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
   - Indirect: moving capital

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, Lin et al. 2022
- **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 risk is aggregate for Jakarta
- 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

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

- $\tilde{r}(d, f)$: **spatial model** of demand for development
- $f(g)$: **hydrological model** of flooding
- $c(d)$: **dynamic model** of supply of development
- $e(g)$: **engineering model** of sea wall costs

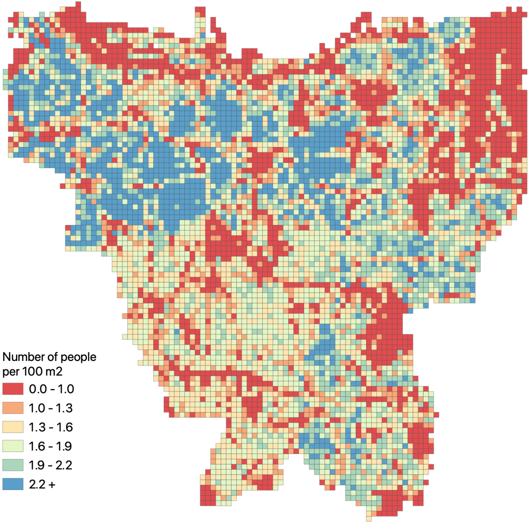
- But W itself is from model, not data
  - *Potential* impact of moral hazard on adaptation

Demand

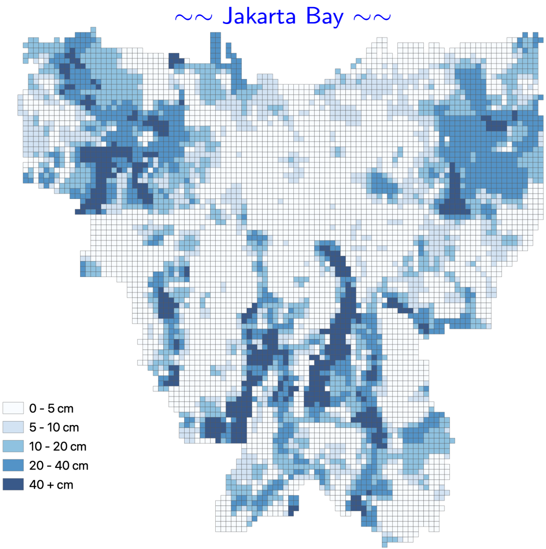
$$u_{ik} = \alpha r_k + \phi f_k + x_k \gamma + \delta_k + \varepsilon_{ik}$$

- **Spatial choice:** residents i, locations k
  - Static renters with private cost $\frac{\phi}{\alpha}$ of flooding f $(r_{dg} > 0)$
  - Moral hazard increasing in $\frac{\phi}{\alpha}$
- **Estimation:** linear IV with 2015 population data
  - Rent endogeneity from unobserved amenities
  - Ruggedness as supply shifter

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

$$\text{①}\quad V_{kt}^{D} = \max\{\alpha r_{kt} + \beta \mathbb{E}[V_{kt+1}^{D}],\ \alpha P_{kt}^{D}\}$$

$$\text{②}\quad V_{kt}^{L} = \max\{V_{kt}^{LD},\ \alpha P_{kt}^{L}\}$$

$$\text{③}\quad V_{kt}^{LD} = \mathbb{E}[\max\{\beta V_{kt+1}^{D} - c_{kt} + \varepsilon_{ikt}^{D},\ \beta V_{kt+1}^{L} + \varepsilon_{ikt}^{L}\}]$$

- **Dynamic choice:** landowners i, locations k, time t, state $\theta_i \in \{D, L\}$
  - Immobile landlords with private cost c of development
  - Moral hazard increasing in α

- **Estimation:** linear IV with 2015 construction data
  - Rent endogeneity from unobserved costs
  - Residential amenities as demand shifter

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Data as continuation values

1. $V^{D}_{kt} = \max\{\alpha r_{kt} + \beta \mathbb{E}[V^{D}_{kt+1}],\ \alpha P^{D}_{kt}\}$ $\qquad V^{D}_{kt} = \alpha P^{D}_{kt} = \alpha \sum_{s=0}^{\infty} \beta^{s} \mathbb{E}[r_{kt+s}]$
2. $V^{L}_{kt} = \max\{V^{LD}_{kt},\ \alpha P^{L}_{kt}\}$ $\qquad V^{L}_{kt} = \alpha P^{L}_{kt} = V^{LD}_{kt}$

- Competitive demand for development and land among REITs
  - Observed prices capture continuation values (Kalouptsidi 2014)
- Small, homogeneous developers within locations (CRS, 14k developers)
  - E.g., local government coordinates, developers react competitively

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Estimation without solving

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- Simple IV estimator (without finite dependence)
  - Developers respond to prices as if statically

- Market expectations capitalize into prices (!)

