Dynamics in Trade and Space

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Two applications

1. **Deforestation** and agricultural land use
   - Palm oil and climate mitigation
2. **Sea level rise** and urban land use
   - Jakarta and climate adaptation

Dynamic elements

- **Theory**
- Data
- **Estimation**
- Counterfactuals

Deforestation

Coordination and Commitment in International Climate Action

- How effective are import tariffs as a substitute for domestic regulation?
  - Target world prices (via demand) instead of production directly
- **Leakage** and **commitment** issues
  - From incomplete regulation and sunk emissions
- **Dynamic empirical framework** for green trade policy
  - Estimated with satellite data and Euler methods

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Palm oil

- IO tradition: detergent, frozen pizza, gasoline, and other homogeneous goods
- Produced largely in Indonesia and Malaysia (85%)
  - Drives widespread deforestation
  - And destruction of carbon-rich peatlands

MARGARINE

CHOCOLATE

SOAP

BIODIESEL

COOKIES

PIZZA DOUGH

SHAMPOO

DETERGENT

PACKAGED BREAD

ICE CREAM

INSTANT NOODLES

LIPSTICK

BIODIESEL

PIZZA DOUGH

DETERGENT

Almost ideal demand system (Deaton & Muellbauer 1980)

- Demand specified in expenditure shares
  1. ω_{okt}: palm vs. other oils (soybean, rapeseed, sunflower, coconut, and olive)
  2. $\ln P_{kt}$: translog price index

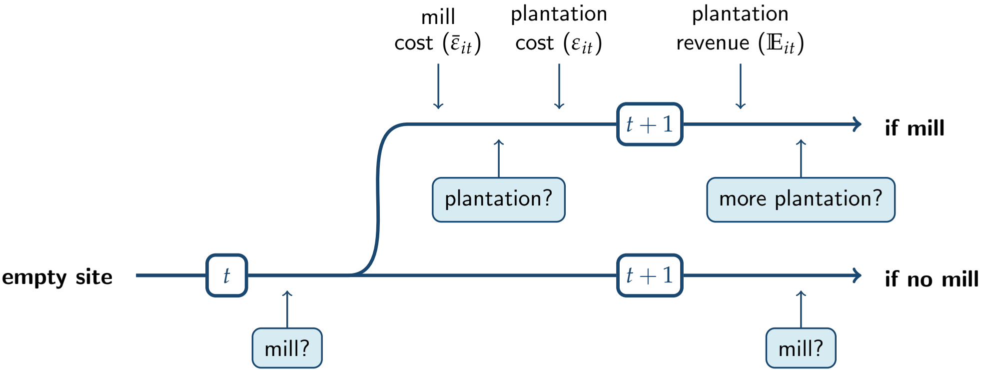
- **Estimation:** iterated linear least squares (Blundell & Robin 1999)

Dynamic supply with sunk investment

- **Sites:** units of land that invest in palm oil (potential entrants)
  - Active sites have one **mill** + some **plantations**

- Entry-investment game with dynamic competitive equilibrium (Hopenhayn 1992)
  - Invest/emit today (no exit) $\rightarrow$ revenues in every future period (net of tariffs)
  - (Expected) future prices matter, not just prices today

Timeline: discrete + continuous choices



Choice and state variables

- Observed choices
    - Mills m_{it}, plantations n_{it}
- Observed states
    - Endogenous mills M_{it}, plantations N_{it}
    - Exogenous world prices p_t, yields y_{it}, cost factors x_i, region g_i
- Unobserved states
    - Mill shocks $\bar{\varepsilon}_{it}$ (logit), plantation shocks ε_{it}

Spatial data

- **Investment:** plantations, mills over time via **satellite**

  PALSAR, MODIS, Landsat: Xu et al. (2020), Song et al. (2018); Universal Mill List: WRI, CIFOR

- **Revenues:** prices, quantities (yields)

  Prices: IMF, World Bank; PALMSIM: Hoffmann et al. (2014); Climate: WorldClim

- **Cost factors:** road, port, urban distances; carbon stocks

  Global Roads Inventory Project; World Port Index, World Port Source; Badan Pusat Statistik

Estimation

- **Euler methods:** classic continuous + newer discrete CCP (Hall 1978, Scott 2013)
  - Short-term perturbation: today vs. delay, so long term cancels
- **Assuming** long-lived owners, atomistic sites, rational expectations
  - Allows instruments, non-stationarity, serial correlation

Intensive-margin continuous choice (plantations)

- **Euler equation:** today vs. delay

$$\beta \mathbb{E}_{it}[r'_{it+1}(n_{it})] = c'_{it}(n_{it}) - \beta \mathbb{E}_{it}[c'_{it+1}(n_{it+1})]$$

