

Sea Level Rise and Urban Adaptation in Jakarta

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Motivation

- **Sea level rise threatens 1B people by 2050** (IPCC 2019)
 - 680M people in low-elevation coastal zones today
- Jakarta will be 35% below sea level by 2050 (Andreas et al. 2018)
 - World's second largest city at 31M (first by 2030)
 - In response, \$40B in proposed infrastructure investments
- **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, Vigdor 2008, Kocornik-Mina et al. 2020, Balboni 2021, Castro-Vicenzi 2022, Jia et al. 2022, Peltzman 1975, Kousky et al. 2006, Boustan et al. 2012, Kousky et al. 2018, Baylis & Boomhower 2022, Fried 2022, Mulder 2022, Wagner 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

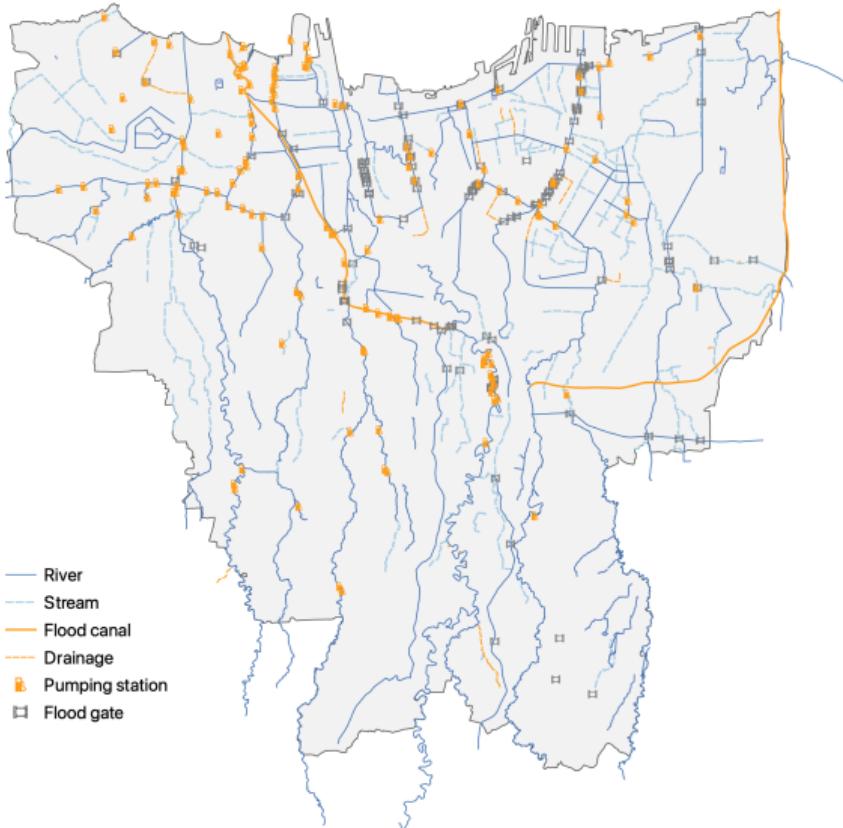
- ① Setting
- ② Theory
- ③ Empirics
- ④ Simulations

Setting



Flood infrastructure

- 1918: West flood canal
- 1960: dams/reservoirs
- 1978: drainage canals
- 2002: East flood canal
- 2011: **sea wall plans**
- 2019: Nusantara plans



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

Wing Park Neighbourhood Waterfront Neighbourhood

Head of Garuda

Wing Park Neighbourhood

Maritime Communities

Core Area

Creative HQ and Research

Tail Area

Creative Living Park

Target Konstruksi

Tahap A

Konstruksi: 2014-2017
Flood safety: 2030

Tahap B

Konstruksi: 2018-2022
Flood Safety: 2030

Tahap C

Konstruksi: 2022



Theory

Coastal development and defense

- ① **Developers** develop d at cost $c(d)$ for $c'' > 0$ (atomistically)
 - ② **Government** defends g at cost $f(g)$ for $f'' > 0$ (wall or otherwise)
 - ③ **Residents** receive $r(d, g)$ for $r_{dg} > 0$ (demand $r'(d; g)$, shifter g)
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- **Welfare** $W(d, g) = r(d, g) - c(d) - f(g)$
 - **Profits** $\pi(d) = r'(d) - c'(d) + r'(g)g'(d)$ (competed away, no f)

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Moral hazard

- The **social planner** maximizes $W(d, g) = r(d, g) - c(d) - f(g)$

$$[d^*] \quad r'(d) = c'(d)$$

$$[g^*] \quad r'(g) = f'(g)$$

- Developers consider $\pi(d)$, and government $W(g; d)$

$$[d^n] \quad r'(d) + r'(g) g'(d) = c'(d)$$

$$[g^n] \quad r'(g) = f'(g)$$

- Moral hazard when $g'(d) > 0$ implies $d^n > d^* > 0, g^n > g^* > 0$

Moral hazard

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Commitment + challenges

- Solution 1: **commit** to g^*
 - $g'(d) = 0$ implies $r'(g) g'(d) = 0$
 - But optimal for government to protect over-development ex post
 - [If $g(d) = 0$, no moral hazard but also no intervention to begin with]
- Solution 2: **commit** to d^*
 - By taxing or restricting development
 - But developers will lobby against enforcement ex post

