Sea Level Rise and Urban Adaptation in Jakarta

Allan Hsiao
Princeton University

January 5, 2023


#CLIMATE NO JUSTICE

Jakarta

- World's second largest city at 31M (first by 2030)
    - By 2050, 35% below sea level
    - Proposed sea wall at up to $40B

- **How does government intervention complicate adaptation?**

This paper

- **Moral hazard** as coastal development forces defense
  - If government cannot commit or regulate
  - Delays inland migration at high social cost
- **Dynamic spatial model** of development and defense
  - Estimated with granular data for Jakarta
- **Result:** severe moral hazard without commitment
  - Policy prescriptions from partial commitment to moving capital

Contributions

- **Adaptation frictions** under endogenous government intervention
  - **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-Vicenzi 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. 2022

Theory

Policy trade-offs

- **Spatial:** adapt in-place at the coast vs. migrate inland
- **Dynamic:** incur costs now vs. damages later

- Defending at the coast avoids costly retreat today
- But then coastal population grows, so bigger damages tomorrow

Policy distortions

- Time-inconsistent government
  - Ex ante, wants new buildings inland
  - Ex post, wants to protect at coast (sunk costs, lobbying)
  - So development can force defense

- **Moral hazard:** uninternalized cost + time inconsistency
  - Coastal lock-in as inland retreat gets crowded out
  - Time inconsistency magnifies typical moral hazard

Agent and principal

1. Developers vs. government
2. Coastal vs. local government
3. Local vs. national government
4. Current vs. future government

Empirics

Components

- **Spatial model** of residential demand
- **Dynamic model** of developer supply

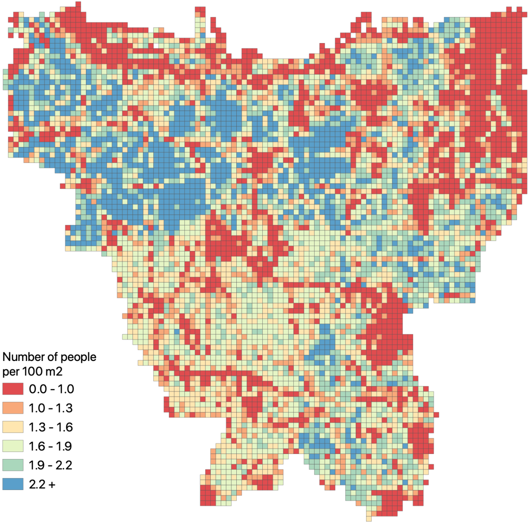
- **Hydrological model** of flooding
- **Engineering model** of sea wall costs

Residential demand

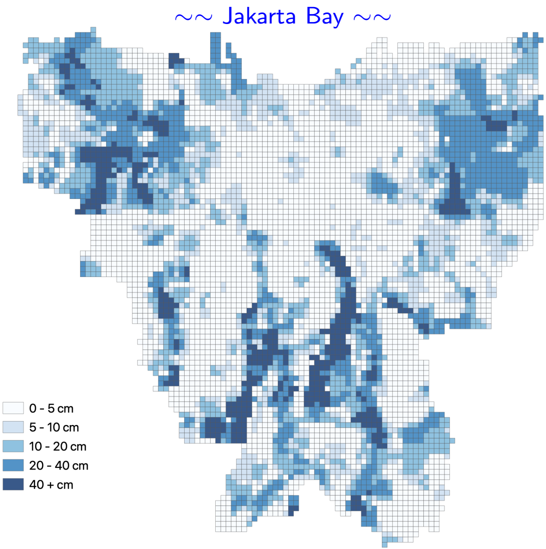
$$U_{ijk} = \alpha r_k + \phi f_k + x_k \gamma + \varepsilon_k + \tau m_{jk} + \epsilon_{ijk}$$

- **Spatial model** of resident renters i, destinations k
  - Benefit $\frac{\phi}{\alpha}$ of reducing flooding f
  - Moral hazard increasing in $\frac{\phi}{\alpha}$
- **Estimation:** match population shares (BLP 1995)
  - Rent endogeneity from unobserved amenities
  - IV with ruggedness as supply shifter

