

# Coordination and Commitment in International Climate Action: Evidence from Palm Oil

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## Weak environmental regulation has global consequences

- Can be pivotal for climate goals: e.g., tropical forests (Amazon, Congo, SE Asia)
- But domestic governments often fail to regulate
  - Weak incentives, weak institutions
- And conventional approaches rely on domestic governments
  - Domestic regulation, improving enforcement, conservation contracts  
(Duflo et al. 2018, Souza-Rodrigues 2019, Harstad 2012/2016, Jayachandran et al. 2017)

## International import tariffs offer an alternative

- Target world prices (via demand) instead of production directly
  - Exported goods: 60% of global CO<sub>2</sub> emissions (Davis et al. 2011)
- **How effective are import tariffs as a substitute for domestic regulation?**

# This paper

- **Dynamic structural model** to assess foreign import tariffs vs. domestic tax
  - Applied to **palm oil** and EU tariffs
- **Leakage** problem from incomplete regulation
  - **Demand elasticities** by country from AIDS demand for palm oil and substitutes
- **Commitment** problem from sunk emissions
  - **Supply elasticities** from dynamic model of palm oil plantations and mills
  - Estimation with Euler methods and satellite data

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# Results

- Tariffs effective if importers **coordinate** and **commit** to long-term policy
  - CO<sub>2</sub> ↓ by 39% vs. 40% under domestic tax
  - But free-riding undermines coordination
  - And static incentives undermine commitment
- **Alternatives:** unilateral EU tariff (6%), export tax (39%)
  - Import tariff: transfers to compensate producers (as payment for ecosystem services)
  - Export tax: producers generate government revenue from foreign consumers

# Contributions

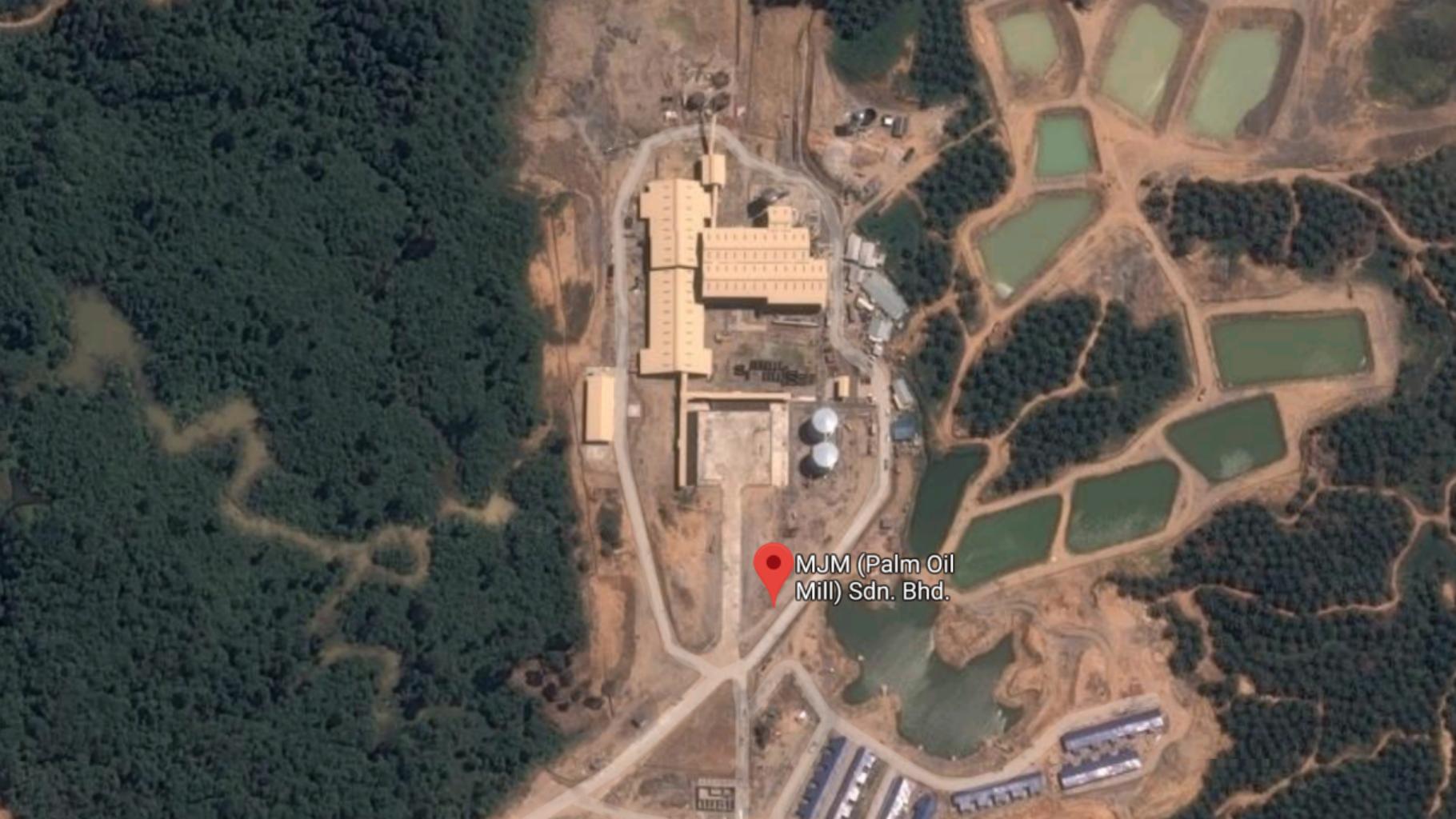
- **Dynamic empirical framework** for emission-based trade policy
  - Methodologically: Hopenhayn 1992, Ericson & Pakes 1995, Ryan 2012, Collard-Wexler 2013, Hall 1978, Hansen & Singleton 1982, Aguirregabiria & Magesan 2013, Scott 2013, Kalouptsidi et al. 2018, Hotz & Miller 1993, Arcidiacono & Miller 2011
- Unified analysis of **leakage** and **commitment** problems
  - **Leakage:** Markusen 1975, Copeland & Taylor 1994/1995, Hoel 1996, Rauscher 1997, Fowlie 2009, Elliott et al. 2010, Nordhaus 2015, Fowlie et al. 2016, Kortum & Weisbach 2017
  - **Commitment:** Marsiliani & Renström 2000, Abrego & Perroni 2002, Helm et al. 2003, Brunner et al. 2012, Harstad 2016/2020, Battaglini & Harstad 2016
- Empirical estimates for **palm oil** and deforestation
  - **Other policies:** Burgess et al. 2019, Souza-Rodrigues 2019, Harstad 2012/2016, Harstad & Mideksa 2017, Jayachandran et al. 2017, Edwards et al. 2020

