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 Green consumers
  - Exported goods: 60% of global CO_2 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 GATT/WTO
- **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
  - $CO_2 \downarrow$ by 39% vs. 40% under domestic tax
- But free-riding undermines coordination; static incentives undermine commitment
- **Alternatives:** unilateral EU action (6%), export tax (39%)
  - Export tax generates government revenue from foreign consumers

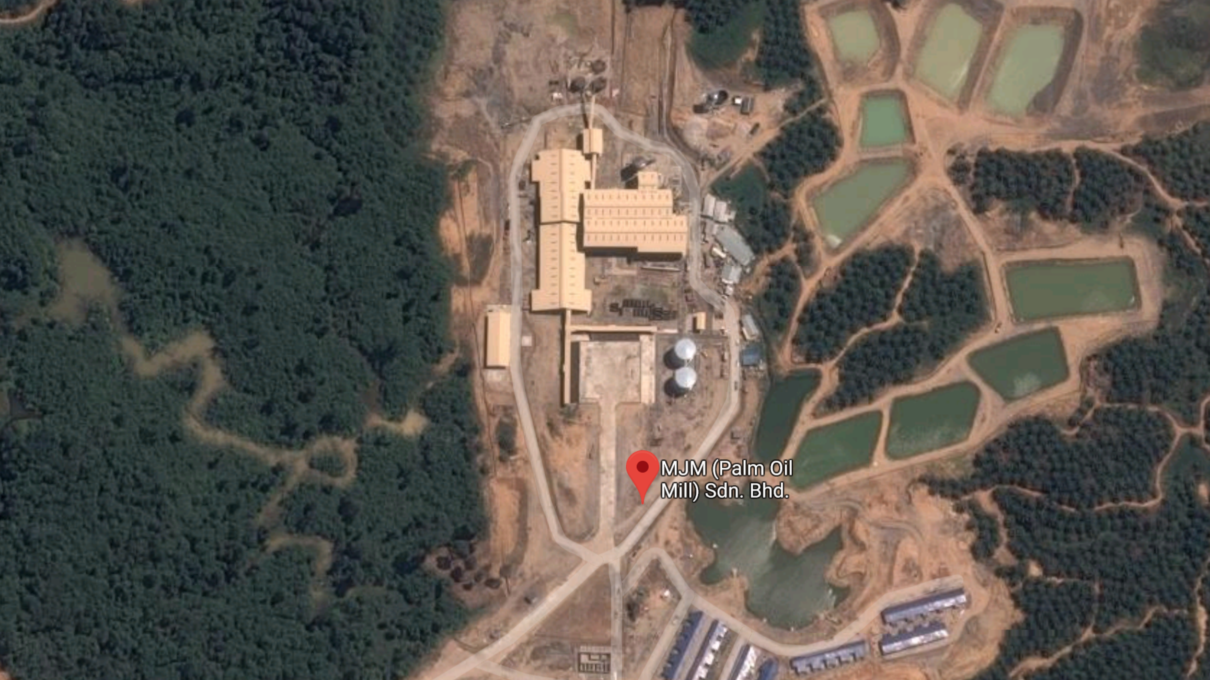
Contributions

- **Dynamic empirical framework** for emission-based trade policy Shapiro (2020)
  - 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, including interaction
  - 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, Acemoglu & Rafey 2019
- 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 $\rightarrow$ 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 CO_2 World CO_2 Market concentration Yields Carbon costs Rest of world

Palm oil has driven rapid, widespread deforestation

Non-palm land use

Plantations (1988)

Palm oil has driven rapid, widespread deforestation

Non-palm land use

Plantations (1993)