Population (global data)



Flooding (2013-2020, past → future)



Developer supply

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

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

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

- **Dynamic model** of landlord developers i, locations k
  - Cost c of convert land L to development D
  - Moral hazard increasing in α
- **Estimation:** data as continuation values (Kalouptsidi 2014)
  - Rent endogeneity from unobserved costs
  - IV with residential amenities as demand shifter

Developer supply

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

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

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

- **Dynamic model** of landlord developers i, locations k
  - Cost c of convert land L to development D
  - Moral hazard increasing in α
- **Estimation:** data as continuation values (Kalouptsidi 2014)
  - Rent endogeneity from unobserved costs
  - IV with residential amenities as demand shifter

Developer supply

$$V_{kt}(D,L) = \alpha r_{kt}(D) + \mathbb{E}[\max_{d\in\{0,1\}} \{v^d_{kt}(D,L) + \epsilon^d_{ikt}\}]$$
$$v^1_{kt}(D,L) = -c_{kt}(x,\varepsilon) + \beta\mathbb{E}[V_{kt+1}(D+1,L-1)]$$
$$v^0_{kt}(D,L) = \beta\mathbb{E}[V_{kt+1}(D,L)]$$

- **Dynamic model** of landlord developers i, locations k
  - Cost c of convert land L to development D
  - Moral hazard increasing in α
- **Estimation:** data as continuation values (Kalouptsidi 2014)
  - Rent endogeneity from unobserved costs
  - IV with residential amenities as demand shifter

Data as continuation values

$$\ln p^1_{kt} - \ln p^0_{kt} = -c_{kt}(x, \varepsilon) + \alpha\beta(P^D_{kt} - P^L_{kt})$$

$$V_{kt}(D, L) = \alpha(P^D_{kt} D + P^L_{kt} L)$$

$$P_{kt} = \mathbb{E}[P_{kt+1}]$$

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

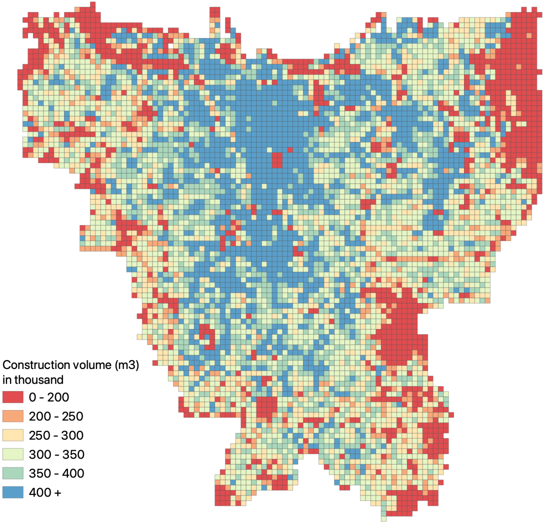
Data as continuation values

$$\ln p_{kt}^1 - \ln p_{kt}^0 = -c_{kt}(x, \varepsilon) + \alpha\beta(P_{kt}^D - P_{kt}^L)$$

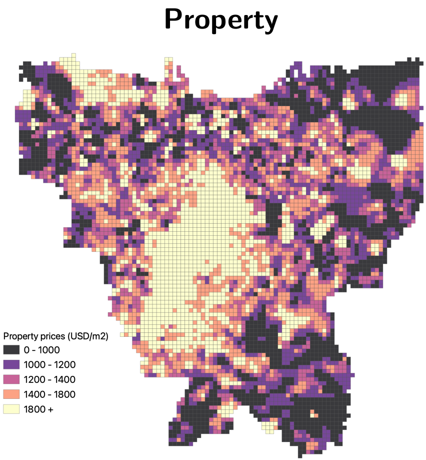
$$V_{kt}(D, L) = \alpha(P_{kt}^D D + P_{kt}^L L)$$
$$P_{kt} = \mathbb{E}[P_{kt+1}]$$