Empirics

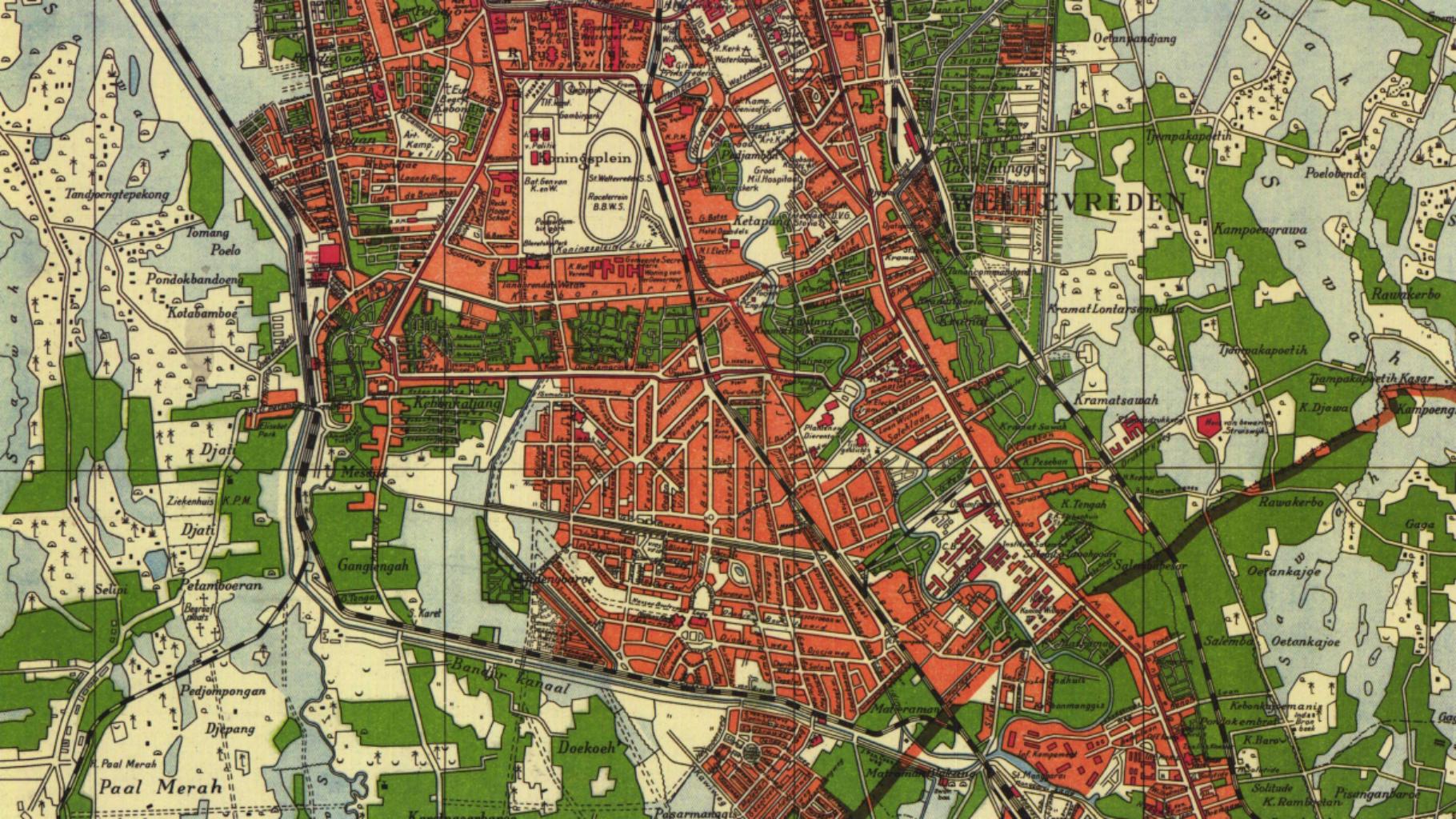
Empirical framework

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

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

High-resolution spatial data (2015/2020)

Variable	Source	Map
Building construction	GHSL	Map
Populations	GHSL	Map
Property values	99.co, brickz.id	Map
Land values	Jakarta Smart City	Map
Flood risk	Hydrological model	Map



Demand from residents

$$U_{ijk} = \underbrace{-\alpha r_k + \rho s_k + \xi_k}_{\delta_k} - \tau m_{jk} + \epsilon_{ijk}$$

- **Spatial model** of residential choice (individual i , origin j , destination k)
 - Static renters consider rents, flood safety, amenities, distances, logit shocks
 - Moving inland abandons high-amenity places and incurs migration costs
 - Will add firms to endogenize (some) amenities
- **Estimation** with 2020 population shares and instruments (BLP 1995)
 - Price endogeneity from correlation of rents and unobserved amenities
 - IV with soil quality and ruggedness as supply shifters