Palm oil has driven rapid, widespread deforestation

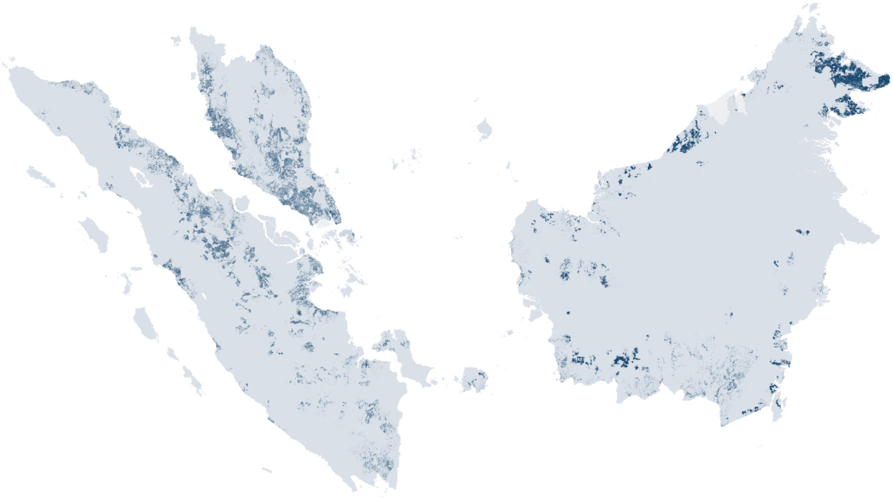
Non-palm land use

Plantations (1998)

Palm oil has driven rapid, widespread deforestation

Non-palm land use

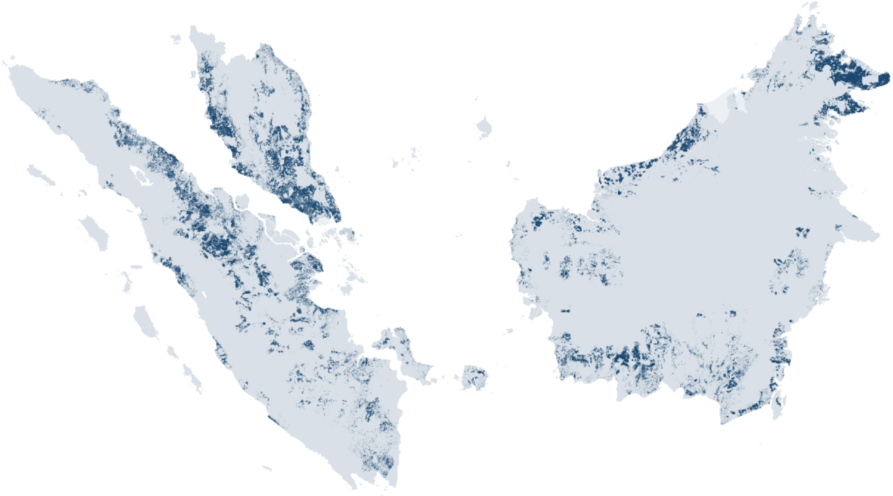
Plantations (2003)



Palm oil has driven rapid, widespread deforestation

Non-palm land use

Plantations (2008)



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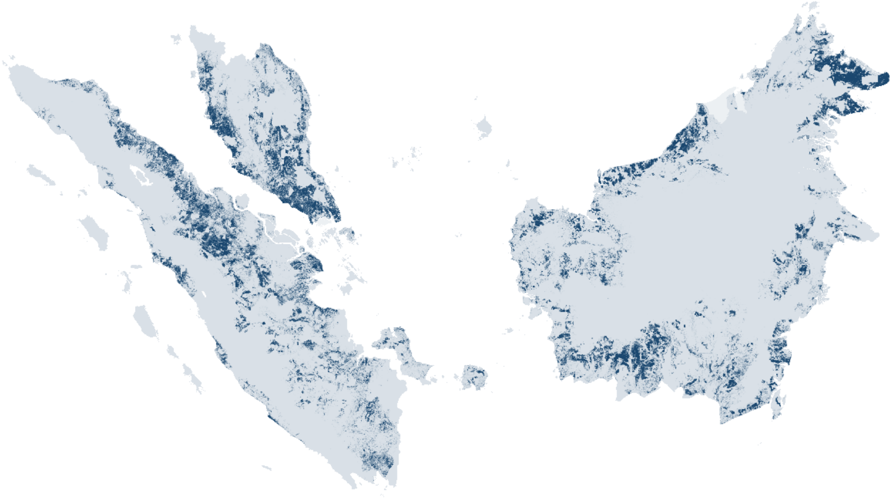
Non-palm land use