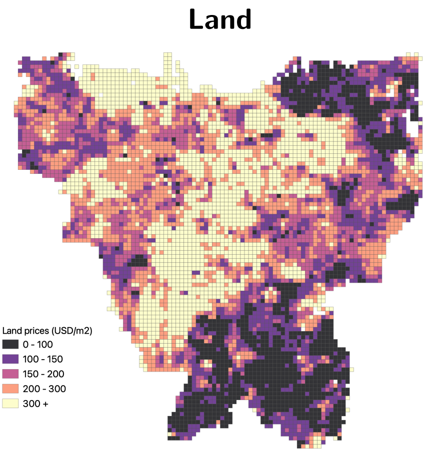
- Simple IV estimation
    - Need efficient real estate market ($P \to V$, frictions as ε)
    - Flexible expectations without finite dependence (P as market offer)

Building construction (global data)



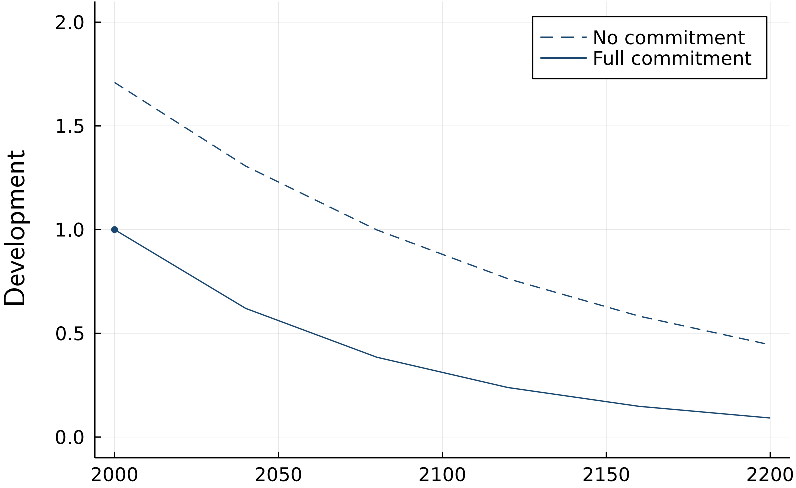
Real estate prices (urban data)