# Outline

- ① **Setting:** palm oil
- ② **Demand:** almost ideal demand system (**leakage**)
  - Structural model captures substitution to other oils
- ③ **Supply:** dynamic model with sunk investment (**commitment**)
  - Structural model captures role of future prices
- ④ **Counterfactuals:** quantify leakage and commitment (**tariffs → emissions**)

Setting





MJM (Palm Oil  
Mill) Sdn. Bhd.







MARGARINE



CHOCOLATE



SOAP



BIODIESEL



COOKIES



PIZZA DOUGH



SHAMPOO



DETERGENT



PACKAGED BREAD



ICE CREAM



INSTANT NOODLES



LIPSTICK

## Indonesia and Malaysia produce palm oil for export

	Production	Consumption	Exports	Imports
Indonesia/Malaysia	0.84	0.20	0.90	0.02
European Union	0.00	0.12	0.00	0.17
China/India	0.00	0.23	0.00	0.31
Rest of world	0.16	0.45	0.10	0.50

Palm oil has driven rapid, widespread deforestation

**Plantations (1988)**



Palm oil has driven rapid, widespread deforestation

**Plantations (1993)**



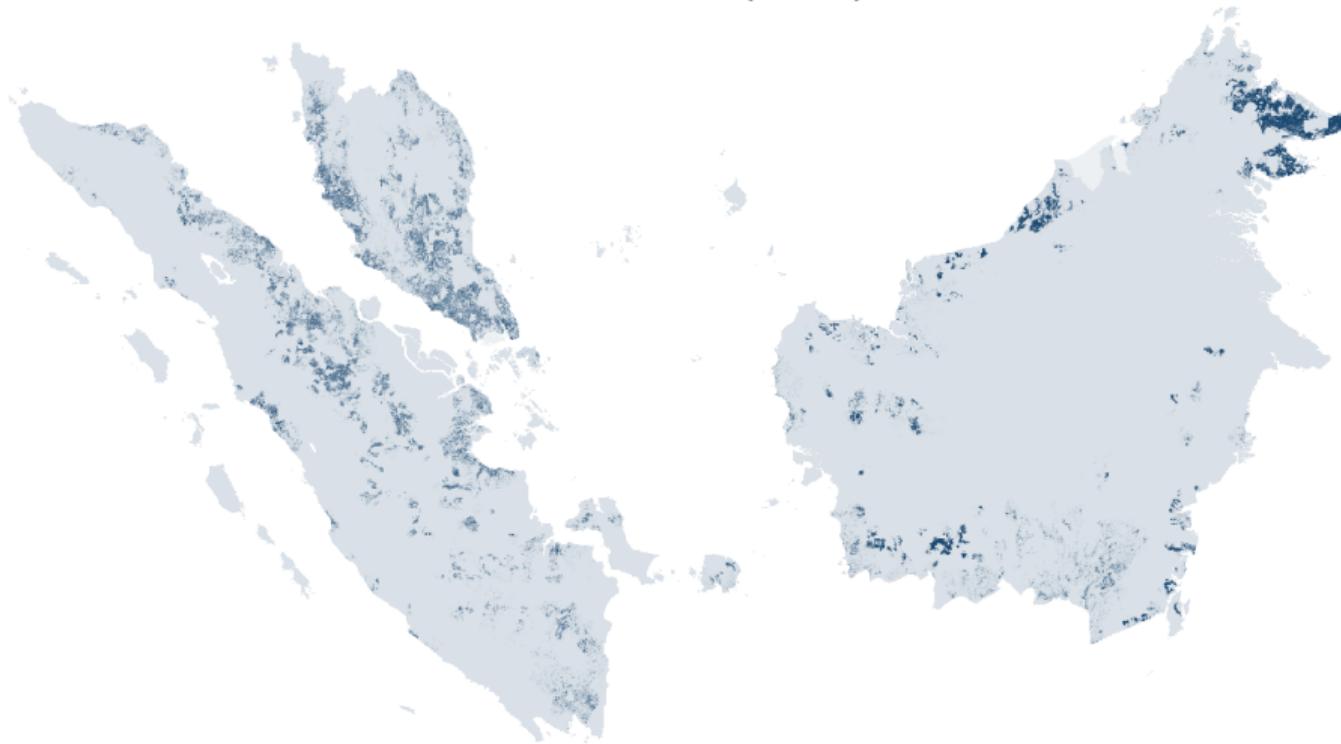
Palm oil has driven rapid, widespread deforestation

