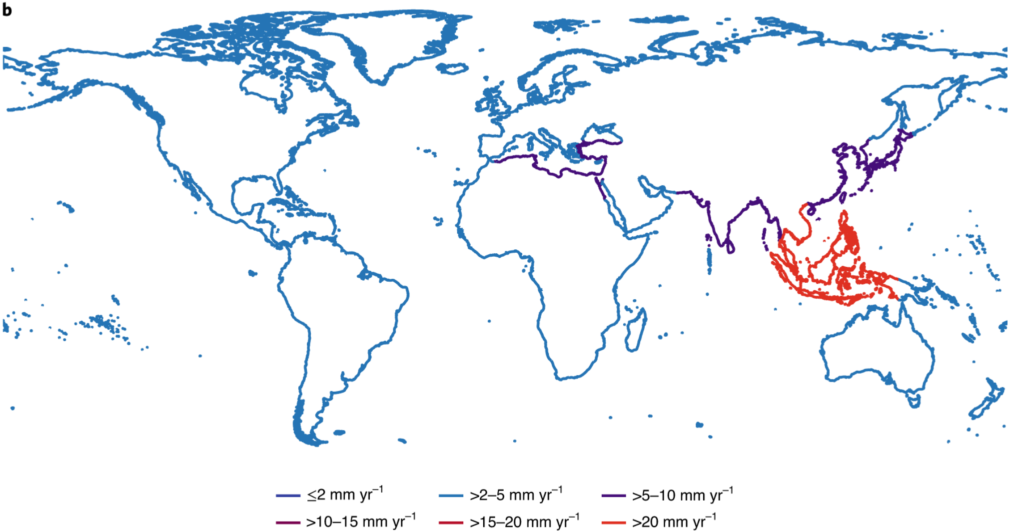
Sea Level Rise and Urban Adaptation in Jakarta

Allan Hsiao
Princeton University

March 11, 2023

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




#CLIMATE NO JUSTICE

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

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

1. **Theory**
2. **Empirics**
3. **Simulations**

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)

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)

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)

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)

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)

Commitment

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)

Commitment over time

1. Developer moral hazard
   - Developers exploit both current and future governments (commitment)
   - Development today raises development tomorrow (persistence)

2. Government moral hazard
   - Current government can exploit future governments (political myopia)
   - Current government can help future governments (forward-looking)