- For linear revenues and convex costs (with convexity ψ),

$$n_{it} - \beta n_{it+1} = \frac{\alpha}{\psi}\beta r_{it+1} - \Delta c_{it}\left(\frac{\theta}{\psi}\right) + \eta_{it}$$

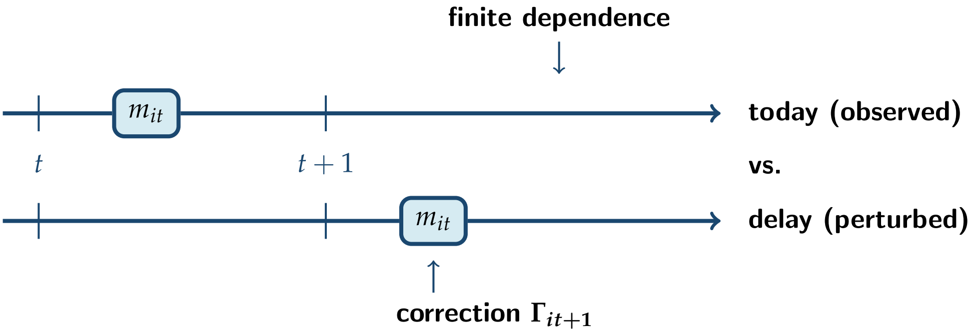
- **Intuition:** continuation values are embedded in agents' choices
  - Observed realizations proxy for unobserved expectations
  - With expectational error η_{it}, where $\mathbb{E}_{it}[\eta_{it}|\mathcal{J}_{it}] = 0$ under rational expectations

Regression equation

$$\underbrace{n_{it} - \beta n_{it+1}}_{\text{data}} = \frac{\alpha}{\psi} \beta r(\underbrace{p_{t+1}, y_{it+1}}_{\text{data}}) - \Delta c_{it}\left(\underbrace{x_i}_{\text{data}}, \overbrace{\varepsilon_{it}}^{\text{error}}; \frac{\theta}{\psi}\right) + \overbrace{\eta_{it}}^{\text{error}}$$

- **Identification:** market price variation + individual suitability
- **Endogeneity:** η_{it} correlated with (p_{t+1}, y_{it+1}), but not (p_t, y_{it}), so use IV

Extensive-margin discrete choice (mills)



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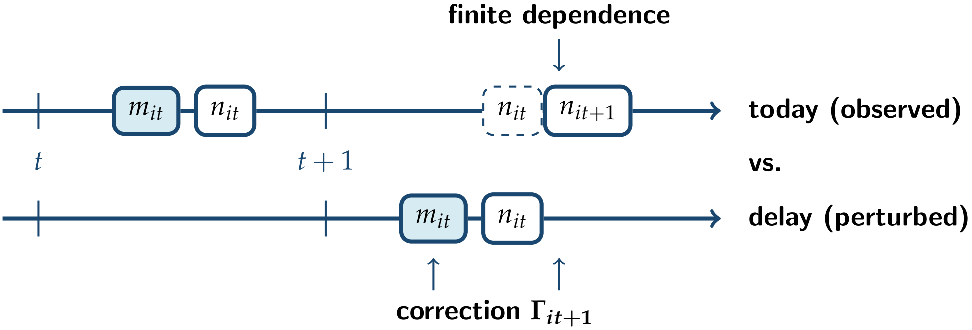

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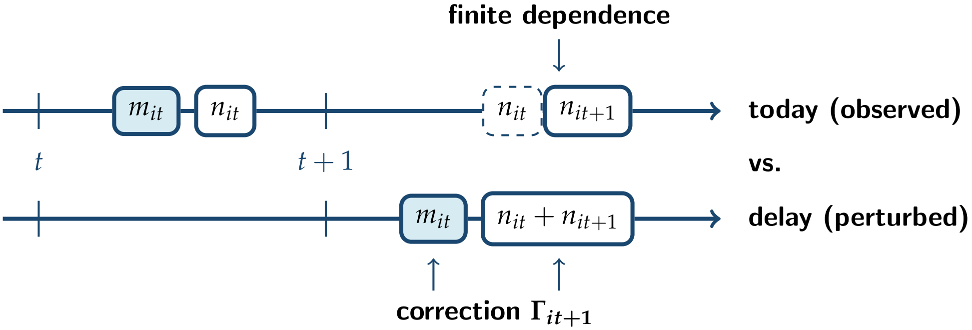