**Plantations (1998)**



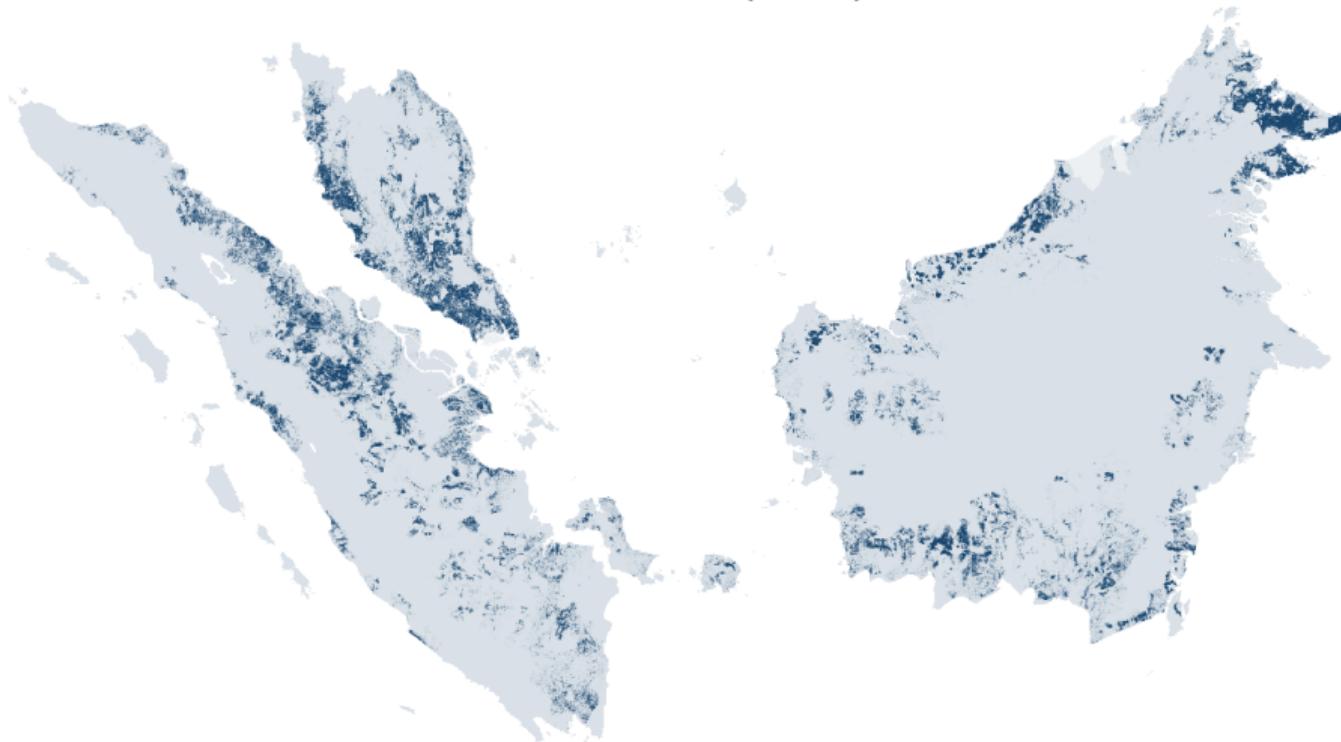
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**Plantations (2003)**



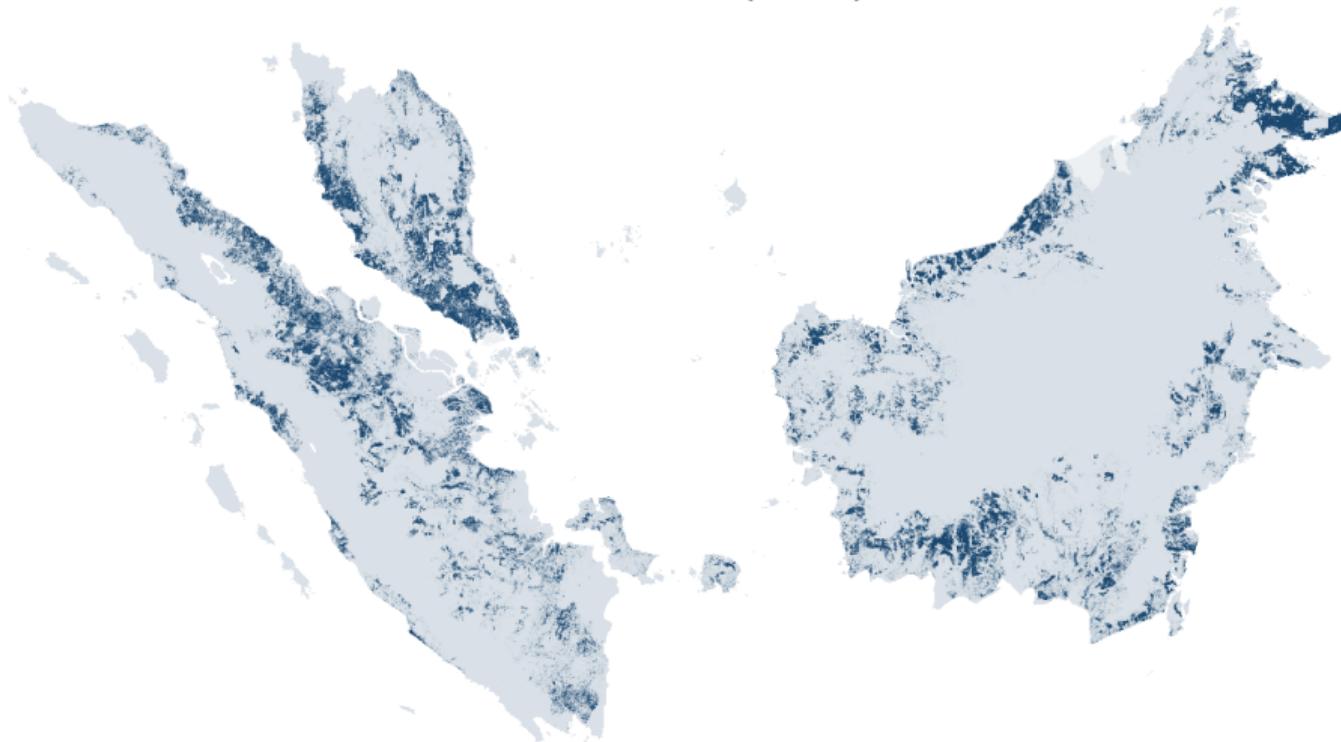
Palm oil has driven rapid, widespread deforestation