Details

Supply from developers

$$V_k(w_t) = r_k(w_t)D_{kt} + \mathbb{E}_{kt}[\max\{v_k^1(w_t) + \epsilon_{kt}^1, v_k^0(w_t) + \epsilon_{kt}^0\}]$$

$$v_k^1(w_t) = -c(x_{kt}, \zeta_{kt}) + \beta \mathbb{E}_{kt}[V_k(w_{t+1}^1)]$$

$$v_k^0(w_t) = \beta \mathbb{E}_{kt}[V_k(w_{t+1}^0)]$$

- **Dynamic model** of developer choice (tract k , time t , $\mathbb{E}_{kt} = \mathbb{E}_k[\cdot | w_t]$)
 - Developer-landlords consider state $w_t = (\{D_{kt}\}, \{G_{kt}\})$, rents, costs, logit shocks
 - 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 resident demographics as demand shifters

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Data as continuation values

$$\ln p_{kt}^1 - \ln p_{kt}^0 = v_k^1(w_t) - v_k^0(w_t)$$

$$v_k^1(w_t) = -c_{kt} + \beta \mathbb{E}_{kt}[V_k(w_{t+1}^1)]$$

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- Estimation by linear IV: property vs. land values as (V^1, V^0)
 - Assuming competitive real estate markets with rational expectations
 - And atomistic developers

Data as continuation values

$$\ln p_{kt}^1 - \ln p_{kt}^0 = -c(x_{kt}, \zeta_{kt}; \theta) + P_{kt}^1 - P_{kt}^0 + \eta_{kt}$$

