Sea Level Rise and Urban Adaptation in Jakarta

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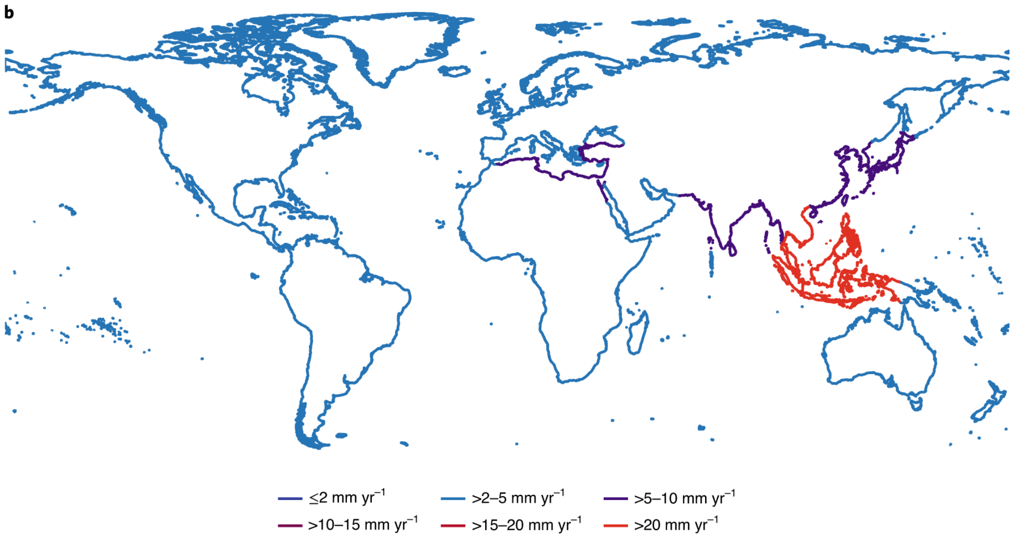
Sea levels are rising globally (Nicholls et al. 2021)

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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 affect long-run adaptation?**
  - How does public adaptation affect private adaptation?

This paper

- **Dynamic spatial model** of coastal development and government 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, Bakkensen & 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

Theory

Coastal development and defense

1. **Developers** develop d at cost $c(d)$ for $c'' > 0$ (price takers)
2. **Government** defends g at cost $e(g)$ for $e'' > 0$ (wall or otherwise)
3. **Residents** receive $r(d,g)$ for $r_{dg} > 0$ (demand $r'(d;g)$, shifter g)

- **Welfare** $W(d,g) = r(d,g) - c(d) - e(g)$
- **Profits** $\pi(d) = r(d,g) - c(d)$ (zero π', externality e)

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Commitment (first best)

1. **Government** commits to $g^* > 0$ (or τ^*)
2. **Developers** develop $d^*(g^*) > 0$ (or $d^{\tau *}$)

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

- But government defends ex post (even absent politics)
- And developers lobby ex post (rezoning, NFIP 2.0)

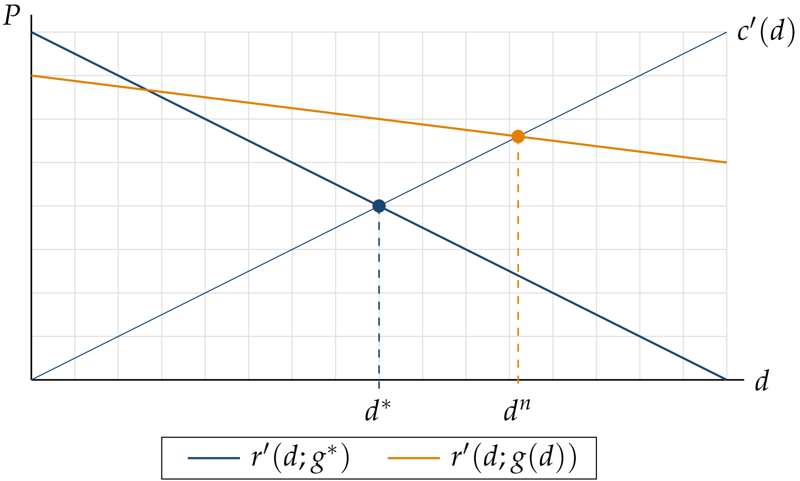
No commitment

1. **Developers** develop $d^n > d^*$
2. **Government** defends $g^n(d^n) > g^*$

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

- Government time inconsistency: static gain, dynamic cost $(g'(d) > 0)$
- Developer moral hazard: coastal lock-in, delayed adaptation ($g'(d)$ magnifier)