**Plantations (2008)**



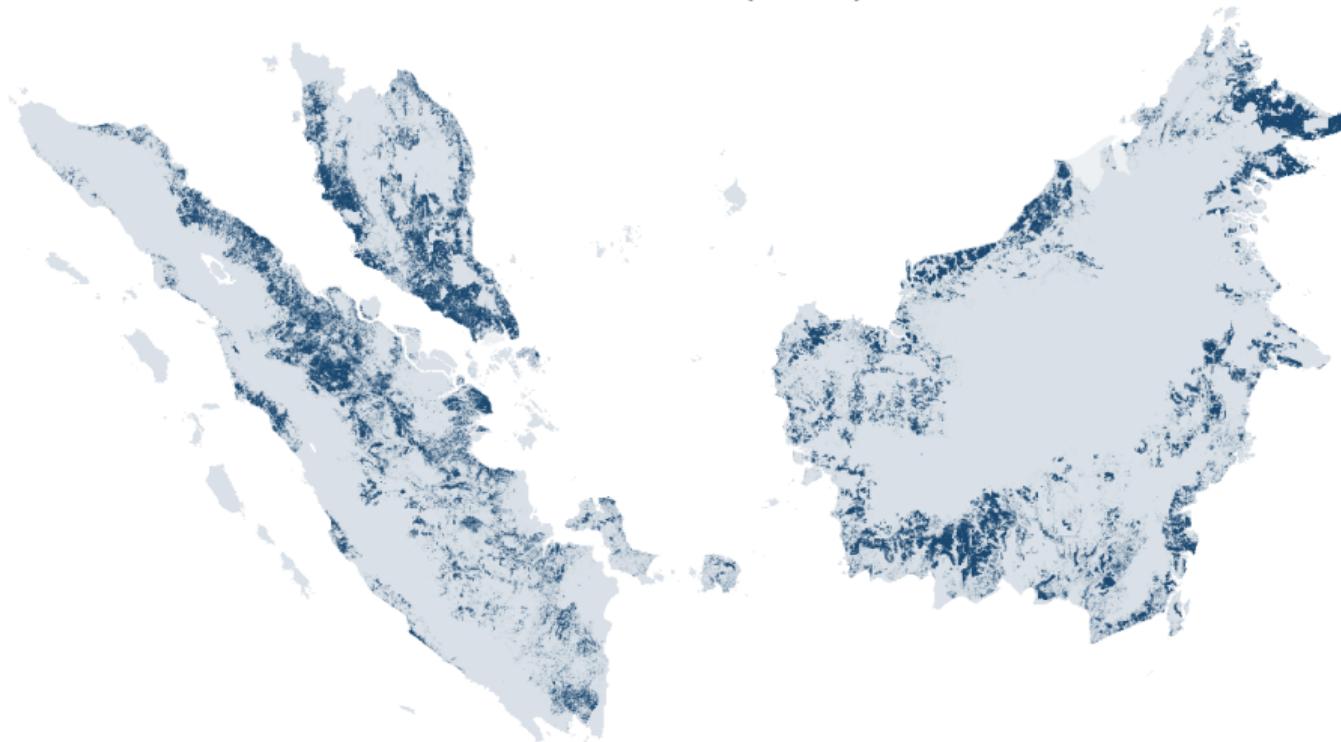
Palm oil has driven rapid, widespread deforestation

**Plantations (2012)**



Palm oil has driven rapid, widespread deforestation

**Plantations (2016)**



Demand

## Almost ideal demand system (Deaton & Muellbauer 1980)

$$① \quad \ln Q_t = \alpha^0 + \alpha^1 t + \gamma \ln P_t + Z_t \beta + \varepsilon_t$$

$$② \quad \omega_{it} = \alpha_i^0 + \alpha_i^1 t + \sum_j \gamma_{ij} \ln p_{jt} + \beta_i \ln \left( \frac{X_t}{P_t} \right) + \varepsilon_{it}$$

- **Two-stage budgeting**

- ①  $\ln Q_t$ : vegetable oils overall

- ②  $\omega_{it}$ : palm vs. other oils (soybean, rapeseed, sunflower, coconut, and olive)