Empirics

Empirical framework

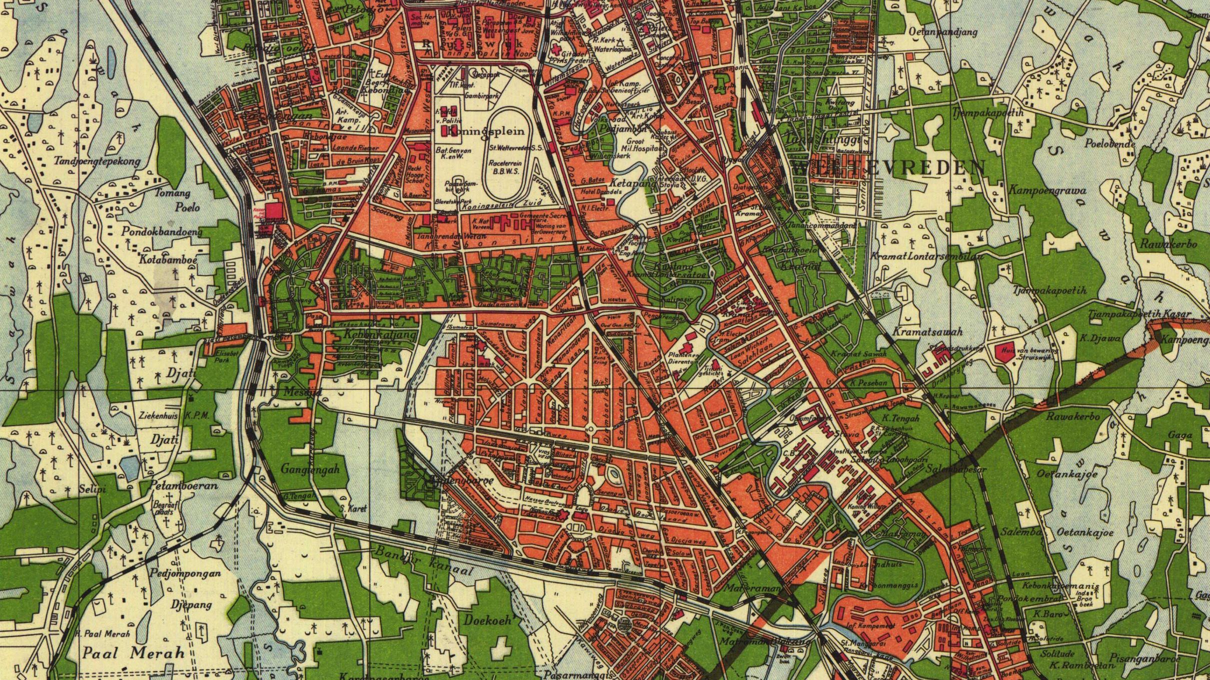
$$W = r(d, g) - c(d) - e(g)$$

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

An historical example

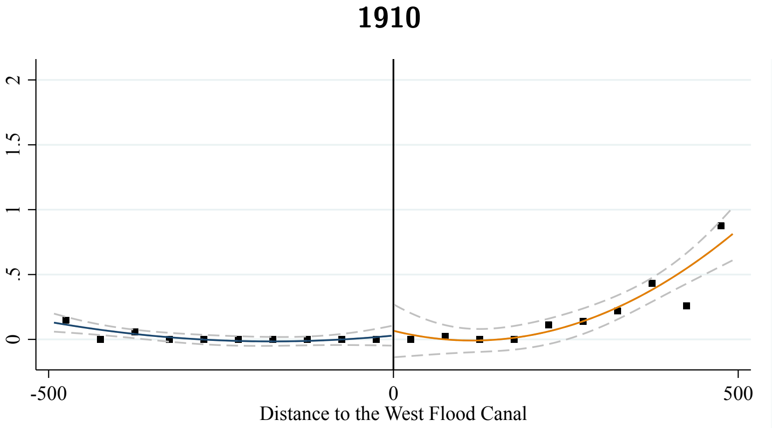
- Has government intervention increased development before? $(g \rightarrow d)$
  - West Flood Canal (1918)
  - Land development from Dutch colonial maps (1887-1945)

- Spatial regression discontinuity
  - Flood protection for the north, but not the south
  - By diverting floodwaters that flow south to north