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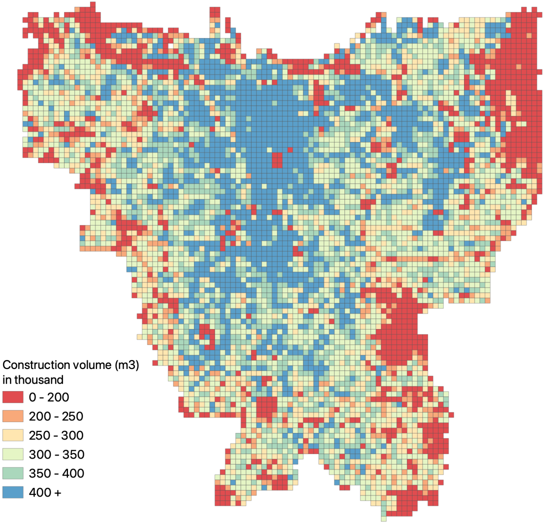
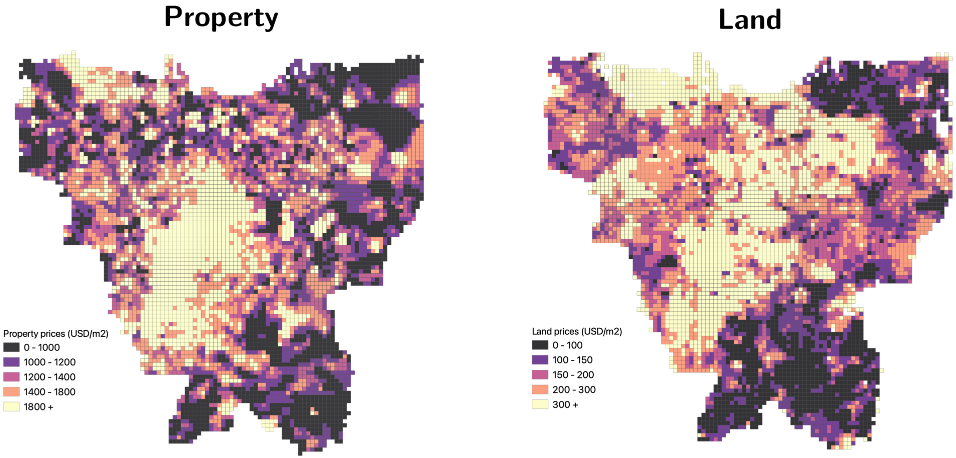
Building construction (global data)



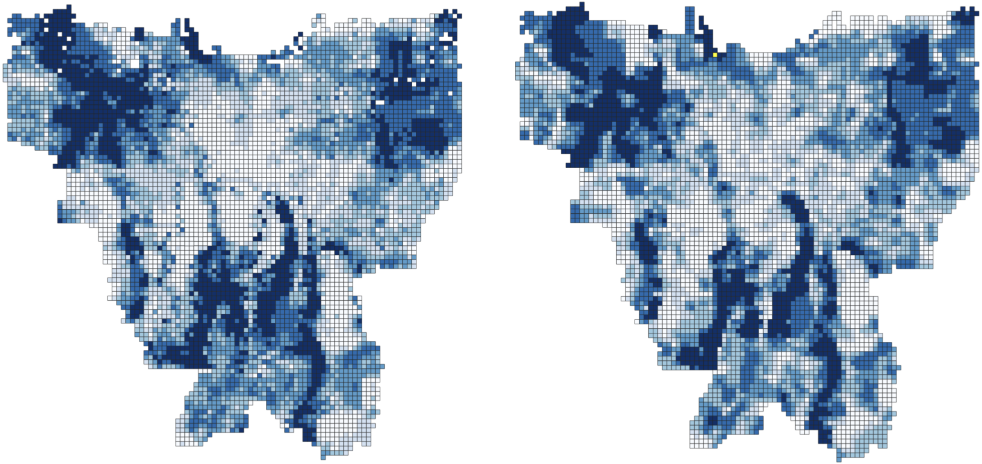
Real estate prices (urban data)