- **Estimation** by market

- Iterated linear least squares (Blundell & Robin 1999)

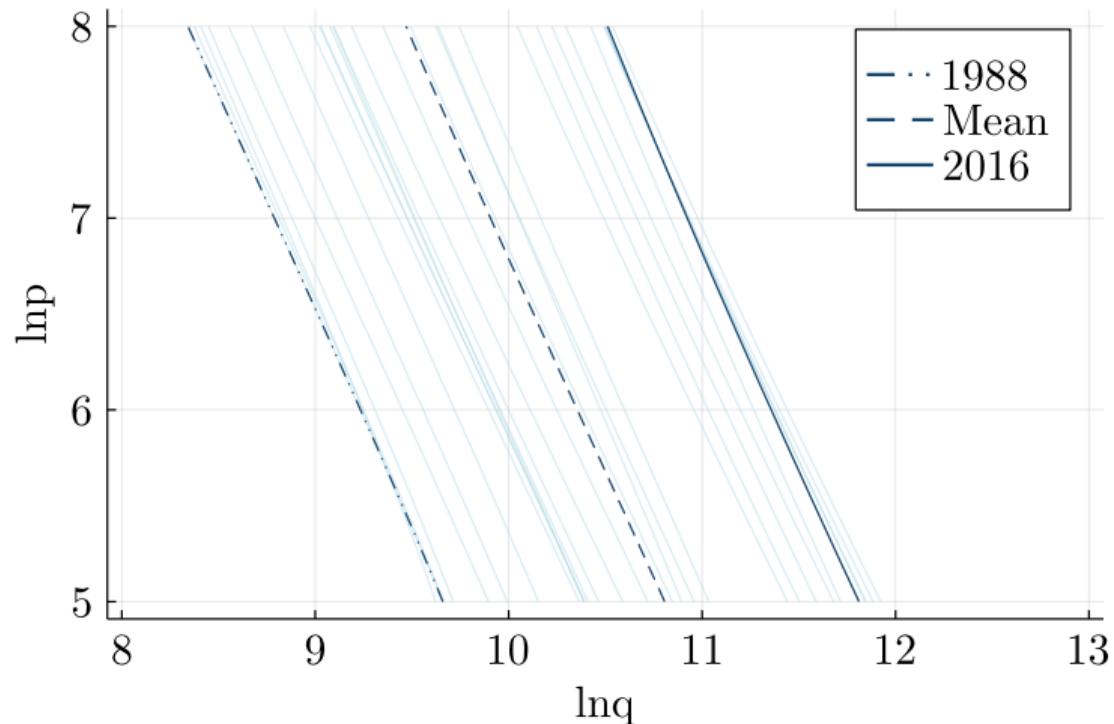
- **Data:** annual oil consumption  $\omega_{it}$ , prices  $p_{it}$  (USDA FAS, 1980-2016)

- **Price IV:** weather shocks to oil production

## Larger elasticities for importers than producers

	European Union	China India	Other importers	Indonesia Malaysia
Palm	-0.51 (0.18)	-0.66 (0.21)	-0.55 (0.13)	-0.02 (0.17)
	-0.30 (0.17)	-0.58 (0.22)	-0.43 (0.14)	-0.41 (0.47)
Other				

World demand is increasing

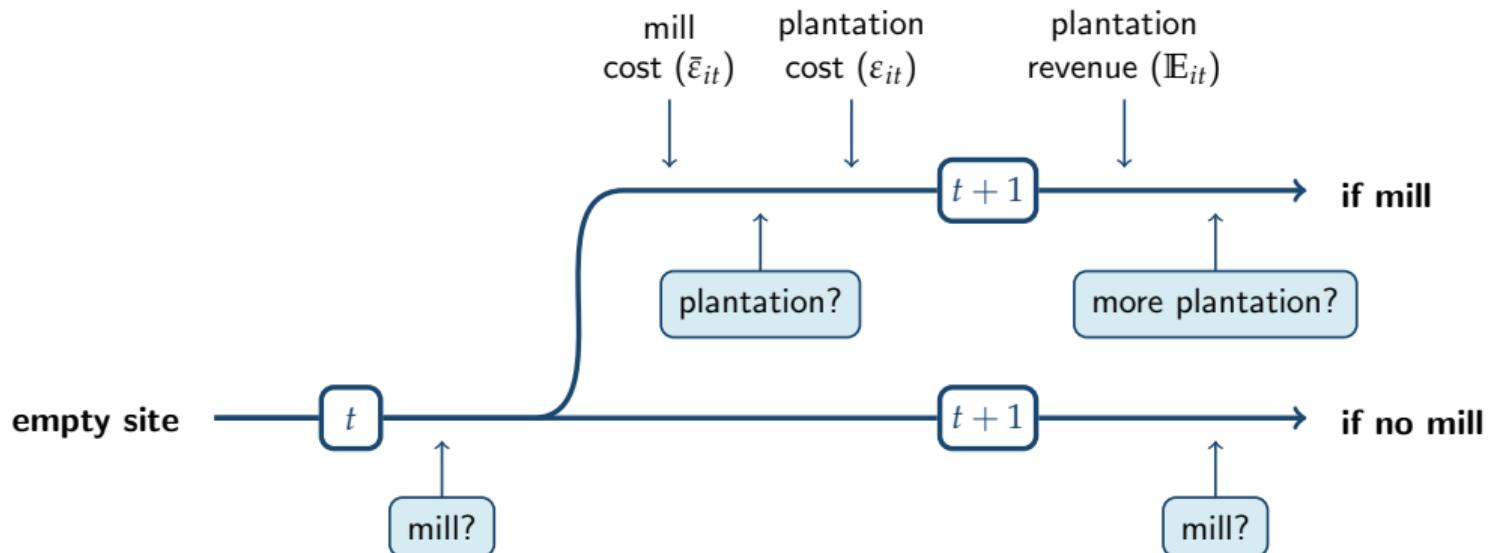


Supply

# Dynamic model 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) → 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  $\varepsilon_{it}$

