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

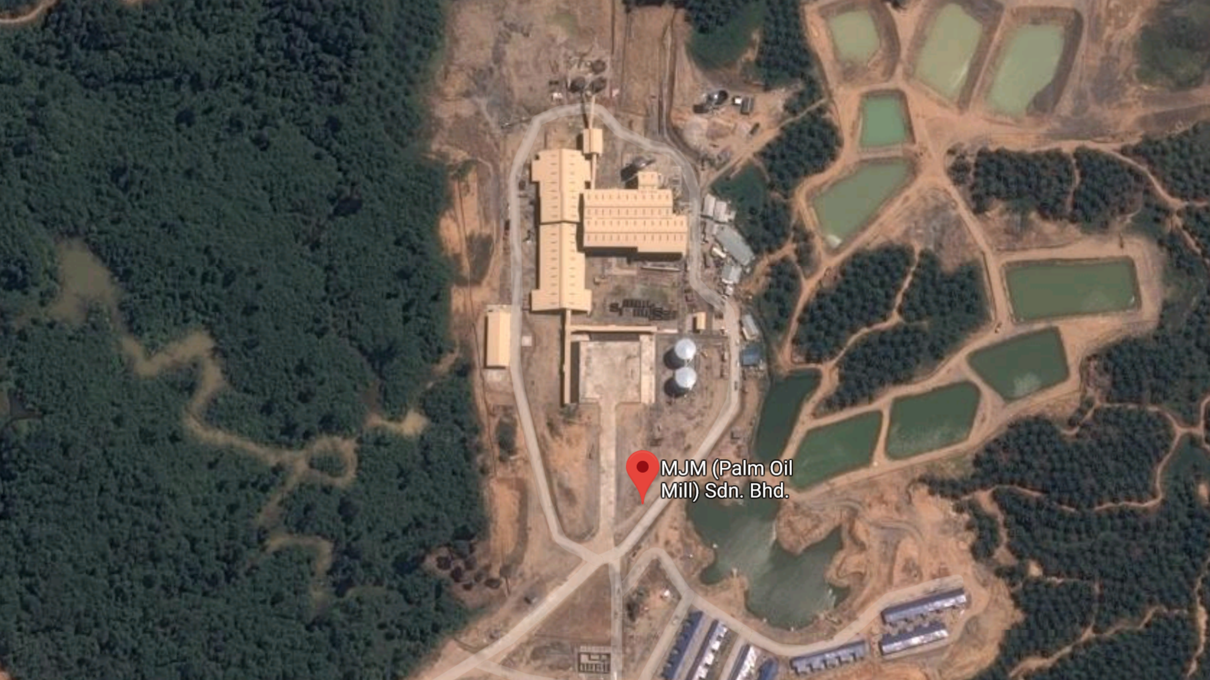
Contributions

- **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)

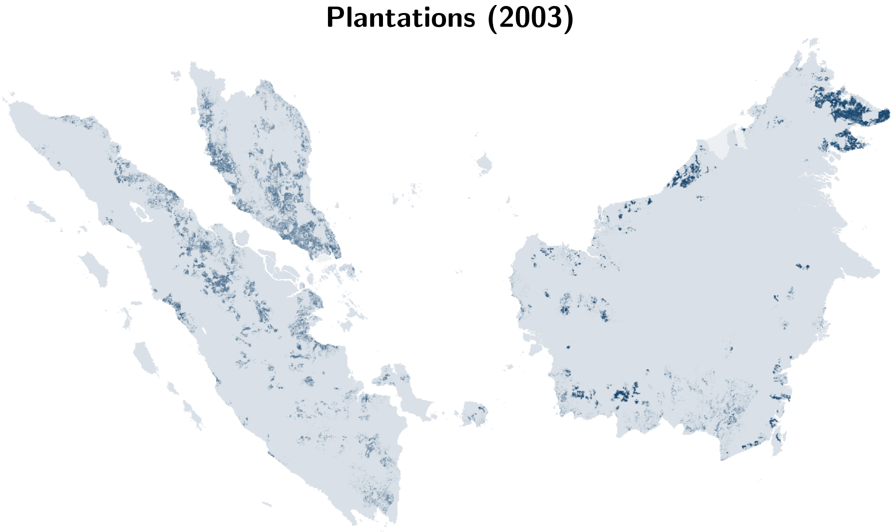
Palm oil has driven rapid, widespread deforestation

Non-palm land use

Plantations (1998)