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Comparing approaches

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

Counterfactuals

- Government maximizes social welfare, given commitment and horizon

Defense $g \rightarrow$ flooding s by **hydrological** model

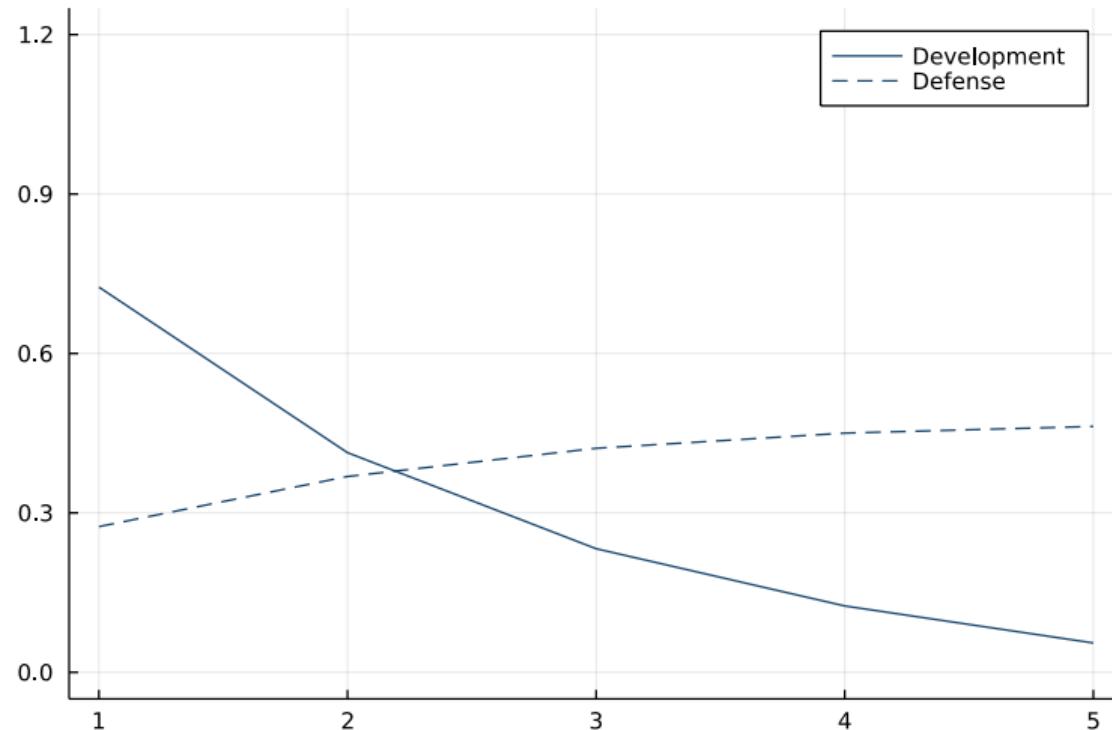
\rightarrow rents r by **demand** model

\rightarrow development d by **supply** model