# 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  $\psi$ ),

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

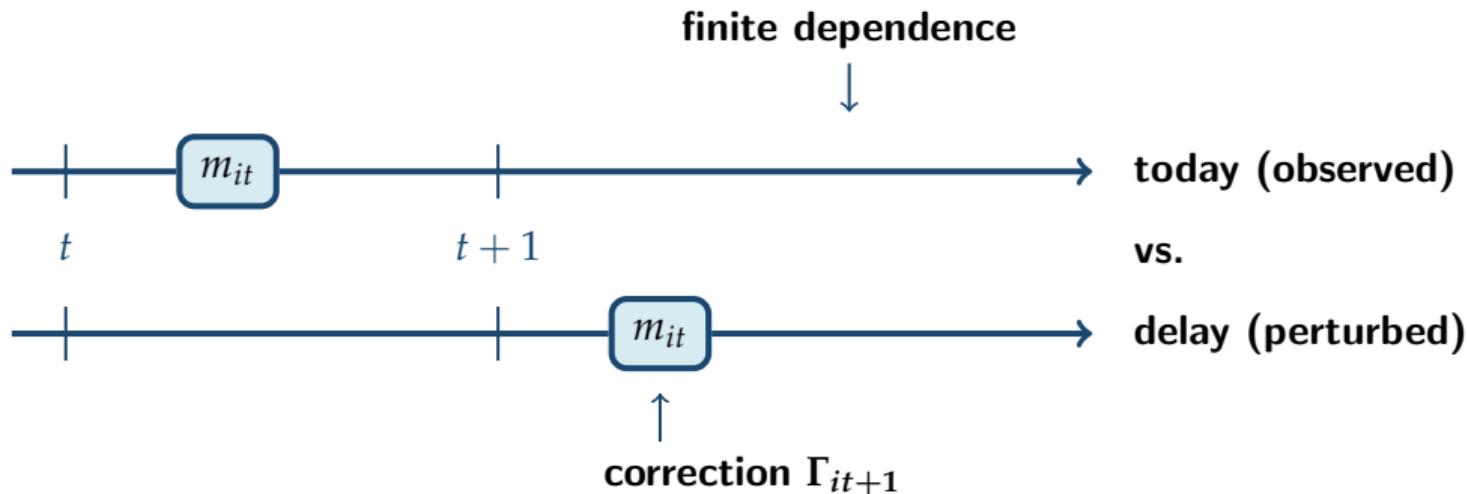
- **Intuition:** continuation values are embedded in agents' choices
  - Observed realizations proxy for unobserved expectations
  - With expectational error  $\eta_{it}$ , where  $\mathbb{E}_{it}[\eta_{it} | \mathcal{J}_{it}] = 0$  under rational expectations

## Regression equation

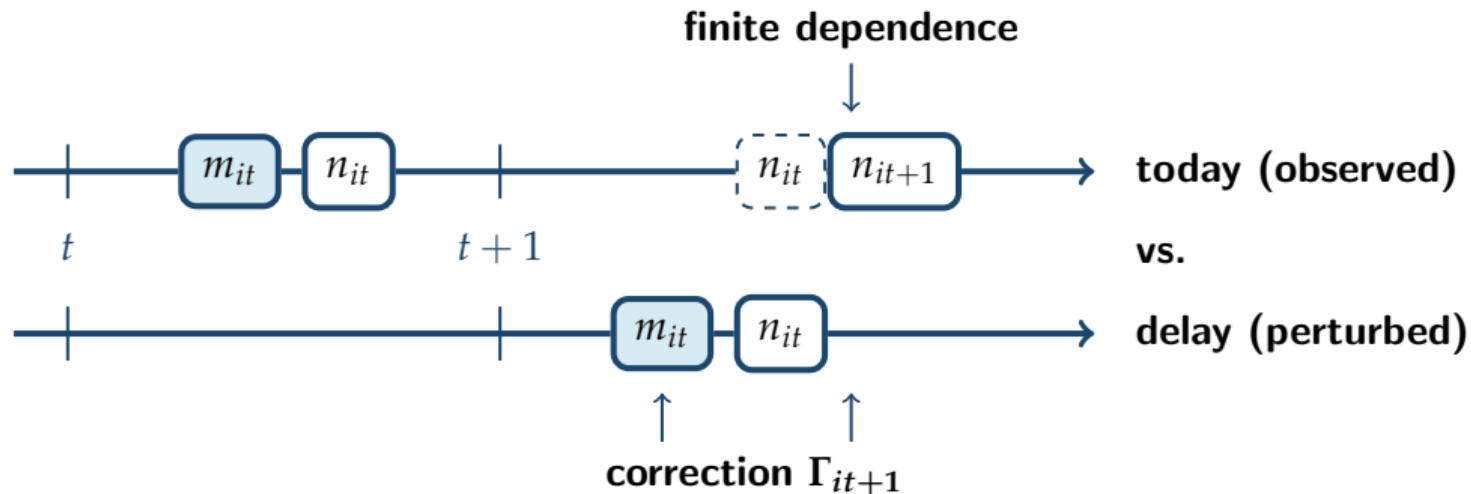
$$\underbrace{n_{it} - \beta n_{it+1}}_{\text{data}} = \frac{\alpha}{\psi} \beta r(\underbrace{p_{t+1}, y_{it+1}}_{\text{data}}) - \Delta c_{it} \left( \underbrace{x_i, \widehat{\varepsilon}_{it}}_{\text{data}}; \frac{\theta}{\psi} \right) + \widehat{\eta}_{it}^{\text{error}}$$