Palm oil has driven rapid, widespread deforestation

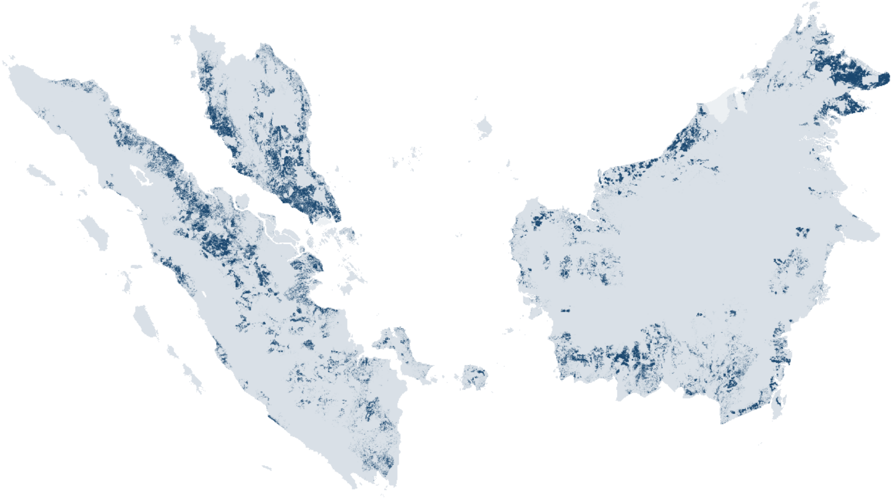
Non-palm land use



Palm oil has driven rapid, widespread deforestation

Non-palm land use

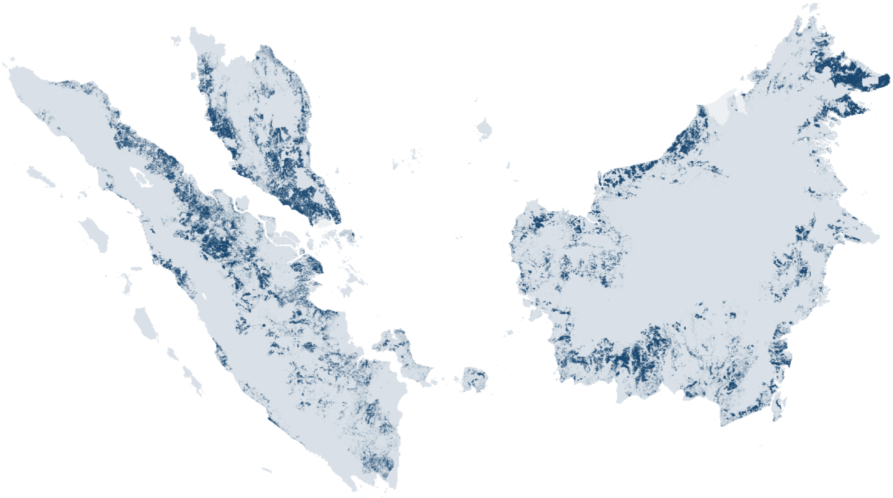
Plantations (2008)



Palm oil has driven rapid, widespread deforestation

Non-palm land use

Plantations (2012)



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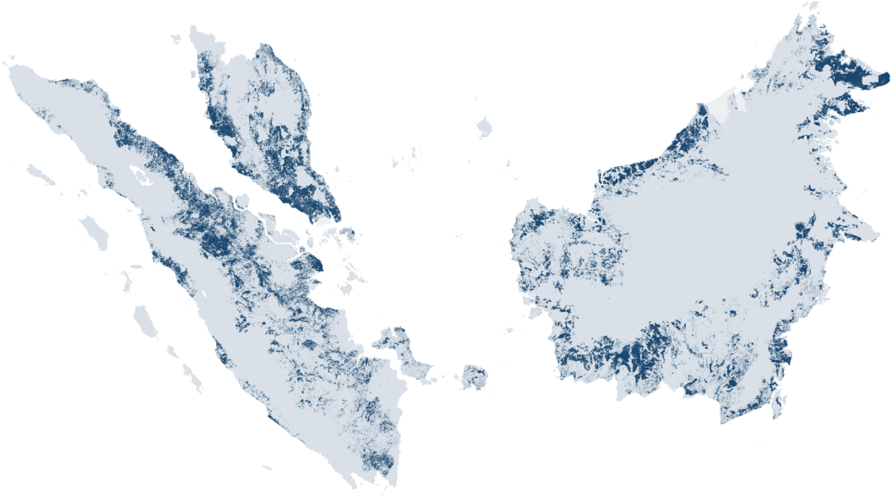


Demand

Almost ideal demand system (Deaton & Muellbauer 1980)