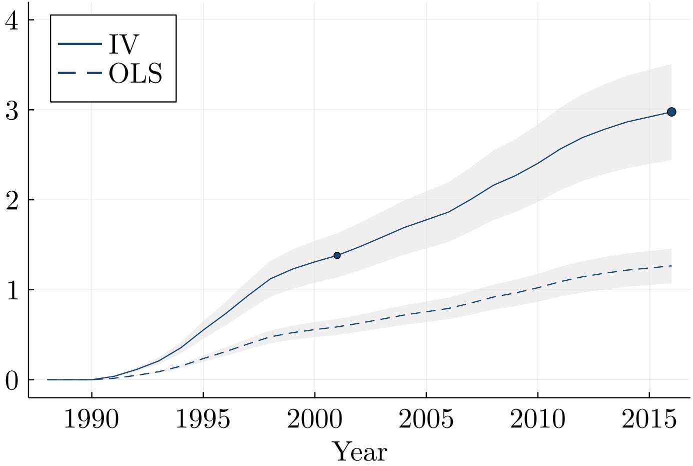
Regression equation

$$\underbrace{\ln\left(\frac{\pi_{it}}{1-\pi_{it}}\right) - \beta \ln \pi_{it+1} = \frac{1}{2}\psi n_{it}^2}_{\text{from data}} - \Delta\bar{c}_{it}(\underbrace{x_i}_{\text{data}};\bar{\theta}) + \overbrace{\bar{\eta}_{it}}^{\text{error}}$$

- **Identification:** same as intensive margin, as embodied by n_{it}
- **Endogeneity:** $\bar{\eta}_{it}$ uncorrelated with n_{it} by rational expectations

- **Challenge:** n_{it} only observed for intensive-margin sample
  - Use predicted n_{it} for extensive-margin sample, assuming $\bar{\varepsilon}_{it}$ and ε_{it} uncorrelated
  - Results robust to test for correlated shocks

Larger elasticities for long-run price changes



Counterfactuals

- Still need to solve the model
  - Common world prices each year
- Import tariffs with coordination and commitment
  - Coordination and commitment achieve most of first best
  - Marginal abatement costs of \$15 per ton, even with compensating transfers
- Policy simulations: unilateral EU tariffs, domestic export taxes, CBAMs

Aside: Food Policy in a Warming World

- Trade policy responds to extreme heat shocks
  - Example: March 2022 heat wave $\rightarrow$ Indian wheat export ban
- Redistributes welfare losses both within and across countries
  - Through equilibrium price effects of trade policy responses
  - And complicates adaptation through trade
- Static model for static story

Sea Level Rise

Sea Level Rise and Urban Adaptation in Jakarta

- How does government intervention complicate adaptation?
- **Coastal moral hazard** as defense bails out development
  - If government is time-inconsistent (Kydland & Prescott 1977)
  - Delays inland migration at high social cost
  - Adaptation frictions under endogenous government action
- **Dynamic spatial model** of development and defense
  - Estimated with granular data for Jakarta
  - New, lightweight estimation framework

Jakarta

- By 2050, 35% below sea level (Andreas et al. 2018)
  - Land subsidence + sea level rise
  - Proposed sea wall at up to $40B


#CLIMATE NO JUSTICE

Quantitative framework

- Development: spatial demand, **dynamic supply**
- Defense: hydrological model, engineering costs

- Moral hazard from model, not data
  - But can rationalize high coastal prices in the data

Spatial demand

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

- Renters i, origins j, destinations k

- **Goal:** flood disutility ϕ
- **Estimation:** linear IV with 2015 population data

Dynamic supply

$$c_{kt} \quad \text{vs.} \quad \alpha(r_{kt} + \beta r_{kt+1} + \beta^2 r_{kt+2} + \cdots)$$

- Landowners i, locations k, time t, state $D_{ikt} \in \{0, 1\}$
- **Goal:** forward-looking rent utility α
  - Moral hazard increasing in rent elasticity $(\alpha^s \neq \alpha^d)$
  - Moving inland incurs construction costs
  - No market power, agglomeration, quality
- **Estimation** will reduce to linear IV and allow flexible expectations

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Small, homogeneous landowners

$$w_t = \{r_{kt}, c_{kt}, P^1_{kt}, P^0_{kt}\}_k$$

- Take aggregate state as given: rents, costs, and property prices
  - 14k developers in Jakarta, 1k with $3.5M annual revenue
  - Constant returns to scale

- "Strong coordination" by local government
  - While developers react competitively
  - Market power lessens development, but helps coordination

Choices

- **Developed plots:** sell or hold

$$V_{kt}^1 = \max\{\alpha P_{kt}^1, \underbrace{\alpha r_{kt} + \beta \mathbb{E}[V_{kt+1}^1]}_{\tilde{V}_{kt}^1}\}$$