Simulations

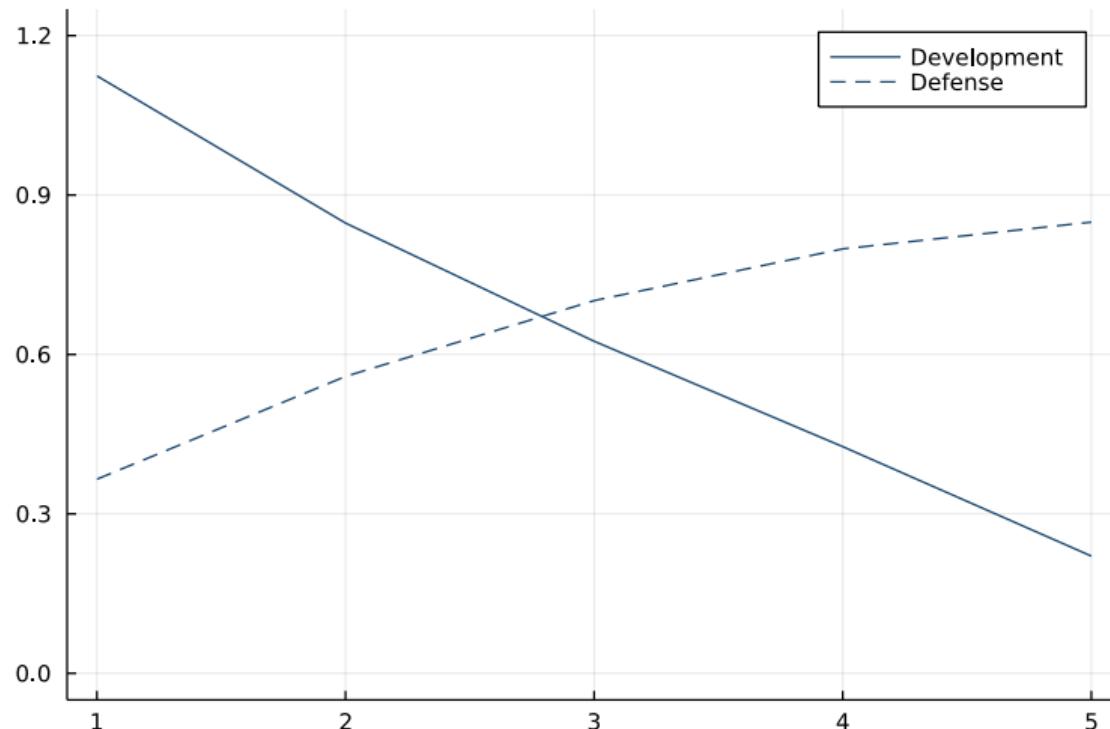
Coastal development and defense

Full commitment



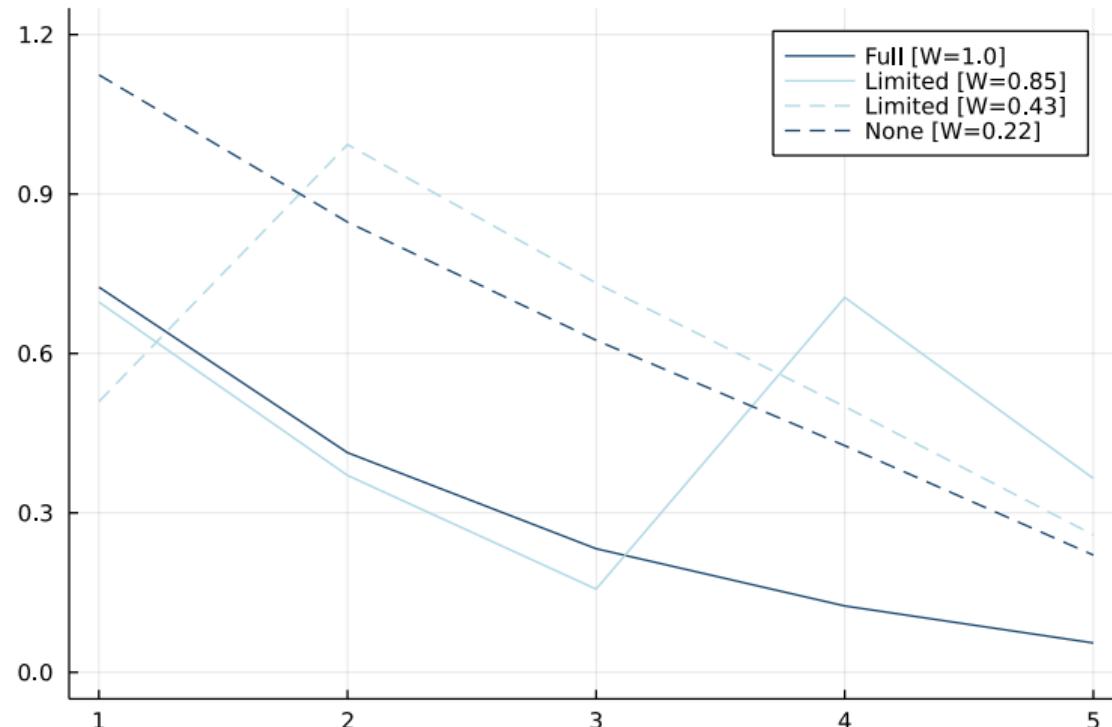
Coastal development and defense

No commitment



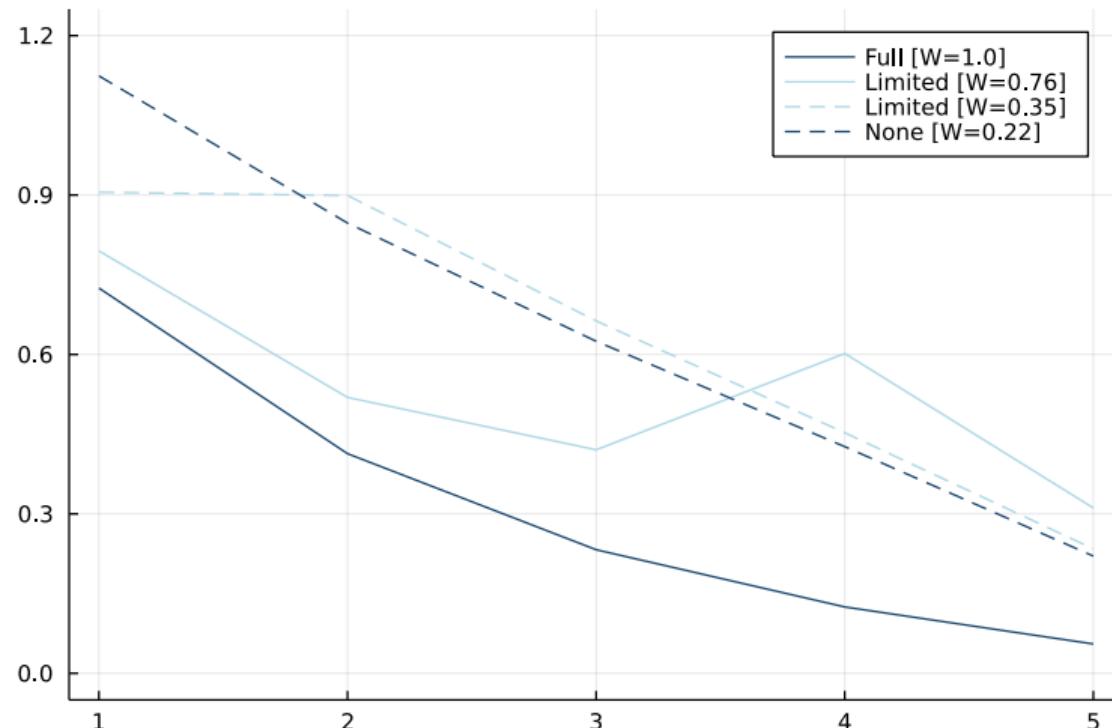
Limited commitment

Development (forward-looking)



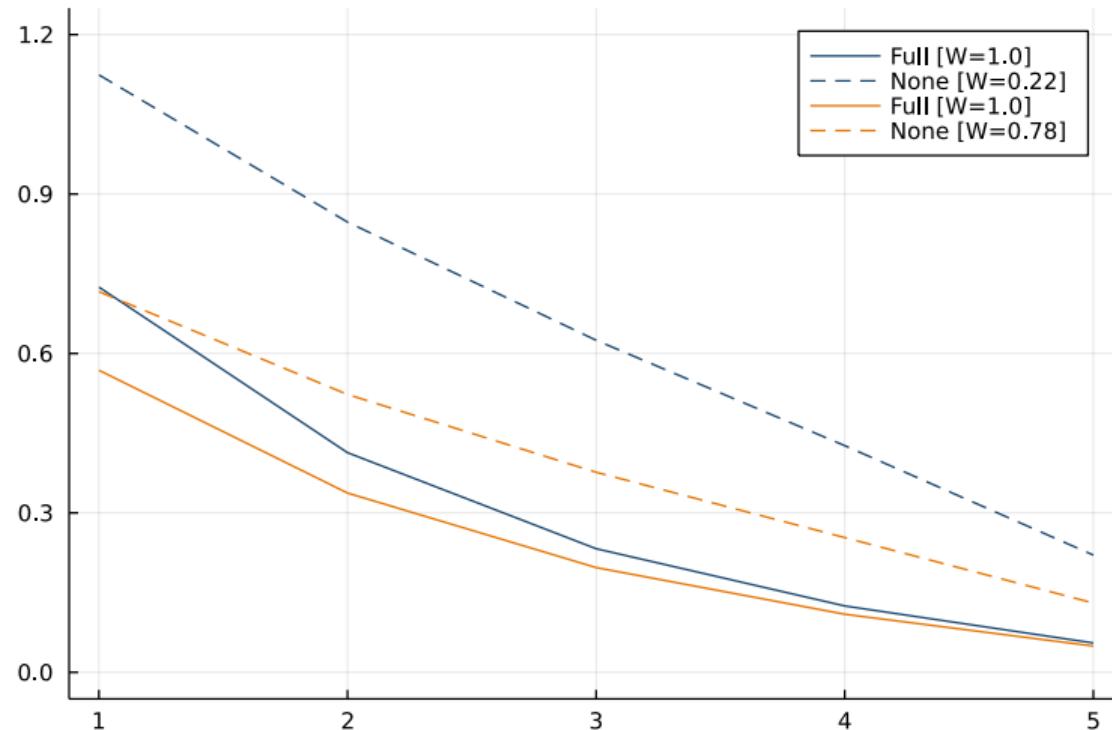
Limited commitment

Development (politically myopic)