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

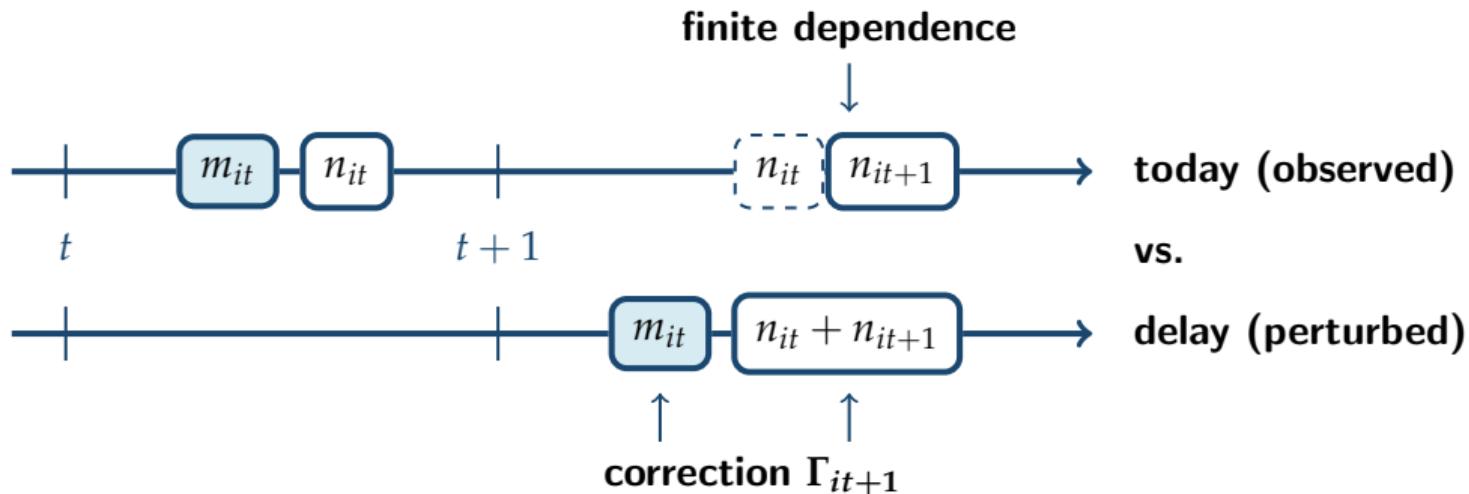
## Extensive-margin discrete choice (mills)



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## Regression equation

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

- **Identification:** same as intensive margin, as embodied by  $n_{it}$
- **Endogeneity:**  $\bar{\eta}_{it}$  correlated with  $n_{it}$ , but not  $n_{it-1}$ , so use IV
- **Challenge:**  $n_{it}$  only observed for intensive-margin sample
  - Use predicted  $n_{it}$  for extensive-margin sample, assuming  $\bar{\varepsilon}_{it}$  and  $\varepsilon_{it}$  uncorrelated
  - Results robust to test for correlated shocks

## Larger elasticities for long-run price changes

		Intensive margin	Extensive margin	Total
Dynamic	Long run	2.80	1.26	3.20
		(0.25)	(0.53)	(0.33)
	Short run	0.39	0.03	0.40
		(0.03)	(0.01)	(0.04)
Static	Short run	-0.41 (0.05)	0.07 (0.03)	-0.38 (0.05)

# Counterfactuals

## Tariffs to emissions

$$P_t^{Dr}(Q_t^r) - \tau_t = P_t^{Du}(Q_t^u)$$

- **Tariffs**  $\tau_t$  → prices  $P_t$  (given **demand** model)  
→ supply  $s_t$  (given **supply** model)  
→ **emissions**  $e_t$  (given carbon map)
- Emissions assume \$75 SCC and low-carbon outside option
  - General equilibrium, but only within palm oil industry

# Setting tariffs (from 1988)

- Baseline: maximize global welfare, uniform across units
- **Leakage**
  - Coalitions: all importers, EU-China-India, EU alone (no game)
- **Commitment**
  - Full: once set, tariff upheld forever
  - None: tariffs reset every period (sequential static optimization)
  - Limited: commit  $L$  periods, then none