Plantations (2012)



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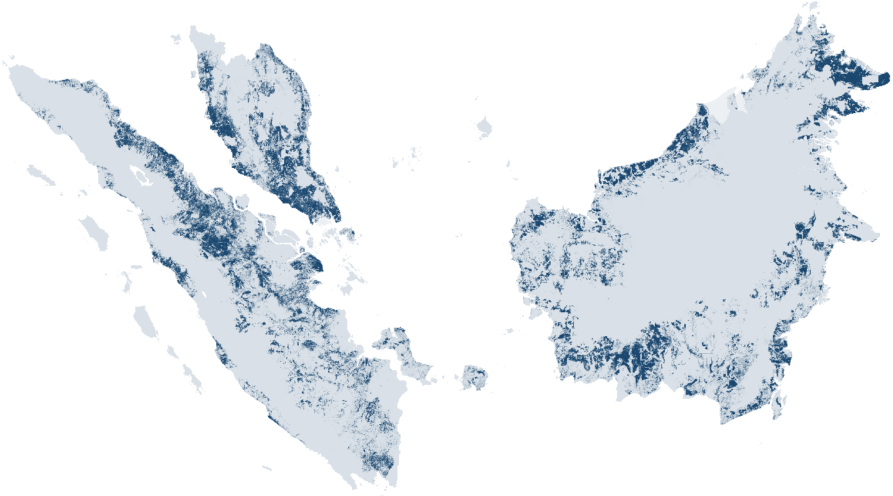
Plantations (2016)



Demand

Almost ideal demand system (Deaton & Muellbauer 1980)

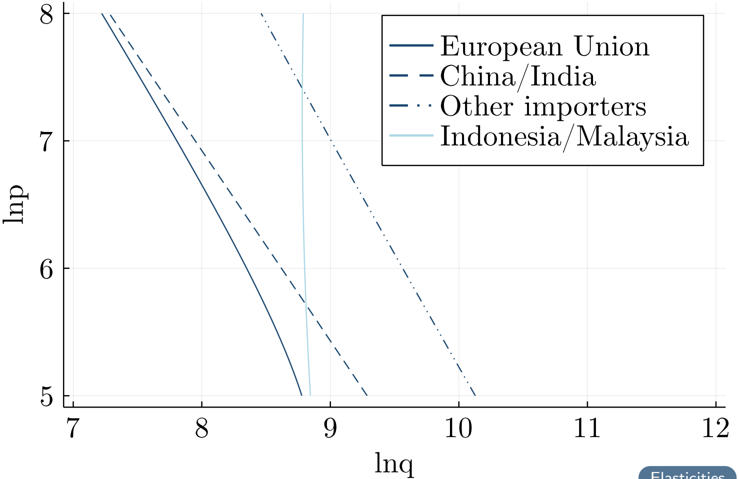
1. $$\ln Q_t = \alpha^0 + \alpha^1 t + \gamma \ln P_t + Z_t \beta + \varepsilon_t$$
2. $$\omega_{it} = \alpha_i^0 + \alpha_i^1 t + \sum_j \gamma_{ij} \ln p_{jt} + \beta_i \ln\left(\frac{X_t}{P_t}\right) + \varepsilon_{it}$$

- **Two-stage budgeting**
  1. $\ln Q_t$: vegetable oils overall
  2. ω_{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 ω_{it}, prices p_{it} (USDA FAS, 1980-2016)
  - **Price IV:** weather shocks to oil production