- **Empty plots:** sell, develop, or hold

$$V_{kt}^0 = \max\{\alpha P_{kt}^0, \underbrace{\max\{\beta \mathbb{E}[V_{kt+1}^1] - c_{kt} + \varepsilon_{ikt}^1, \ \beta \mathbb{E}[V_{kt+1}^0] + \varepsilon_{ikt}^0\}}_{\tilde{V}_{kt}^0}\}$$

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Equilibrium prices

- Rents clear rental markets: $D^{\text{res}}_{kt}(r_t; f_t) = D^{\text{dev}}_{kt}(r_{kt}, r_{kt+1}, \ldots)$
- REITs arbitrage property prices
  - Can buy assets and collect rents
  - Observed prices capture continuation values (Kalouptsidi 2014)

$$V^1_{kt} = \max\{\alpha P^1_{kt},\, \tilde{V}^1_{kt}\} \qquad V^1_{kt} = \alpha P^1_{kt} = \tilde{V}^1_{kt}$$
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Logit inversion

$$\tilde{V}_{kt}^{0} = \max\{\beta\mathbb{E}[V_{kt+1}^{1}] - c_{kt} + \varepsilon_{ikt}^{1},\ \beta\mathbb{E}[V_{kt+1}^{0}] + \varepsilon_{ikt}^{0}\}$$

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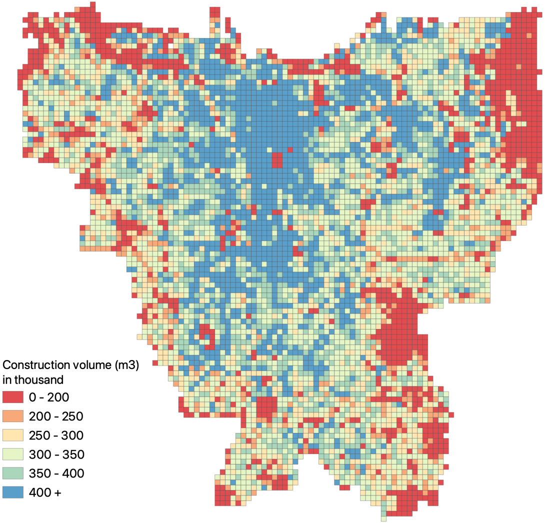
Estimation

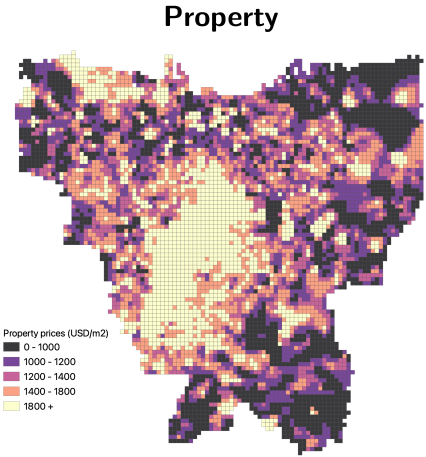
$$\ln \pi^1_{kt} - \ln \pi^0_{kt} = \alpha\beta(P^1_{kt} - P^0_{kt}) - c_{kt}$$

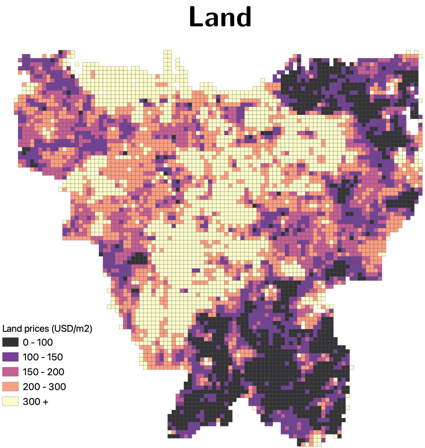
- **Estimation:** linear IV with 2015 construction data
  - Rent endogeneity from unobserved costs
  - Residential amenities as demand shifter
- Policy-invariant with respect to commitment
  - Market expectations capitalize into prices flexibly
  - Developers respond to prices as if statically
  - Can invert to infer commitment
- Alternatives: full-solution, two-step, Euler CCP

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	

Counterfactuals

- Still need to solve the model
  - By restricting time periods in a stylized way
  - Sea wall built every 40 years
- Adaptation with and without commitment
  - Model inversion gives expected government commitment
  - Rationalizes high coastal prices despite high future risk
- Policy simulations: partial commitment of various forms

Aside: Sea Level Rise and Urban Inequality

- Sea level rise induces spatial sorting
    - Estimated with granular data for Jakarta
- The rich move to higher ground, pushing the poor elsewhere
    - Through equilibrium price effects in housing markets
    - Pecuniary externality with distributional consequences
- Static model for static story

Conclusion

Summary

- Dynamic models for dynamic stories
- Estimation reduces to linear IV
  - Subject to strong assumptions
  - And availability of dynamic data