Over-development without commitment



Empirics

Empirical framework

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

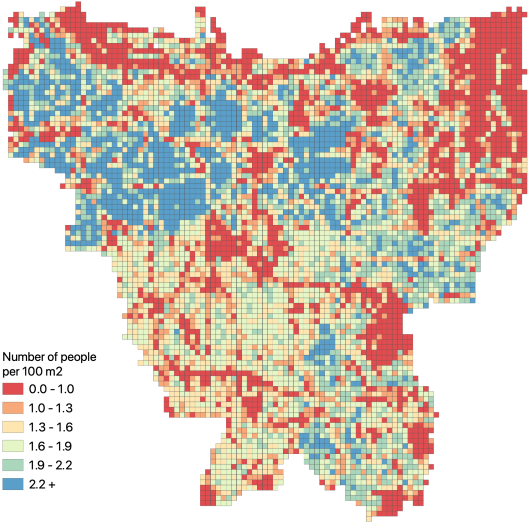
- $r(d, f(g))$: **spatial model** of residential demand
- $f(g)$: **hydrological model** of flood risk
- $c(d)$: **dynamic model** of developer supply
- $e(g)$: **engineering estimates**

Demand from residents

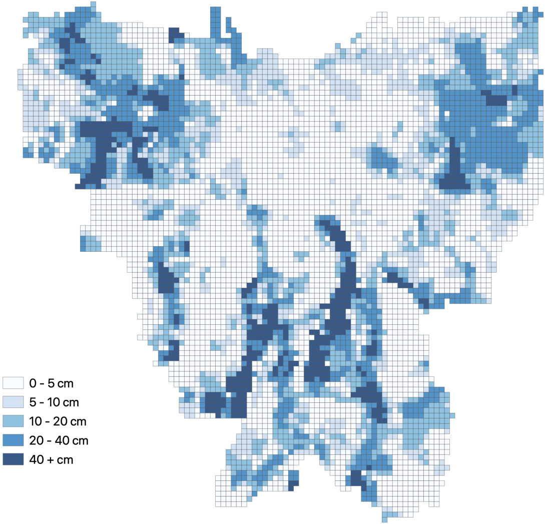
$$U_{ijk} = \underbrace{\alpha r_k + \phi f_k + x_k \gamma + \varepsilon_k}_{\delta_k} + \tau m_{jk} + \epsilon_{ijk}$$

- **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
  - Can endogenize observed amenities
- **Estimation** with 2020 population shares and instruments (BLP 1995) Details
  - Price endogeneity from correlation of rents and unobserved amenities
  - IV with ruggedness as supply shifter

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

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

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

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

- **Dynamic model** of 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

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

$$\begin{aligned}
\ln p^{1}_{kt} - \ln p^{0}_{kt} &= v^{1}_{kt}(D,L) - v^{0}_{kt}(D,L) \\
&= -c_{kt}(x,\varepsilon) + \beta \mathbb{E}[V_{kt+1}(D+1,L-1) - V_{kt+1}(D,L)] \\
&= -c_{kt}(x,\varepsilon) + \alpha\beta \mathbb{E}[P^{D}_{kt+1} - P^{L}_{kt+1}] \\
&= -c_{kt}(x,\varepsilon) + \alpha\beta (P^{D}_{kt} - P^{L}_{kt})
\end{aligned}$$