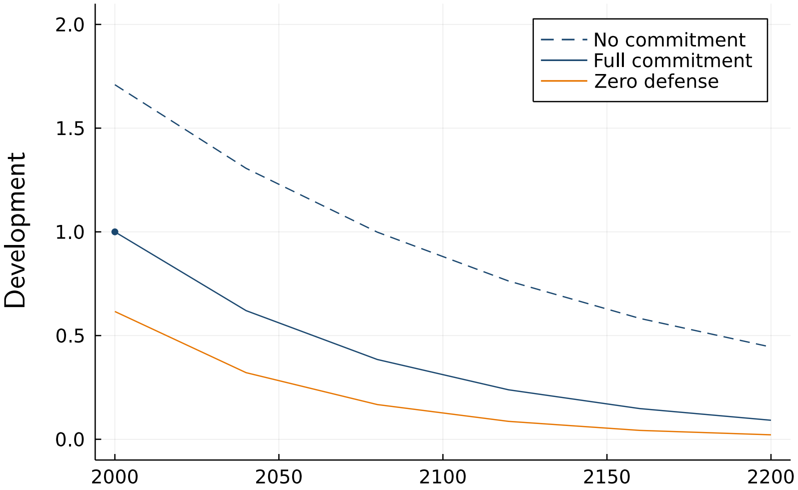


Counterfactuals

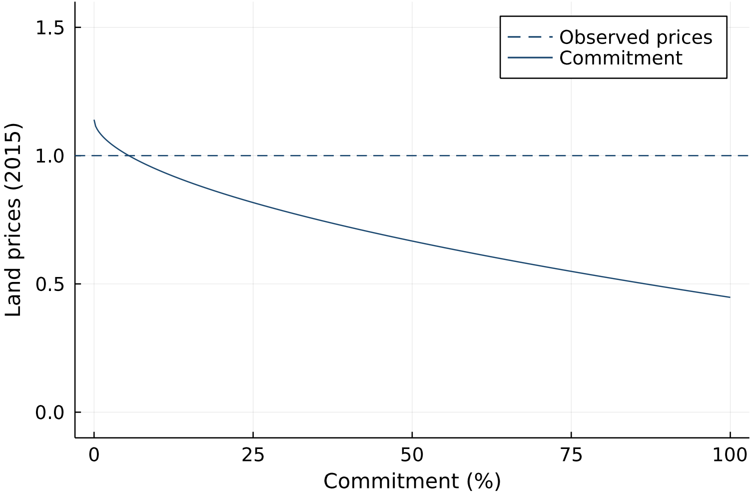
Moral hazard delays adaptation



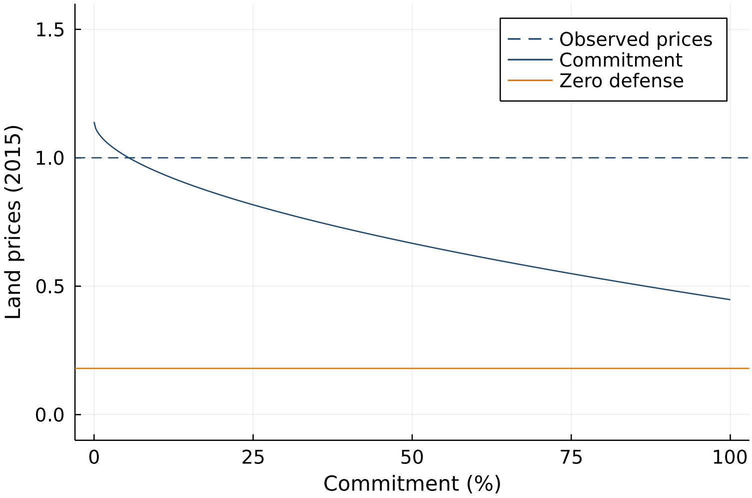
Moral hazard delays adaptation



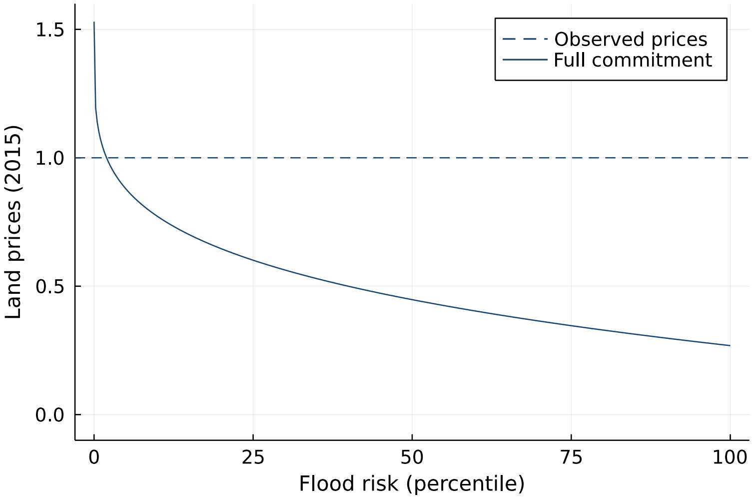
Moral hazard can rationalize observed prices