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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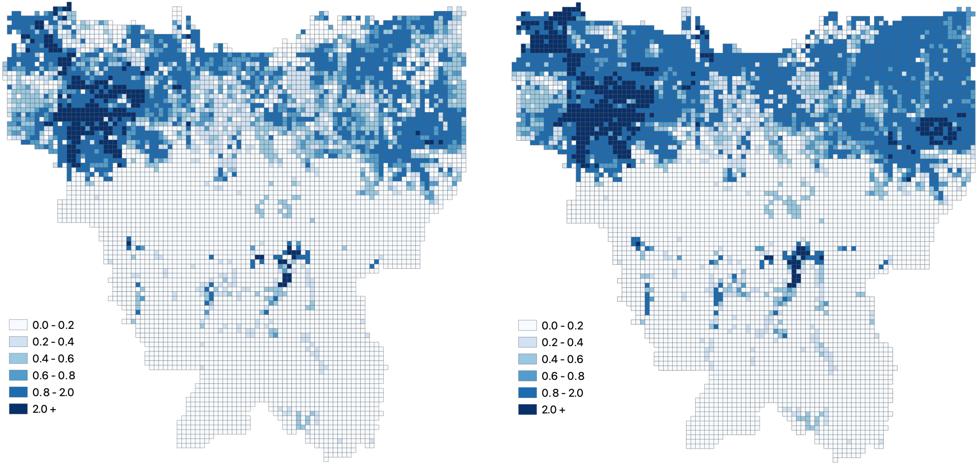


3m vs. 5m sea wall

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

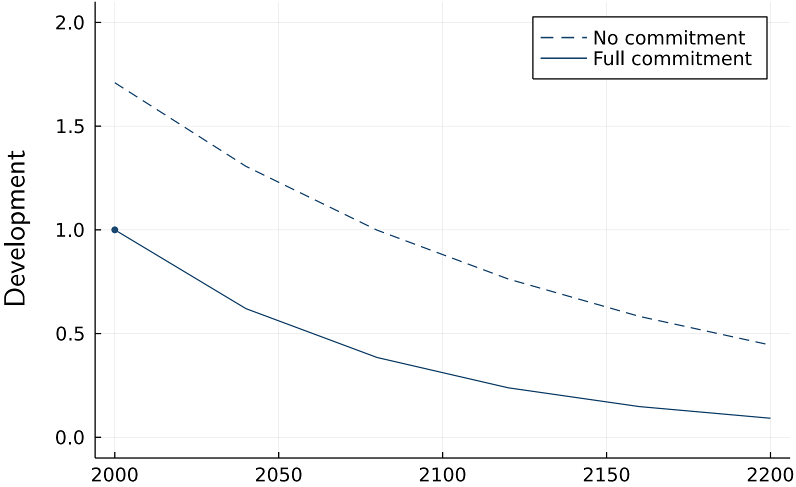
Equilibrium given $r(d,g)$, $c(d)$, and $e(g)$

$$
\begin{aligned}
g^*(d) &= \arg\max \{r(g;d) - c(d) - e(g)\} \\
d^*(g) &= \arg\max \{r(d;g) - c(d)\}
\end{aligned}
$$

$$
P^{\text{res}}(d,g) = P^{\text{dev}}(d,g)
$$

- Solving full model (more assumptions)
  - Across locations in spatial equilibrium
  - Across periods by backward induction