- 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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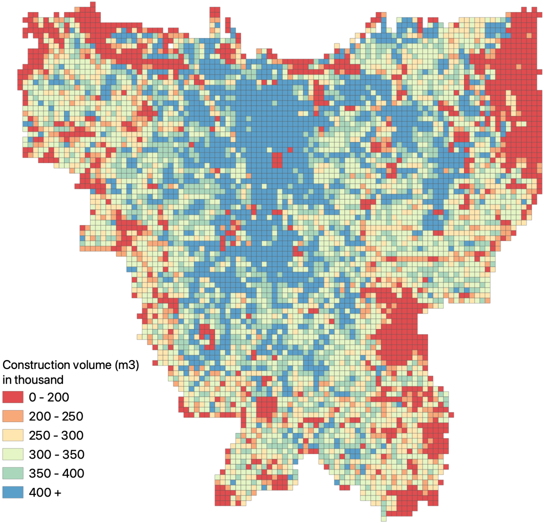
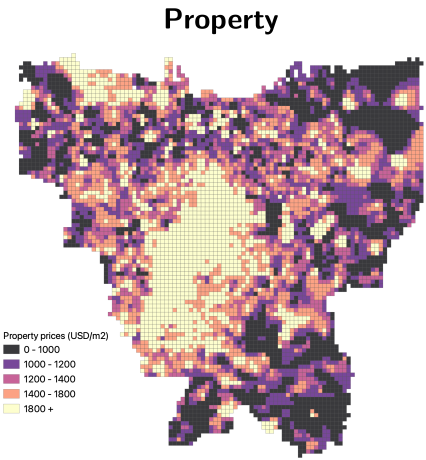
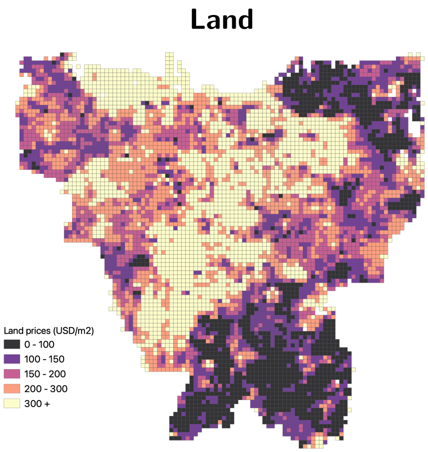
Building construction (global data)



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	

Government

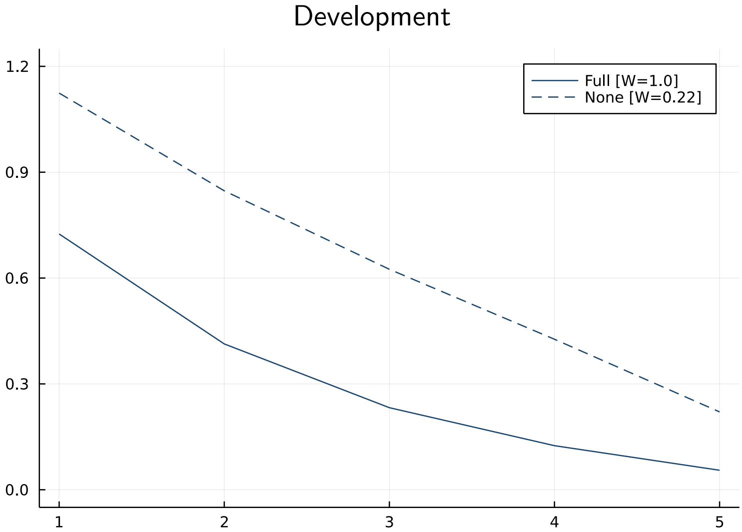
- Commitment level and political turnover by assumption
  - Hydrological model of flood risk
  - Engineering estimates of costs
  - Equilibrium rents

- Counterfactuals (need to solve model)