Reducing coastal demand

Development



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)





Appendix

Commitment over time

Consider two periods. Welfare and profits for $\bar{D}_1 = 0$ are

$$W_1 = [r(G_1) + \beta r(G_2)]D_1 - c(D_1) - f(G_1),$$
$$\pi_1 = [r(G_1) + \beta r(G_2)]D_1 - c(D_1),$$

The **social planner** chooses (D_1, G_1, D_2, G_2) to maximize $W_1 + \beta W_2$.

Otherwise, **moral hazard**. Period two same as before; period one worse.

- ① D_1 does not internalize $f(G_1)$ or $f(G_2)$
- ② G_1 may not internalize $f(G_2)$

Commitment over time

Consider two periods. Welfare and profits for $\bar{D}_1 = 0$ are

$$W_2 = r(G_2)D_2 - c(D_2) - f(G_2),$$
$$\pi_2 = r(G_2)D_2 - c(D_2).$$

The **social planner** chooses (D_1, G_1, D_2, G_2) to maximize $W_1 + \beta W_2$.

Otherwise, **moral hazard**. Period two same as before; period one worse.

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Commitment over time (2)

Commitment for $t = 1, 2$: choose (D_1, G_1, D_2, G_2) to max $W_1 + \beta W_2$.

$$[D_1^*] \quad \tilde{r}(G_1, G_2) = c'(D_1)$$

$$[G_1^*] \quad r'(G_1)D_1 = f'(G_1)$$

$$[\tilde{r}(G_1, G_2) = r(G_1) + \beta r(G_2)]$$

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Commitment for $t = 1$: choose (D_1, G_1) to max $W_1 + \beta W_2$, then G_2 to max W_2 .

$$[D_1] \quad \tilde{r}(G_1, G_2) = c'(D_1) + \beta r'(G_2)D_2G'_2$$

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No commitment + political myopia: choose G_1 to max W_1 , then G_2 to max W_2 .

$$[D_1] \quad \tilde{r}(G_1, G_2) + r'(G_1)D_1G'_1 + \beta r'(G_2)D_1G'_2 = c'(D_1)$$

$$[G_1] \quad r'(G_1)D_1 + \beta r'(G_2)D_1G'_2 = f'(G_1)$$

Commitment over time (3)

Lock in: over-development today raises development tomorrow.

$$\begin{aligned}[D_2] \quad & r(G_2) + r'(G_2)D_2 G'_2 = c'(D_2), \\ [G_2] \quad & r'(G_2)(D_1 + D_2) = f'(G_2),\end{aligned}$$

$D_1 \uparrow$ implies $G_2 \uparrow$ given more to defend.

Then $D_2 \uparrow$ implies $G_2 \uparrow\uparrow$ given strategic complementarity $\left(\frac{\partial D_2}{\partial G_2}, \frac{\partial G_2}{\partial D_2} > 0\right)$.