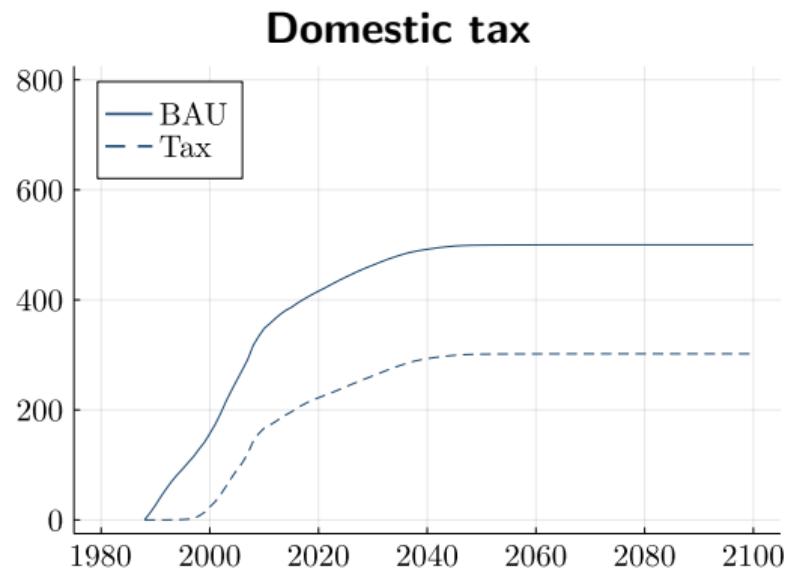
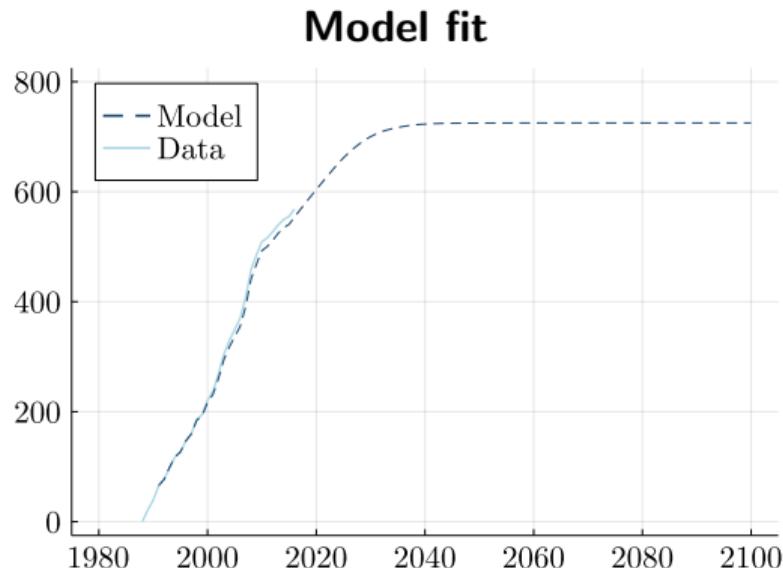
## Solving the model

- **Dynamic entry game** solved as a fixed point ( $P \rightarrow Q \rightarrow P$ )

$$Q_{it} = F(P_{t+1}(Q_t), P_{t+2}(Q_t, Q_{t+1}), \dots)$$

- **Backward induction** from terminal 2100 (given tariffs)
  - Only total supply enters, so not tracking supply over space
  - In-sample residuals capture future expectations and current cost shocks

# Model-predicted emissions (NPV<sub>1998</sub>)



## Tariffs can work well

	$\Delta E (\%)$			$\Delta W (\$1B)$		
	Full	30-yr	10-yr	Full	30-yr	10-yr
Domestic regulation	40	33	8	115	95	26
Tariffs: all importers	39	32	7	108	89	22
Tariffs: EU, China, India	15	12	2	39	30	6
Tariffs: EU alone	6	5	1	15	12	3

- Tariffs as effective as first-best regulation, but only if coordinated and committed
- Average costs of \$25-40 per ton (marginal \$75) remain low-hanging fruit

## Coordination and commitment are difficult

(\$1B)	$\Delta W^{\text{EU}}$		$\Delta W^{\text{CI}}$		$\Delta W^{\text{OI}}$	
	Full	10-yr	Full	10-yr	Full	10-yr
Domestic regulation	-21	-4	0	3	74	18
Tariffs: all importers	-3	0	24	5	138	29
Tariffs: EU, China, India	-8	-1	0	0	64	9
Tariffs: EU alone	-8	-1	6	1	25	5
SCC burden	1%		17%		80%	

- For coordination, defectors can free-ride on  $E \downarrow$  and  $P \downarrow$  (but prefer  $E \Downarrow$ )
- For commitment, optimal to set tariffs to zero ex post (but not ex ante)

## Europe can act unilaterally

	$\Delta E (\%)$		$\Delta W^{\text{EU}} (\$1\text{B})$		$\Delta W (\$1\text{B})$	
	Full	10-yr	Full	10-yr	Full	10-yr
Domestic regulation	40	8	-21	-4	115	26
Tariffs: all importers	39	7	-3	0	108	22
Tariffs: EU, China, India	15	2	-8	-1	39	6
Tariffs: EU alone	6	1	-8	-1	15	3

- Leveraging comparative advantage in strong institutions (given global interests)

## Indonesia and Malaysia can act too

	$\Delta W^{IM}$ (\$1B)	
	Full	10-yr
Domestic regulation	62	8
Tariffs: all importers	-51	-12
Tariffs: EU, China, India	-18	-3
Tariffs: EU alone	-8	-2
SCC burden		2%

- Government revenue from inelastic foreign consumers (including with export tax)
- Otherwise, large losses from tariffs of \$1k-2k motivate transfers (as PES)

# Conclusion

# Summary

- **Import tariffs** effective if **coordinated** and **committed**
  - Helpful where domestic issues take time to fix
- **Palm oil:** 5% of global CO<sub>2</sub> emissions (1990-2016)
  - Past deforestation sunk, but Papua still intact