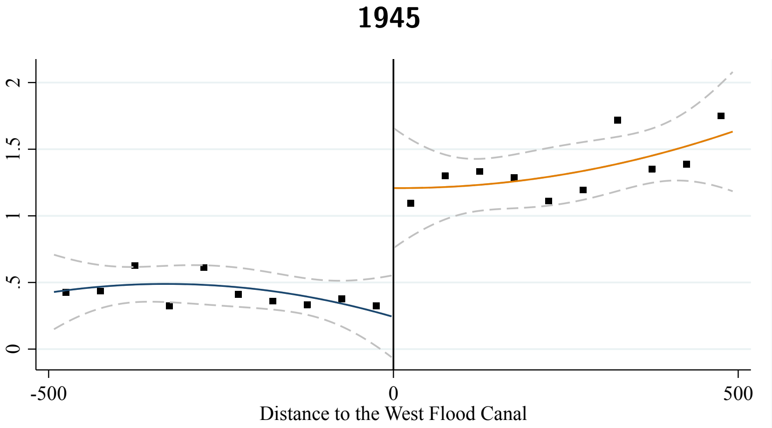


Koningsplein
WELTEVREDEN
Tandjongtepekong
Tomang
Poelo
Pondokbandoeng
Kotabamboe
Kebonkatjang
Djati
Mesdjid
Ziekenhuis
Gangtengah
Selipi
Petamboeran
Pedjompongan
Djepang
Paal Merah
Bandjir kanaal
Doekoeh
Materaman
Pegangsaan
Kampoengrawa
Poelobende
Tjempakapoetih
Rawakerbo
Kramat Lontarsembilan
Kramatsawah
Salembabesar
Salemba
Oetankajoe
Kebonkapemanis
Pisanganbaroe
Oetanpandjang
Ketapang
Pedjambon
Raceterrein B.B.W.S.
St.Weltevreden S.S.
Gambirpark
Koningsplein Zuid
Tanahabang
Kwitang
Kalipasir
Planten en Dierentuin
St. Manggarai
Pasarmanggis
Solitude
K. Djawa
K. Tengah
K. Baro
Rawakerbo
Gaga

West Flood Canal (1918)



West Flood Canal (1918)

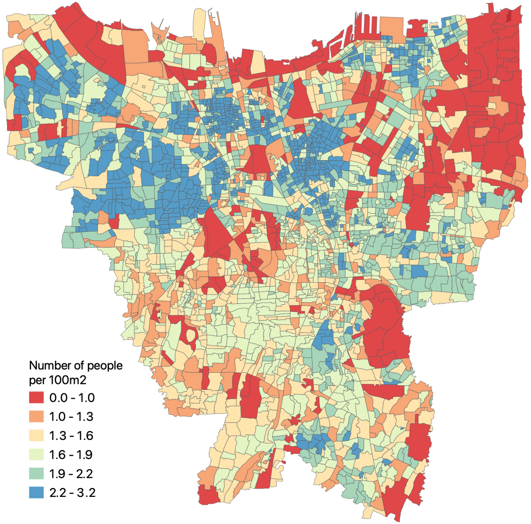


Demand from residents

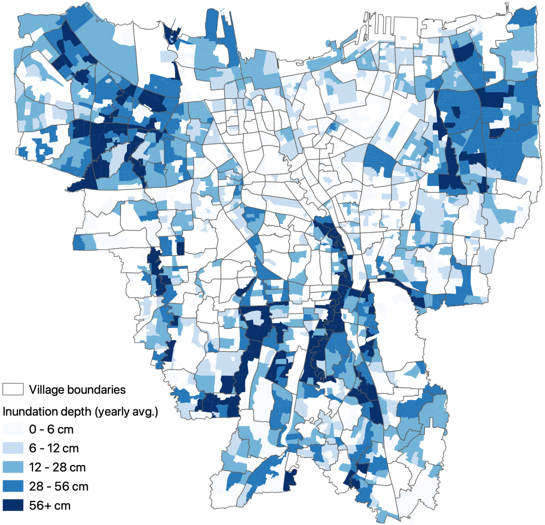
$$U_{ijk} = \underbrace{\alpha r_k + \phi f_k + x_k \gamma + \varepsilon_k}_{\delta_k} + \tau m_{jk} + \epsilon_{ijk}$$

- **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

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

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

Data as continuation values

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

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

- Simple IV estimation
  - Need efficient real estate market ($P \to V$, frictions as ε)
  - And atomistic developers (P as data, 14k developers)
  - And short-run rational expectations (P as market offer)

Data as continuation values

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

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

- Simple IV estimation
  - Need efficient real estate market ($P \to V$, frictions as ε)
  - And atomistic developers (P as data, 14k developers)
  - And short-run rational expectations (P as market offer)

Data as continuation values

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

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

- Simple IV estimation
  - Need efficient real estate market ($P \to V$, frictions as ε)
  - And atomistic developers (P as data, 14k developers)
  - And short-run rational expectations (P as market offer)

Data as continuation values

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

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

- Simple IV estimation
  - Need efficient real estate market ($P \to V$, frictions as ε)
  - And atomistic developers (P as data, 14k developers)
  - And short-run rational expectations (P as market offer)

Data as continuation values

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

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

- Simple IV estimation
  - Need efficient real estate market ($P \to V$, frictions as ε)
  - And atomistic developers (P as data, 14k developers)
  - And short-run rational expectations (P as market offer)