Back

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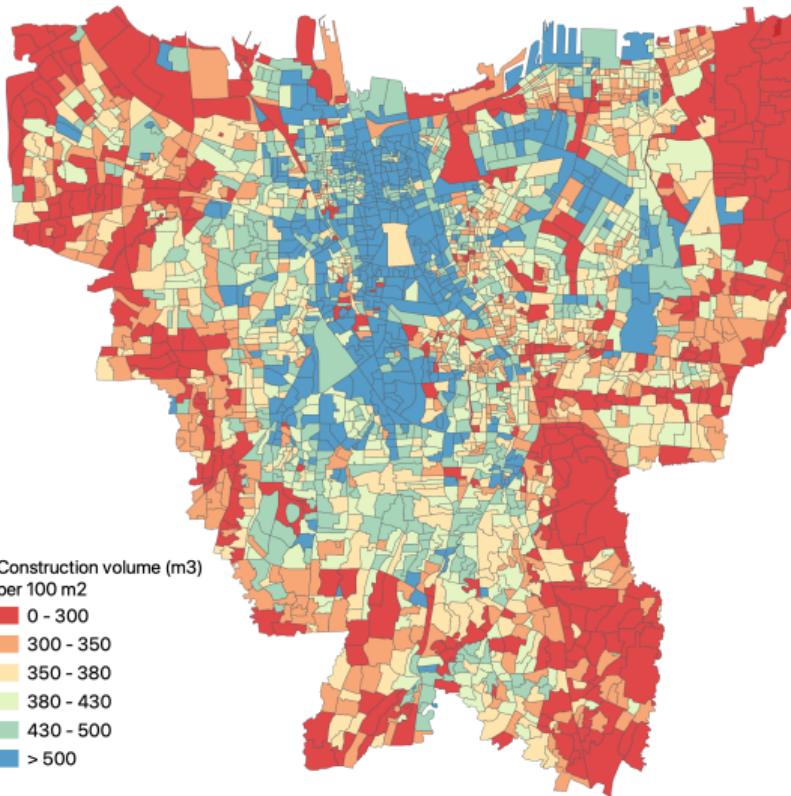
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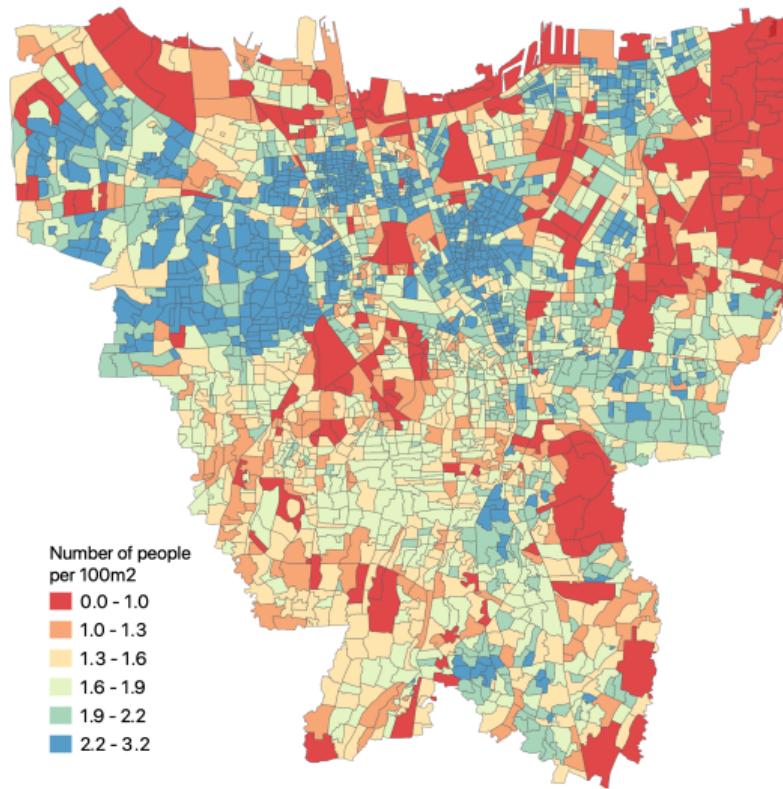
Building construction

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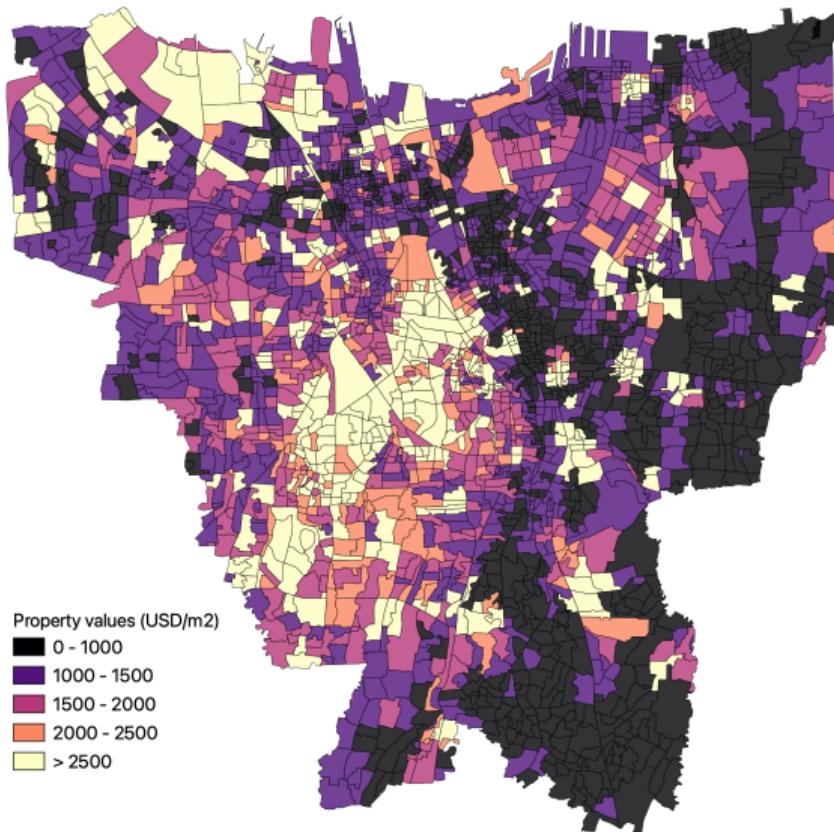
Populations