Moral hazard delays adaptation



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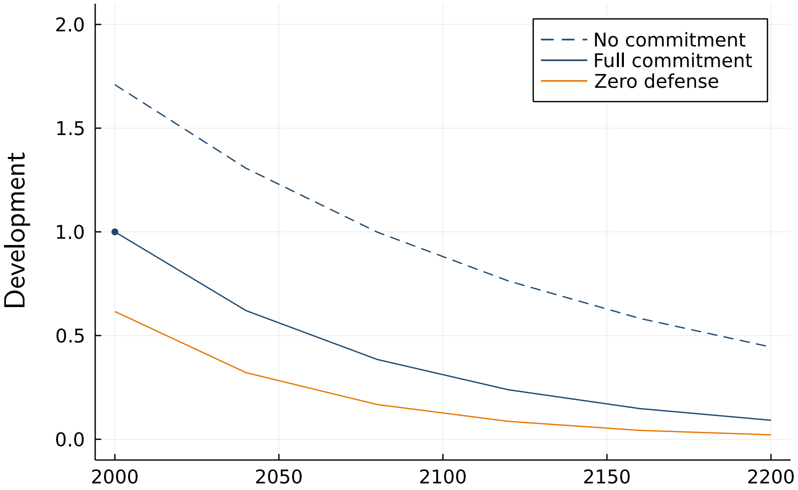
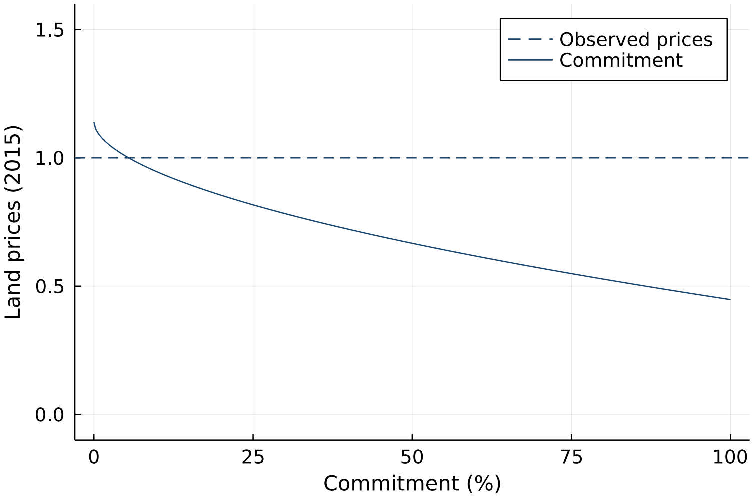


Moral hazard can rationalize observed prices



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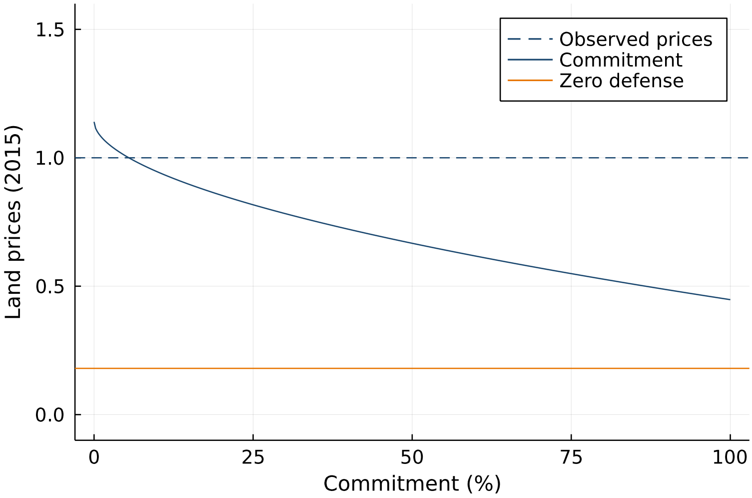
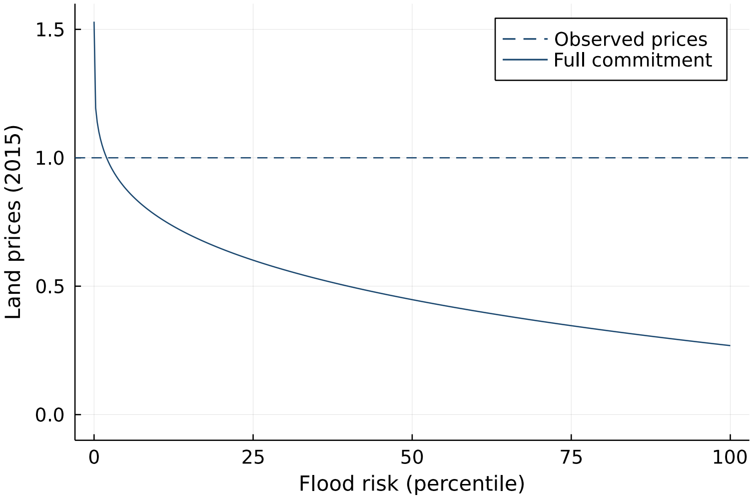


