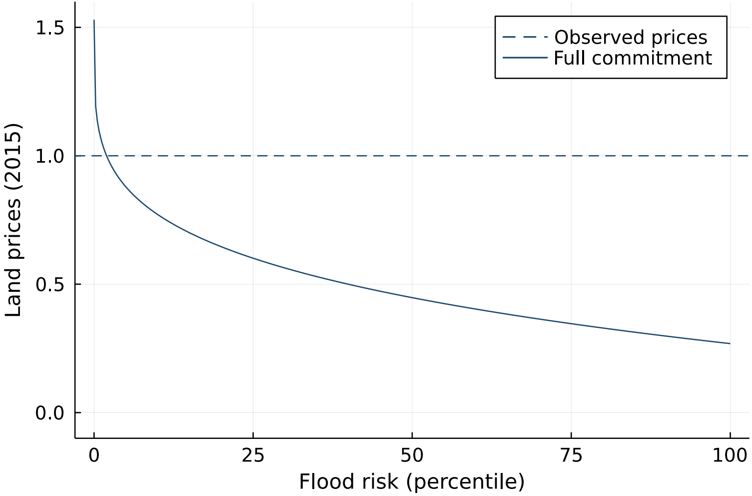


Flood risk cannot rationalize observed prices



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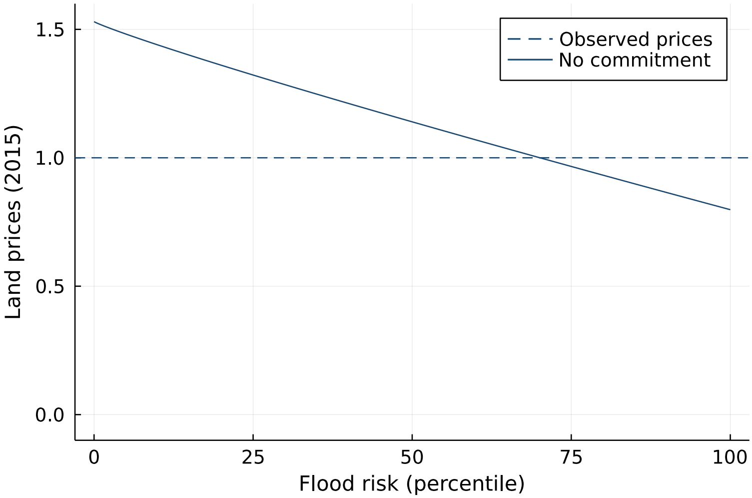
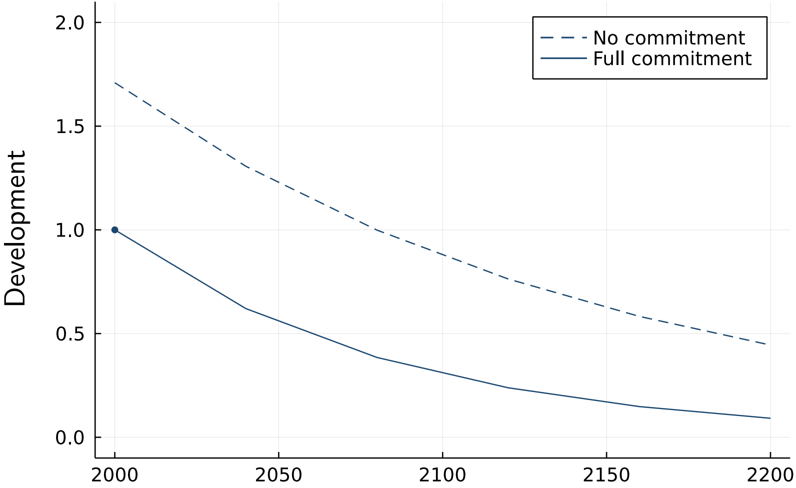


Partial commitment helps, subject to politics (53% vs. 63% loss)



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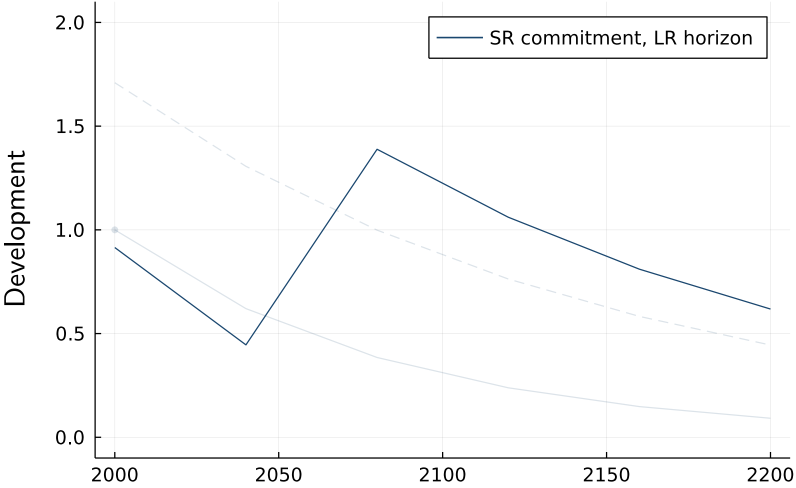