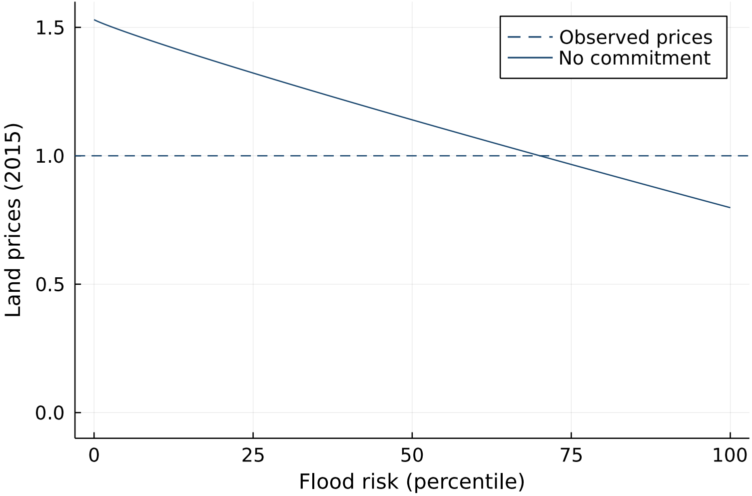
Moral hazard can rationalize observed prices



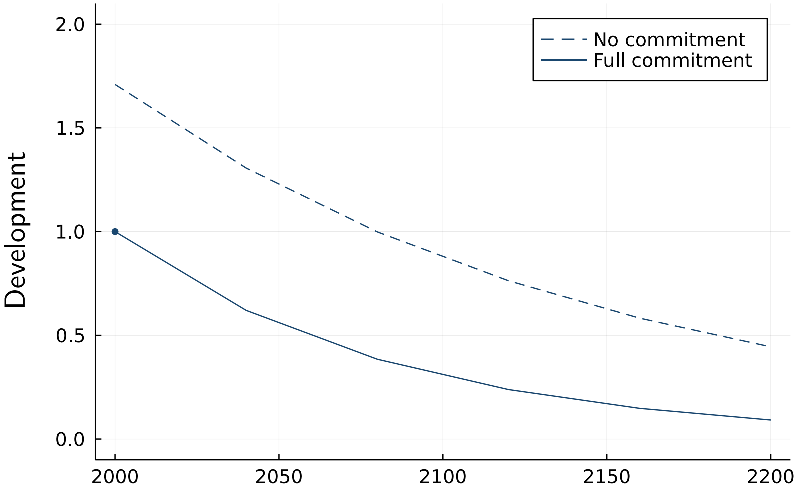
Flood risk cannot rationalize observed prices



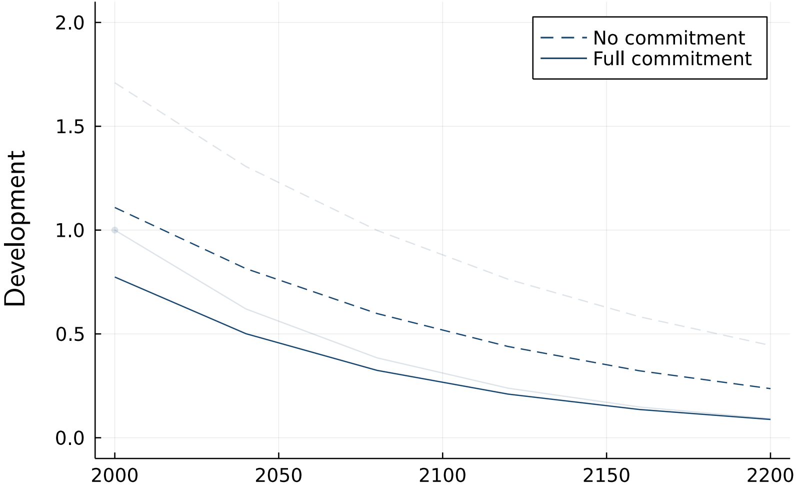
Flood risk cannot rationalize observed prices



Moving the capital reduces moral hazard



Moving the capital reduces moral hazard



Sea Level Rise and Urban Inequality

- Simple sorting model
  - Wage-specific price elasticities + endogenous prices
  - Granular wage and flooding data for Jakarta
- Sea level rise exacerbates sorting
  - Coastal flooding leads high-wage individuals inland
  - Bids up prices, pushing low-wage individuals elsewhere
- The rich crowd out the poor in pursuit of higher ground
  - Inequality in flood exposure and welfare
  - Before and after sea level rise

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)