# Sea Level Rise and Urban Adaptation in Jakarta

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#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)
    - 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

# Theory of coastal development and defense

1. **Developers** develop $d$ at cost $c(d)$ for $c'' > 0$ (atomistically)
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** $\pi(d) = r(d, g) - c(d)$ ($\pi' = 0$)

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# Moral hazard

- **First best** maximizes $W(d,g) = r(d,g) - c(d) - e(g)$

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

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

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

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

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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

# Empirical framework

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

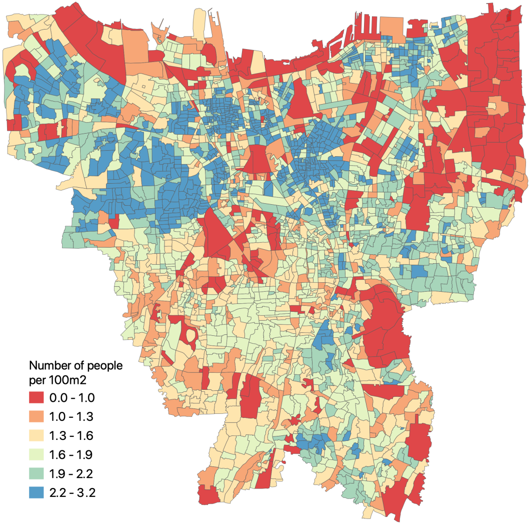
- $r(d, f(g))$: **spatial model** of residential demand
- $f(g)$: **hydrologic model** of flood risk
- $c(d)$: **dynamic model** of developer supply
- $e(g)$: **engineering estimates**

# Demand from residents

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

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

# Populations



# Supply from developers

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

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

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

- **Dynamic model** of developer choice (tract $k$, time $t, t'$)
  - 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 resident demographics as demand shifter

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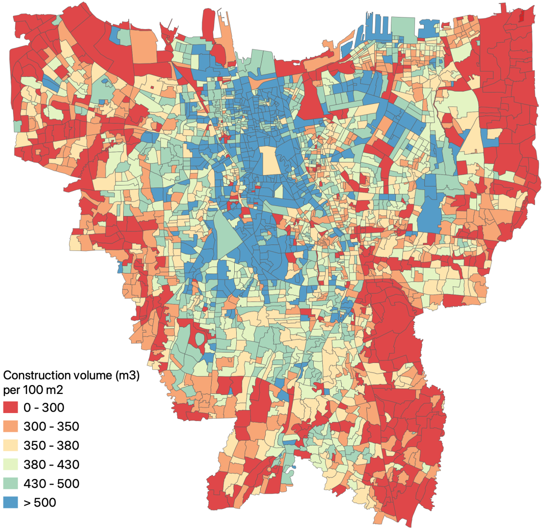
# Data as continuation values

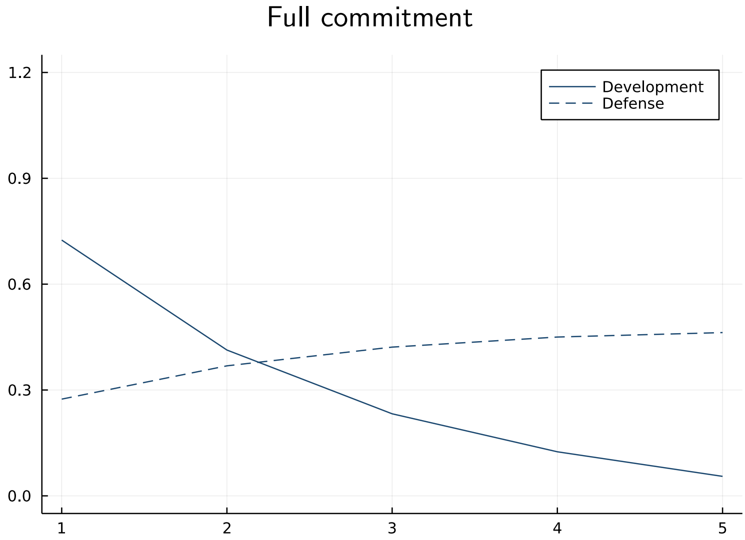
$$\begin{aligned}\ln p_{kt}^1 - \ln p_{kt}^0 &= v_k^1(D,L) - v_k^0(D,L) \\ &= -c_{kt}(d;\varepsilon) + \beta\mathbb{E}[V_{kt+1}(D+1,L-1) - V_{kt+1}(D,L)] \\ &= -c_{kt}(d;\varepsilon) + P_{kt}^D d - P_{kt}^L d\end{aligned}$$

- Simple IV estimation
  - Key assumption: $\beta\mathbb{E}[V_{kt+1}(D+d,L-d)] = P_{kt}^D(D+d) - P_{kt}^L(L-d)$
  - Need efficient real estate markets and atomistic developers
  - Do not need rational expectations