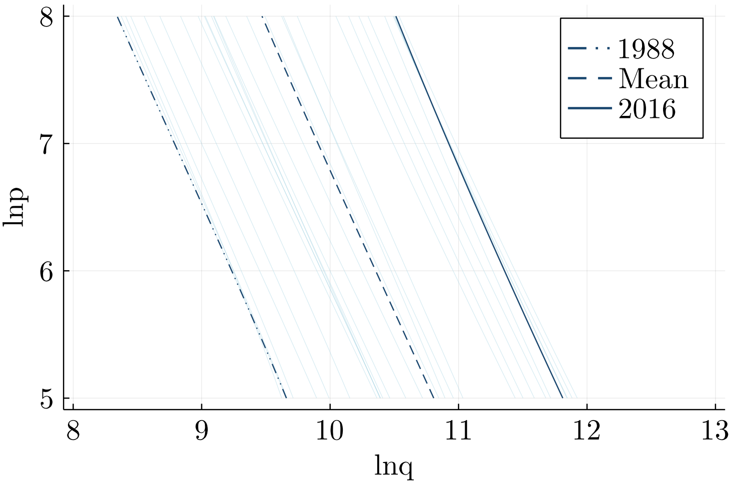
AIDS details | Price IV | IV exclusion | Static demand | Other oils CO_2 | AIDS vs. BLP | Market concentration

Leakage to other importers, but not to domestic consumers



Elasticities Elasticities (no IV)

World demand is increasing



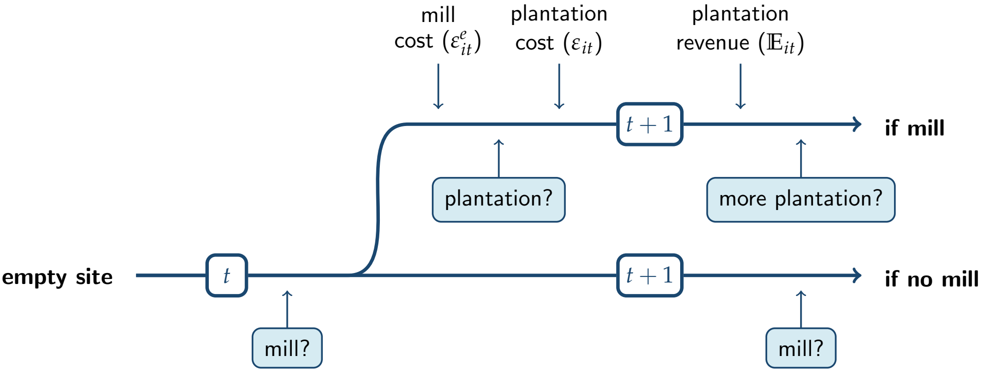
Supply

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) $\rightarrow$ revenues in every future period (net of tariffs)
  - (Expected) future prices matter, not just prices today

Defining sites | Non-palm land use | Smallholders | Non-uniform tariffs | Price variation | Reduced-form

Timeline: discrete + continuous choices



State variables and spatial heterogeneity

- Observed aggregate states $\rightarrow P(s_t, d_t)$
  - Supply $s_t = \sum_i Y_{it} s_{it}$, demand d_t
- Observed heterogeneity
  - By site: yields Y_{it}, cost factors x_i
- Unobserved heterogeneity
  - By site: cost shocks $\varepsilon^e_{it}, \varepsilon_{it}$ (logit)
  - By region: fixed effects κ^e_m, κ_m, time trends α^e_m, α_m

ε^e_{it} vs. ε_{it}

Site-level ζ_i

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

Data | Data 2 | PALMSIM | Carbon map

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

Market concentration Market power

Intensive-margin continuous choice (plantations)

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

Value function

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

- For linear revenues and quadratic costs,

Regression

$$a_{it} - \beta a_{it+1} = \beta r_{it+1}(\theta) - \Delta c_{it}(\theta) + \underbrace{\eta_{it}}_{\mathbb{E}_{it}[c'_{it+1}+r'_{it+1}]-c'_{it+1}-r'_{it+1}}$$