Flood risk cannot rationalize observed prices



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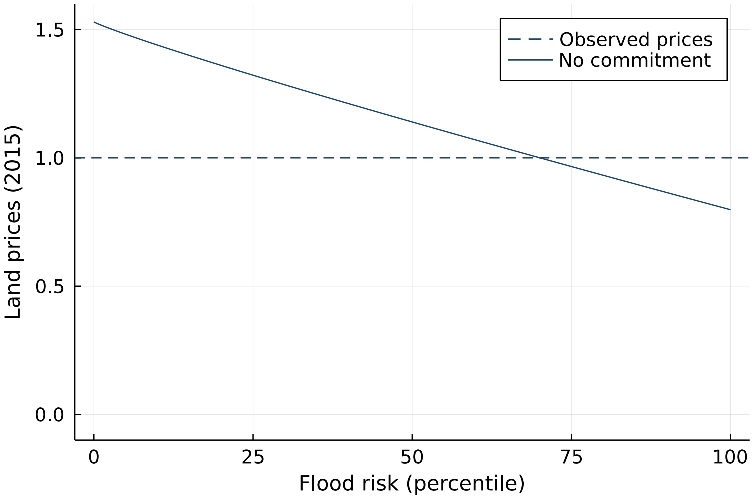
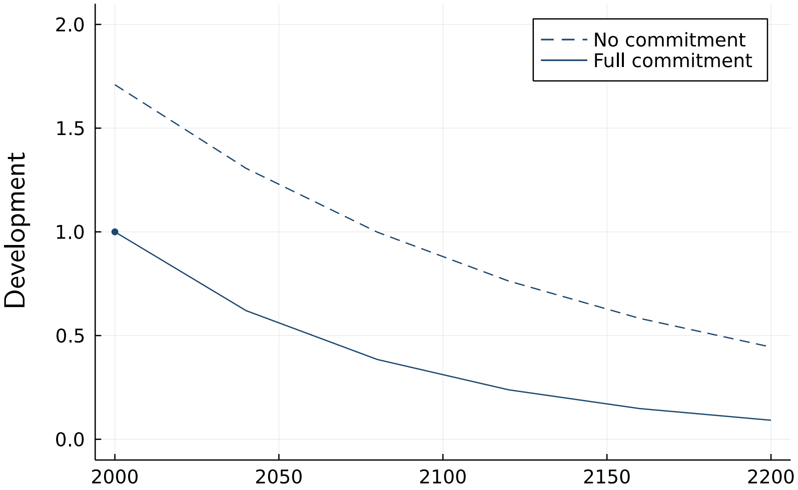


Partial commitment helps, subject to politics



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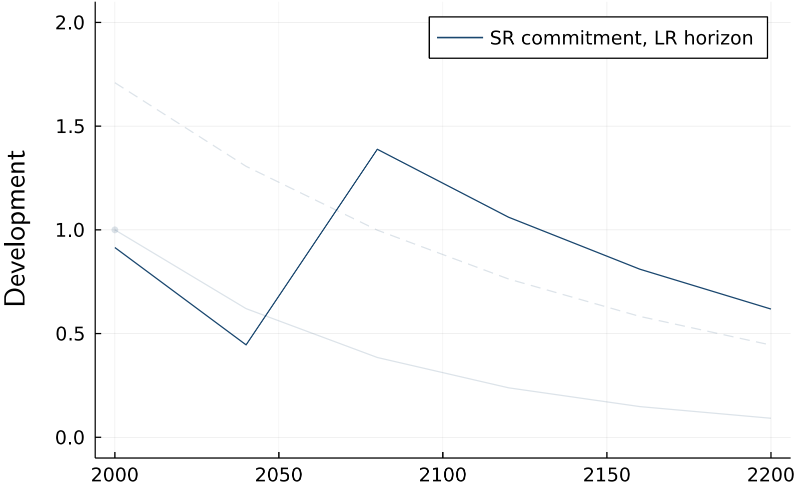