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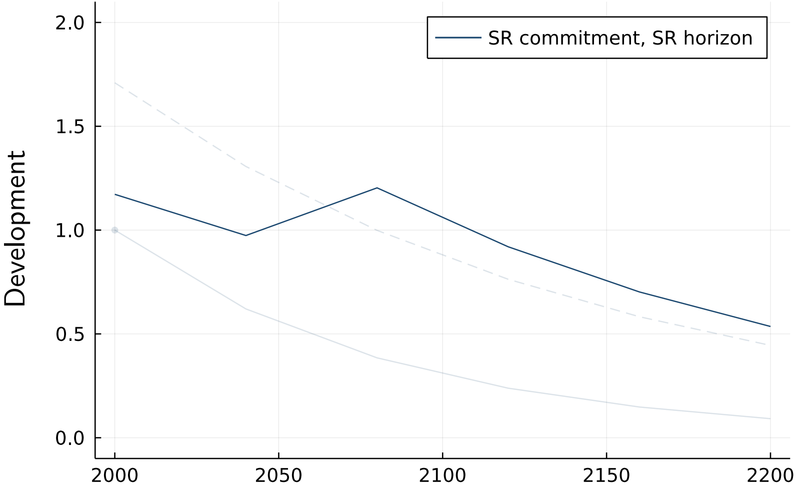
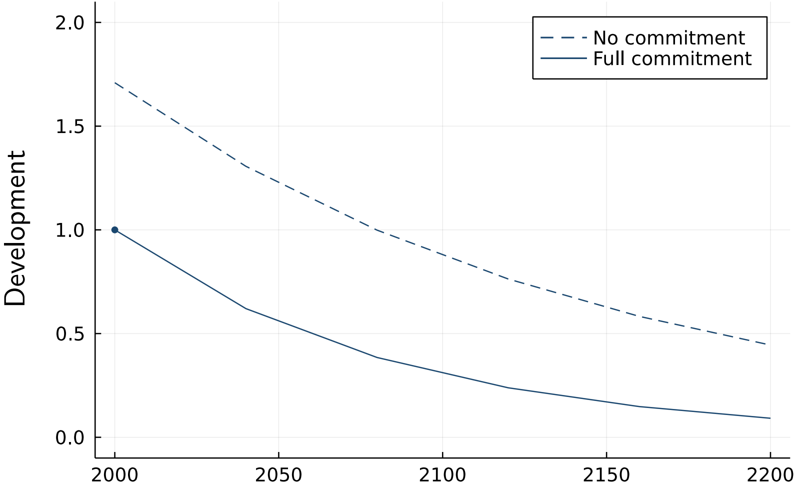
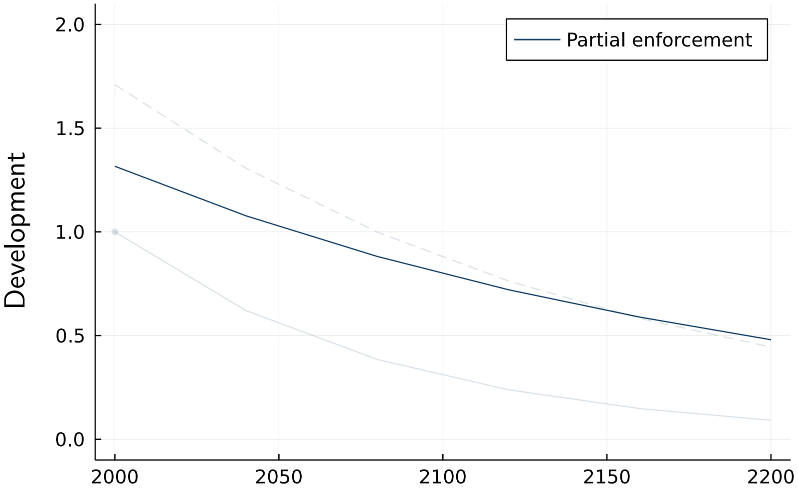