- Under rational expectations, $\mathbb{E}_{it}[\eta_{it}|\mathcal{J}_{it}] = 0$

Identification

$$\underbrace{a_{it} - \beta a_{it+1}}_{\text{data}} = \beta r(\underbrace{P_{t+1}, Y_{it+1}}_{\text{data}}; \theta) - \Delta c_{it}(\underbrace{x_i}_{\text{data}}, \overbrace{\varepsilon_{it}}^{\text{error}}; \theta) + \overbrace{\eta_{it}}^{\text{error}}$$

- **Price endogeneity:** low costs $\varepsilon_{it} \xrightarrow{\text{entry}}$ low prices P_{t+1} IV estimates
  1. Demand shifter: $\widehat{d}_t$ from $\ln p_t = \widehat{\phi} \ln q_t + \widehat{d}_t$ (GDP)
  2. Interaction: yields Y_{it+1} (climate)

- IV with d_t: $\mathbb{E}[\eta_{it}|\mathcal{J}_{it}] = 0$, but $\mathbb{E}[\eta_{it}|\mathcal{J}_{it+1}] \neq 0$
- IV with potential Y_i^p: high effort $\varepsilon_{it} \rightarrow$ high yield Y_{it+1}

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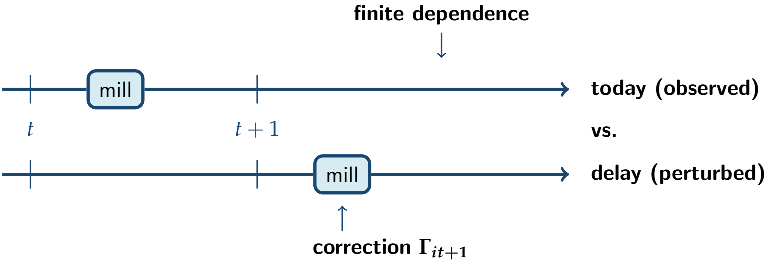
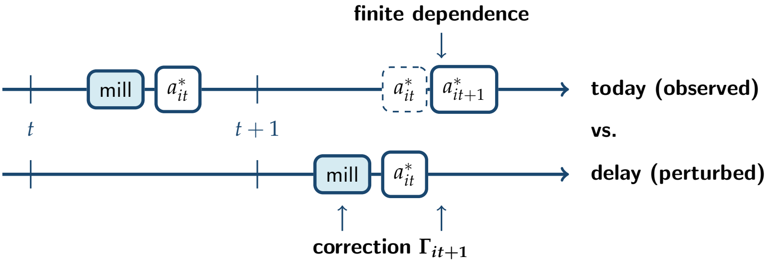
Extensive-margin discrete choice (mills)



$$\underbrace{\ln\left(\frac{\widehat{p}^e_{it}}{1-\widehat{p}^e_{it}}\right)}_{\substack{\text{from data}\\ \text{(Hotz-Miller)}}} - \widehat{\Gamma}_{it+1} = \underbrace{\left[\beta r_{it+1}(\widehat{\theta}) - \Delta c_{it}(\widehat{\theta})\right] a^*_{it}}_{\text{intensive margin}} - \Delta c^e_{it}(\theta^e) + \eta^e_{it}$$

Value function Regression

Extensive-margin discrete choice (mills)



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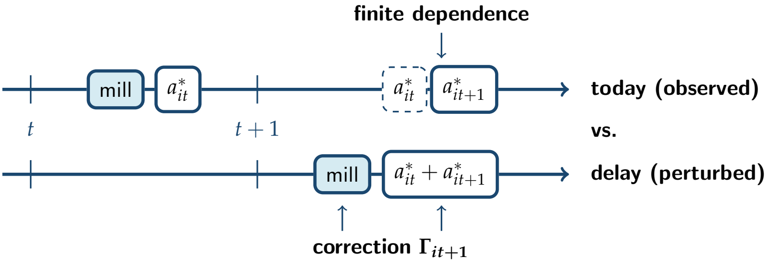

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Value function Regression

Intensive-margin estimates vs. \$7k accounting costs (Butler et al. 2009)