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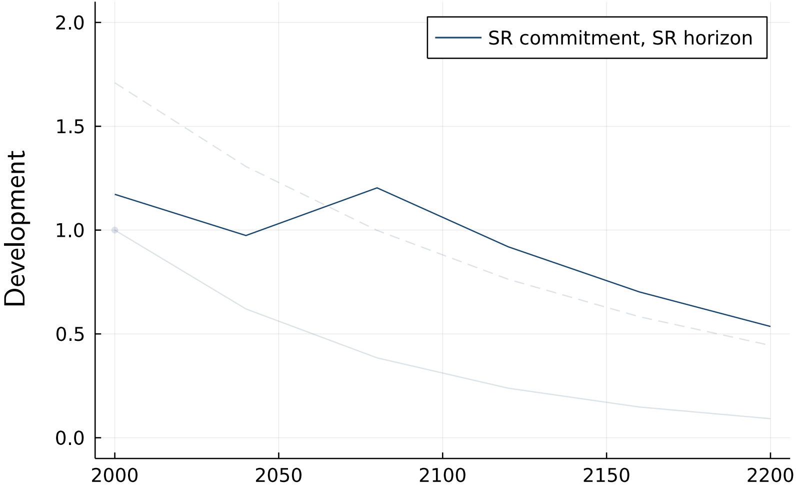
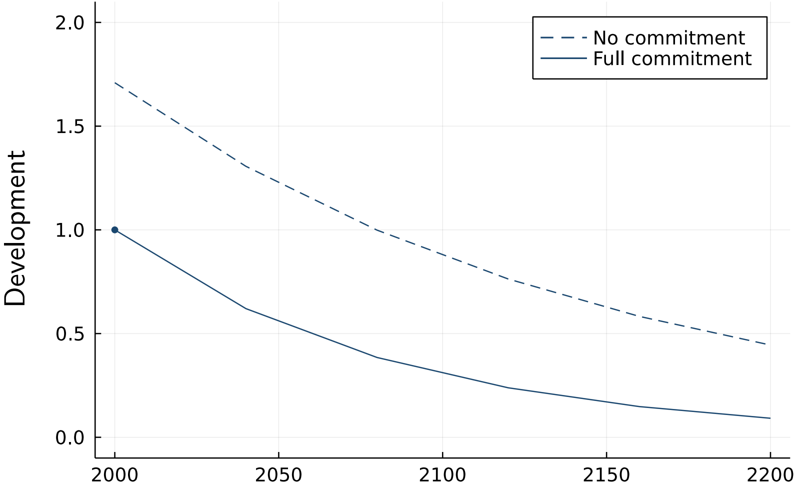


Moving the capital reduces moral hazard $[\frac{1}{2}r(d,g) - c(d) - e(g)]$



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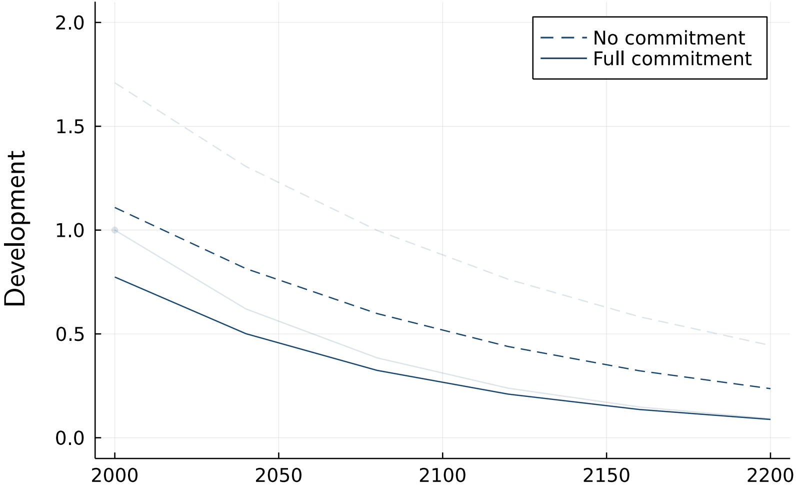

Policy recommendations

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)