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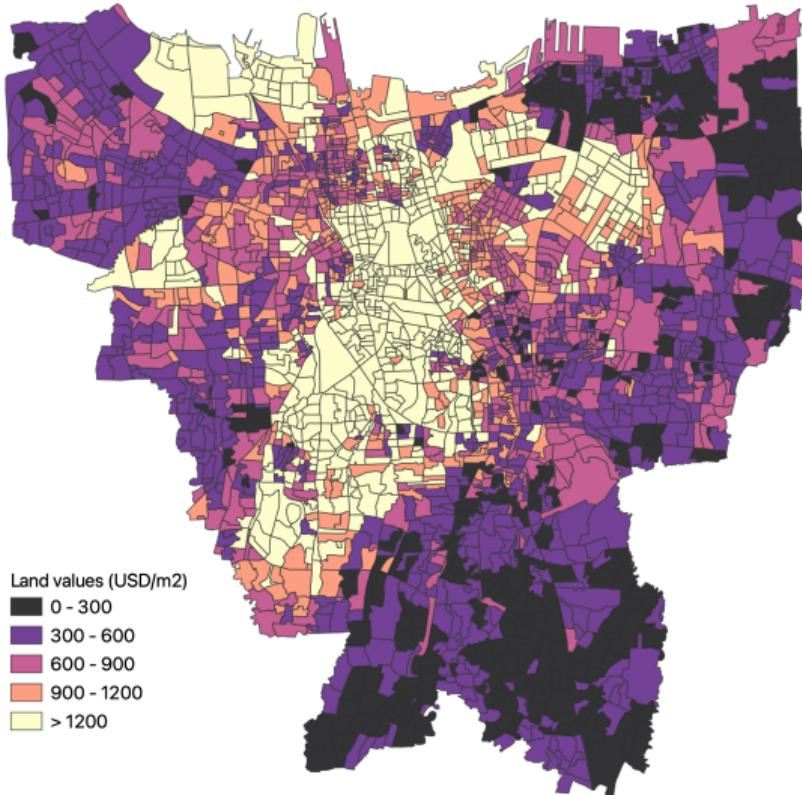
Property values

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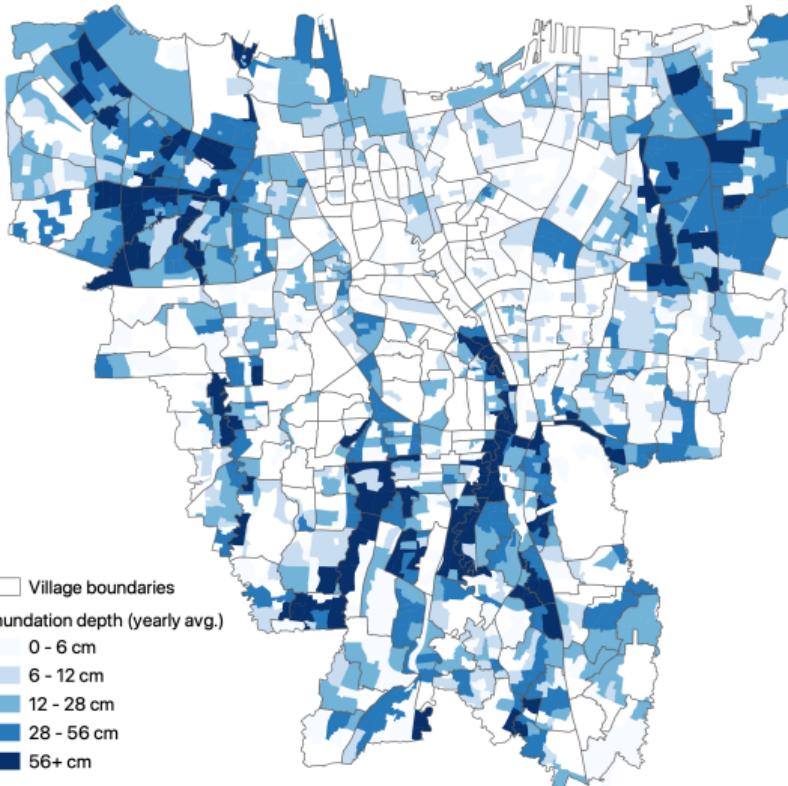
Land values

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Flood risk

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Estimating demand

- Origin populations with 2015 data, destination populations with 2020 data
- Focus on core, but allow one choice aggregating over periphery

① Given $\theta_2 = \tau$, estimate δ by contraction mapping

$$\text{population}_k = \frac{1}{\phi} D_k^{\text{res}}(\delta, \theta_2)$$

② Estimate $\theta_1 = (\alpha, \rho)$ and ξ by regression

$$\xi_k = \delta_k + \alpha r_k - \rho s_k$$

③ Estimate θ_2 by minimizing GMM objective function

$$Q(\theta) = g(\xi(\theta))' W g(\xi(\theta)) \quad \text{for} \quad \mathbb{E}[Z\xi(\theta)] = 0$$

Demand estimates

First stage	Rents	IV	Population
Ruggedness	0.010*** (0.001)	Rents	-0.113*** (0.019)
Flood safety	7.888** (4.018)	Flood safety	1.031** (0.507)
Coastal distance	-0.630*** (0.082)	Coastal distance	-0.072*** (0.016)
District FE	x	District FE	x
Observations	2,181	Observations	2,181
F-stat	76.38		