	Estimate	SE
Province-specific costs ($\bar{\kappa}_m$)	7,412***	(167)
Province-specific cost trends ($\bar{\alpha}_m$)	-384***	(18)
Cost factors (γ)		
Log port distance, km	-303	(324)
Log road distance, km	-98	(129)
Log urban distance, km	109	(212)
Log carbon in tree biomass, t	381	(302)
Log carbon in peat deposits, t	-58	(40)
Quadratic costs (δ)	3**	(1)

Extensive-margin estimates vs. $20M acct costs (Man & Baharum 2011)

	Estimate	SE
Province-specific costs ($\bar{\kappa}^e_m$)	22,745,198***	(2,019,229)
Province-specific cost trends ($\bar{\alpha}^e_m$)	-1,370,062***	(153,467)
Cost factors (γ^e)		
Log port distance, km	3,974,558***	(824,272)
Log road distance, km	2,605,341***	(398,823)
Log urban distance, km	2,133,386***	(471,598)
Log carbon in tree biomass, t	959,958*	(500,588)
Log carbon in peat deposits, t	-152,701	(111,080)
Logit scale (σ^e)	6,718,816***	(663,730)

Counterfactuals

Tariffs, demand, supply, and emissions

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

- **Tariffs $\boldsymbol{\tau_t}$** $\rightarrow$ prices P_t (given **demand** model)
  $\rightarrow$ supply s_t (given **supply** model)
  $\rightarrow$ **emissions $\boldsymbol{e_t}$** (given carbon map)

- Emissions assume \$75 SCC and low-carbon outside option
  - General equilibrium, but only within palm oil industry

Carbon map | Non-palm land use | EU motivations | GATT/WTO | Lobbying | Retaliation

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

Own-surplus Non-uniform Quotas

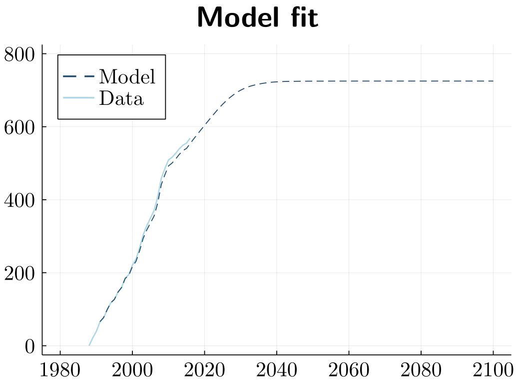
Solving the model

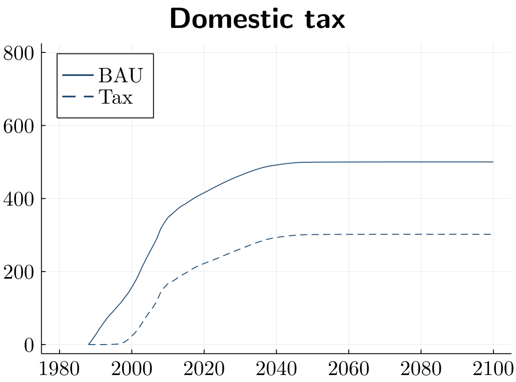
- **Dynamic entry game** solved as a fixed point ($P \to Q \to P$)

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

- **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





Tariffs can work well

	ΔE (%)			ΔW ($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)	ΔW^{EU}		ΔW^{CI}		ΔW^{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 $E \downdownarrows$)
- For commitment, optimal to set tariffs to zero ex post (but not ex ante)

Europe can act unilaterally

	ΔE (%)		ΔW^{EU} ($1B)		ΔW ($1B)	
	Full	10-yr	Full	10-yr	Full	10-yr
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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

	ΔW^{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 may motivate transfers

Conclusion

Summary

- **Import tariffs** effective if **coordinated** and **committed**
  - Helpful where domestic issues take time to fix
- **Palm oil:** 5% of global CO_2 emissions (1990-2016)
  - Past deforestation sunk, but Papua still intact