# Building construction



# Simulated coastal development and defense



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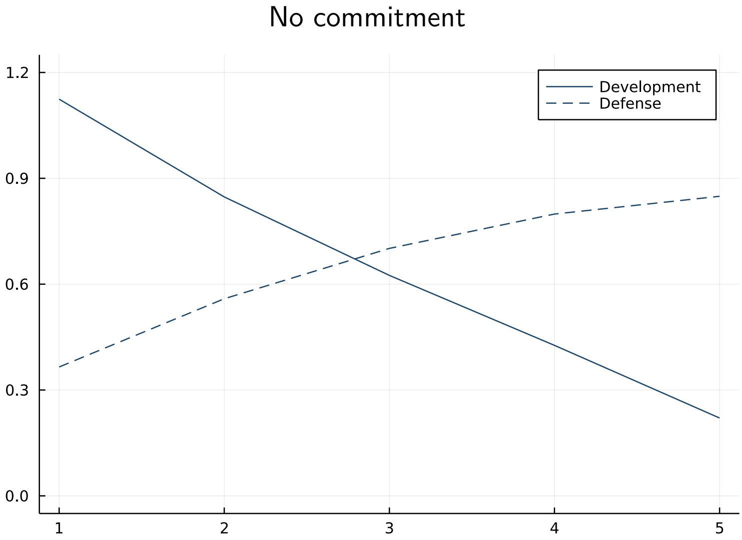
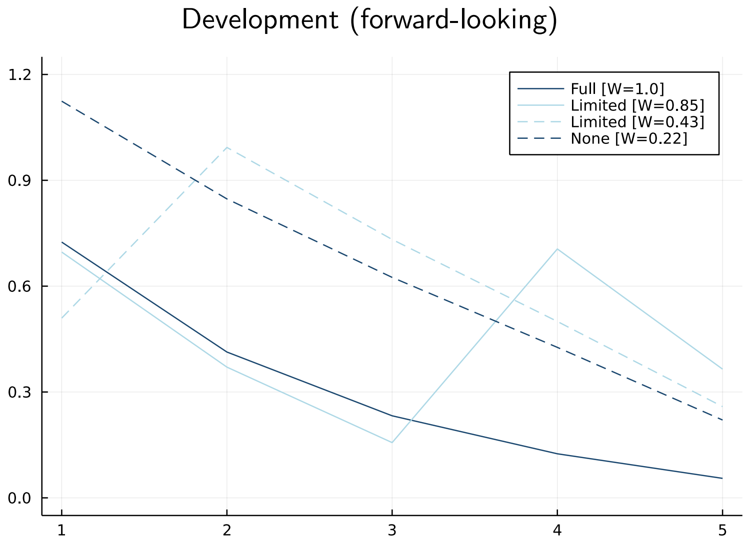


# Limited commitment



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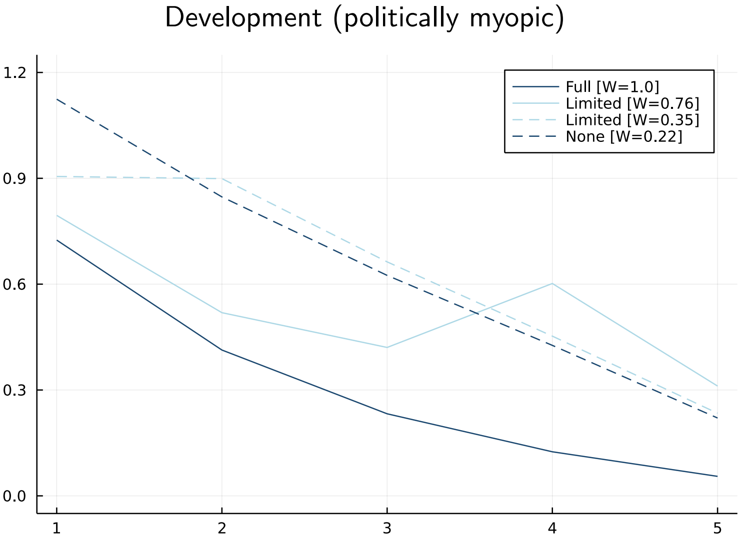
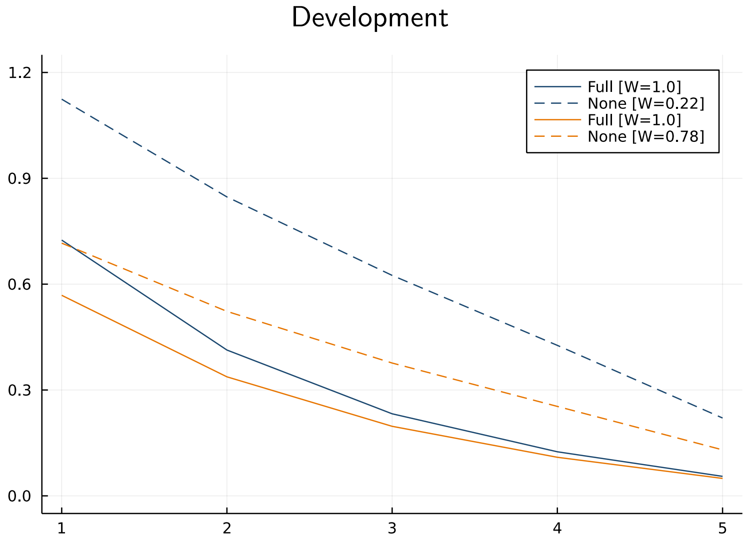


# Reducing coastal demand



# 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)