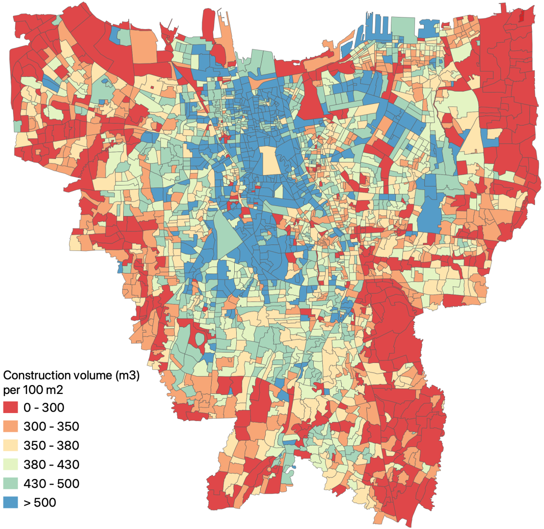
Data as continuation values

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

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

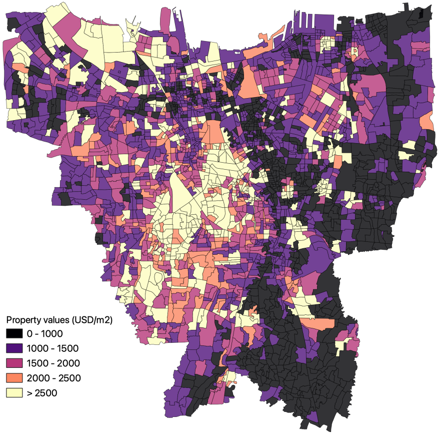
- Simple IV estimation
  - Need efficient real estate market ($P \to V$, frictions as ε)
  - And atomistic developers (P as data, 14k developers)
  - And short-run rational expectations (P as market offer)

Building construction (global data)

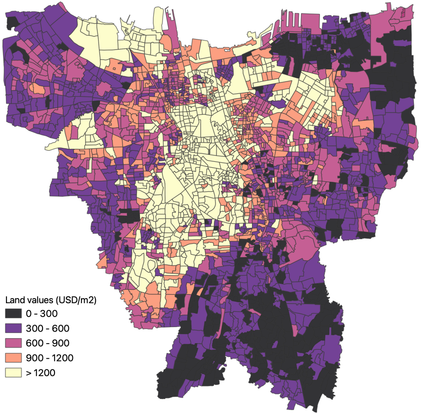


Real estate prices (urban data)

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	

Comparing approaches

Estimation	Speed	Expectations
Full-solution (NFP)	Slow	Specified
Two-step (BBL)	Fast	Specified
Euler CCPs	Fast	Rational (LR)
Baseline	Fast	Rational (SR)

(transparent identification)

Government

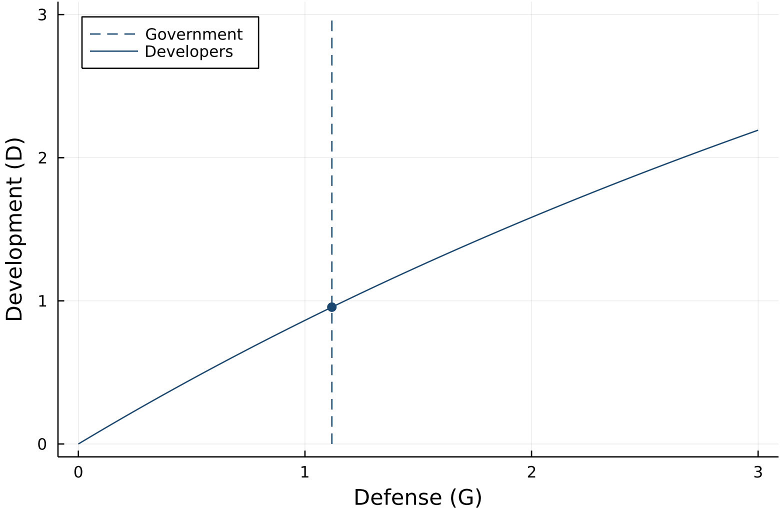
- Commitment level and political turnover by assumption
  - Hydrological model of flood risk $s_k(G)$
  - Engineering estimates of costs $e(G)$
  - Equilibrium rents clear markets for development