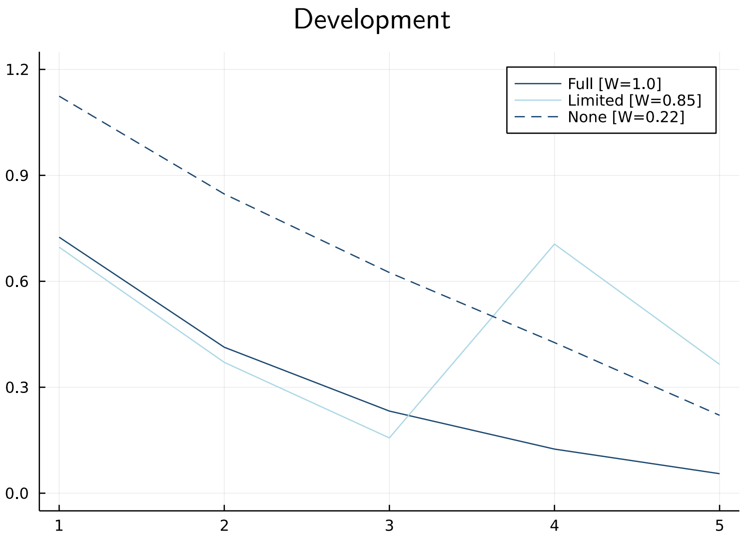
$$\begin{aligned} \text{Defense } g &\rightarrow \text{ flooding } s \text{ by } \textbf{hydrological} \text{ model} \\ &\rightarrow \text{ rents } r \text{ by } \textbf{demand} \text{ model} \\ &\rightarrow \text{ development } d \text{ by } \textbf{supply} \text{ model} \end{aligned}$$

Simulations

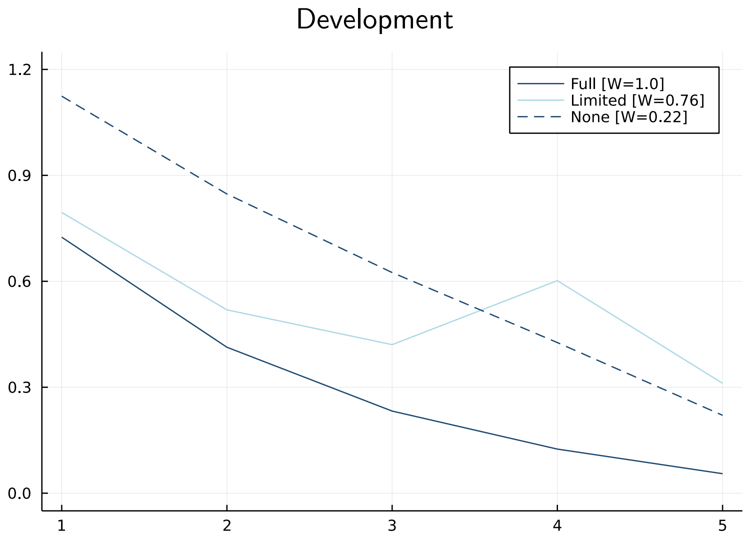
Commitment over time



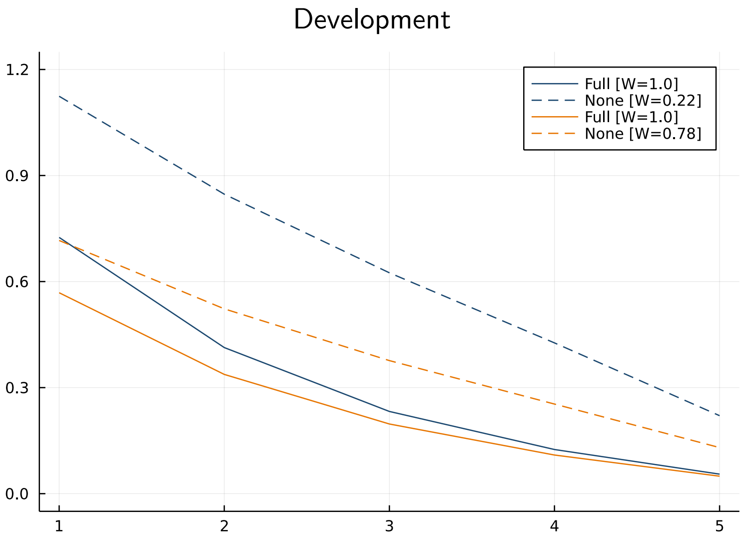
Limited commitment (forward-looking)



Limited commitment (political myopia)



Reducing coastal demand



Policy implications

1. Political economy matters
    - Commitment is simple in theory, but difficult in practice
    - Politics can hinder adaptation and exacerbate damages
2. Some policies are more politically feasible
    - Encourage vs. punish, indirect vs. direct (e.g., inland subsidies)
    - Even if below the theoretical first best

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)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