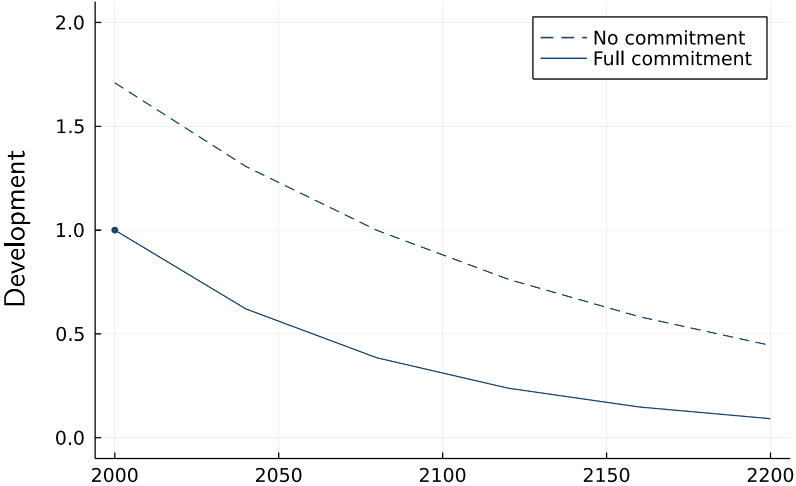
Partial enforcement helps, if consistent (79% loss)



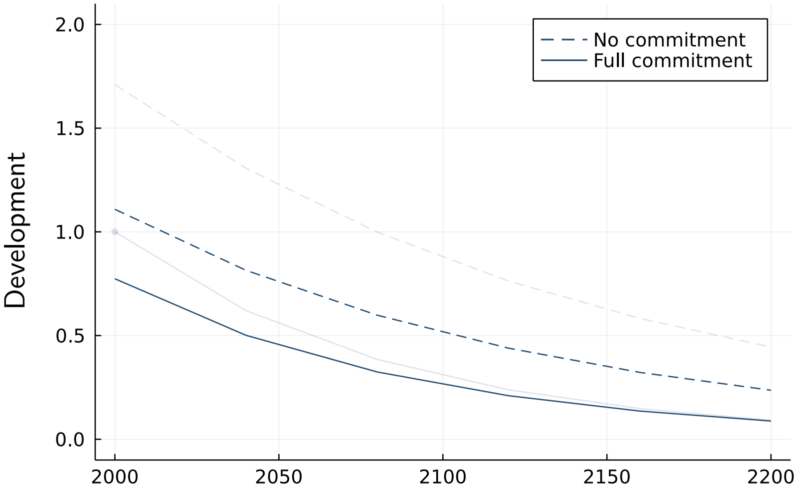
Partial enforcement helps, if consistent (79% loss)



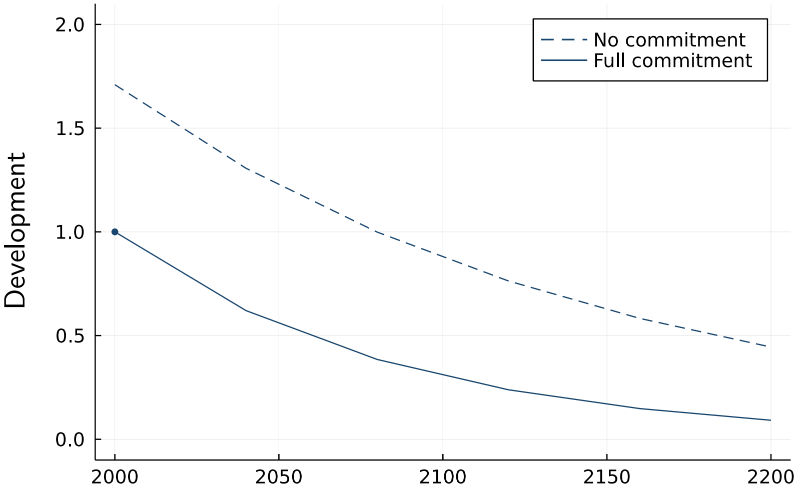
Moving the capital reduces moral hazard (26% loss)



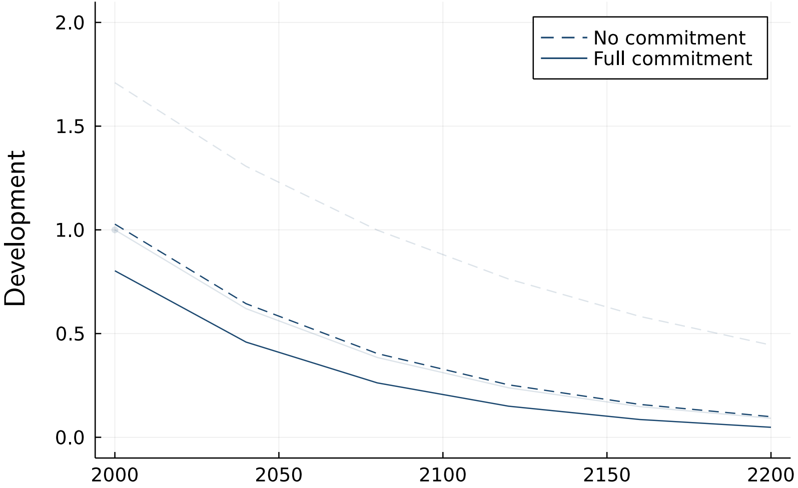
Moving the capital reduces moral hazard (26% loss)



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)