- Counterfactuals (need to solve model)

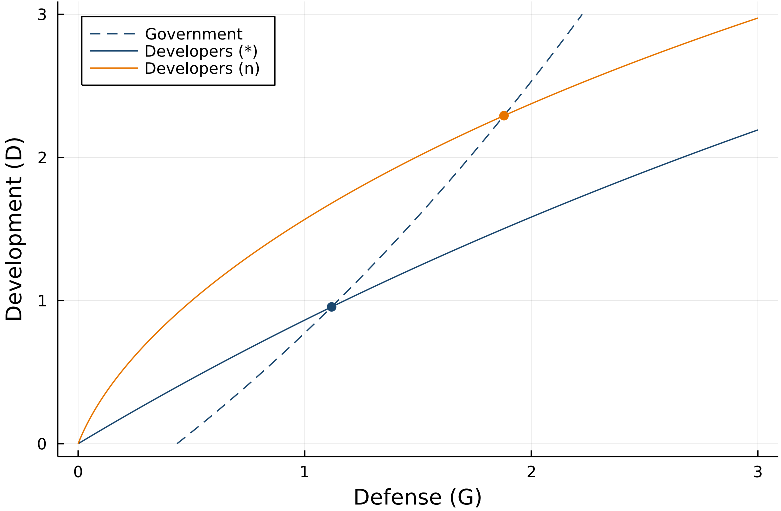
$$\begin{aligned} \text{Defense } g &\rightarrow \text{ flooding } s \text{ by } \textbf{hydrological} \text{ model} \\ &\rightarrow \text{ rents } r \text{ by } \textbf{demand} \text{ model} \\ &\rightarrow \text{ development } d \text{ by } \textbf{supply} \text{ model} \end{aligned}$$

Simulations

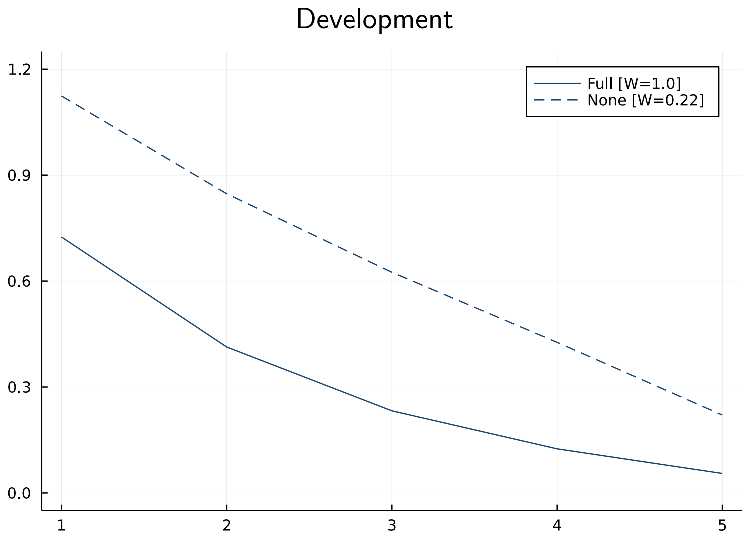
Commitment



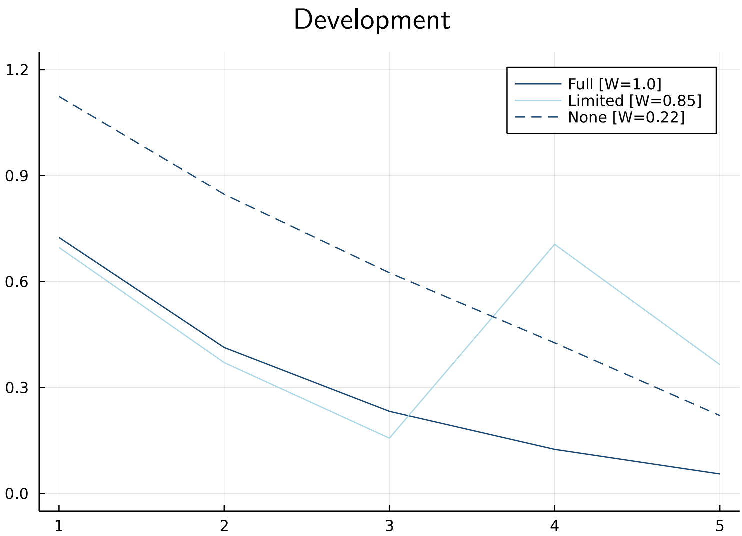
No commitment



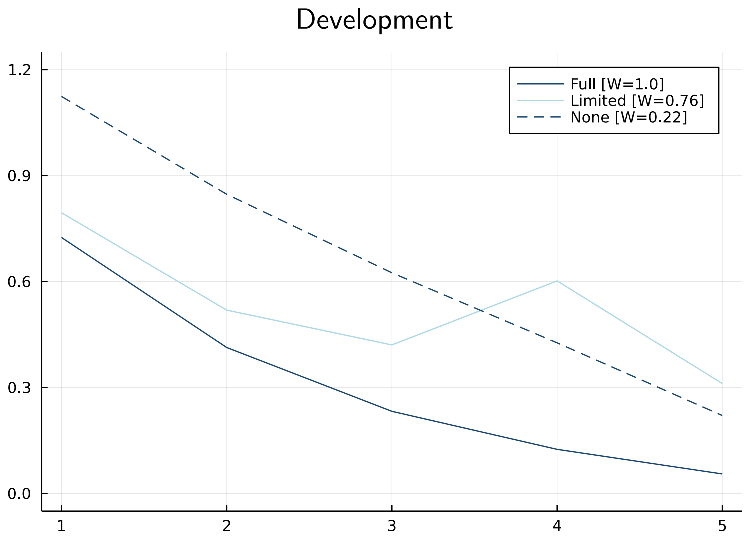
Commitment over time



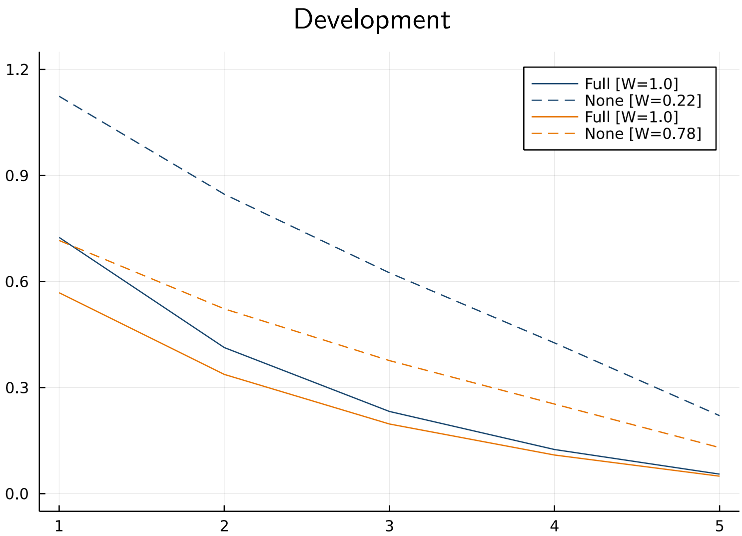
Limited commitment (forward-looking)



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
3. Policy has dynamic effects
   - Persistence amplifies good policy, even if temporary
   - Interactions across administrations add to moral hazard

Conclusion

Summary

- **Major frictions impede adaptation** to climate change
  - Government intervention induces moral hazard and lock-in
  - Commitment helps but faces political challenges

- **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)


#CLIMATE NO JUSTICE


TAN-SER
SMPI 187
HARKAS