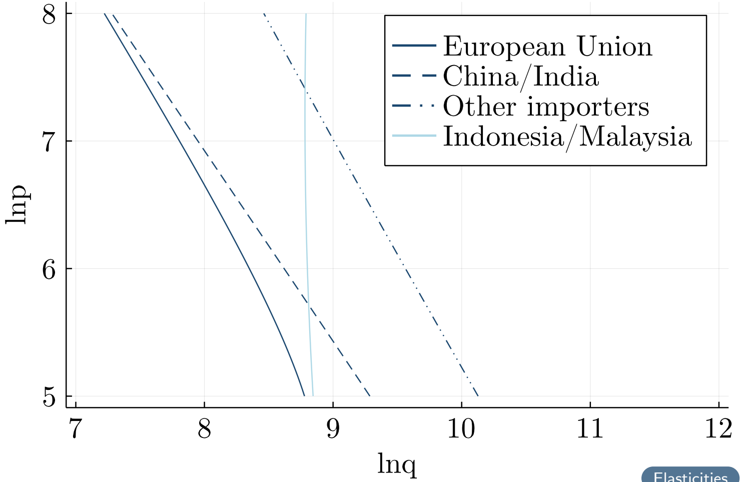
1. $$\ln Q_t = \alpha^0 + \alpha^1 t + \gamma \ln P_t + Z_t \beta + \varepsilon_t$$
2. $$\omega_{it} = \alpha_i^0 + \alpha_i^1 t + \sum_j \gamma_{ij} \ln p_{jt} + \beta_i \ln \left(\frac{X_t}{P_t} \right) + \varepsilon_{it}$$

- **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

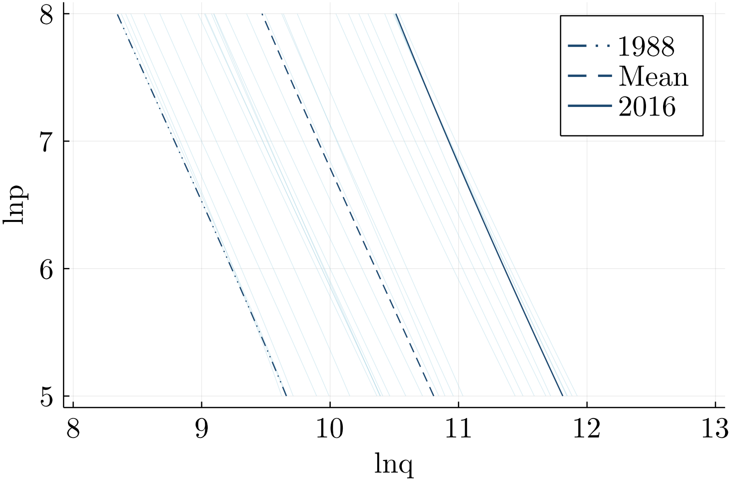
AIDS details | Price IV | IV exclusion | Static demand | Other oils CO_2 | AIDS vs. BLP | Market concentration

Leakage to other importers, but not to domestic consumers



Elasticities Elasticities (no IV)

World demand is increasing



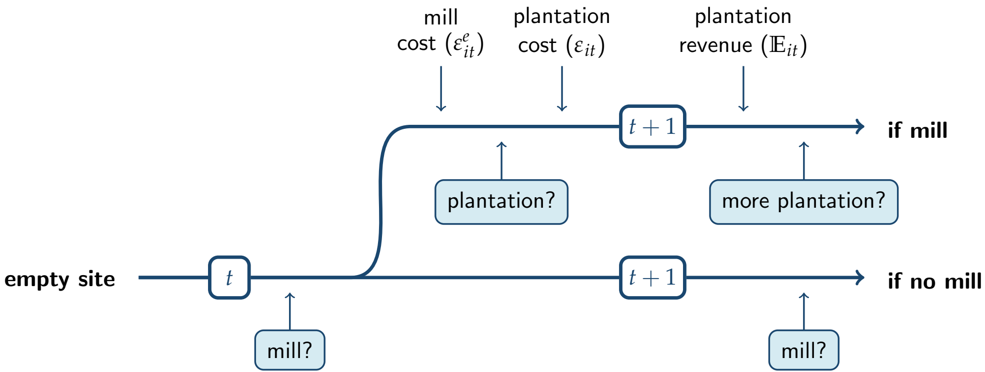
Supply

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 $\varepsilon_{it} \to$ high yield Y_{it+1}

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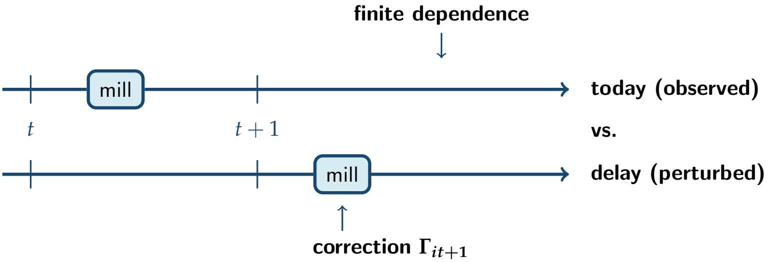
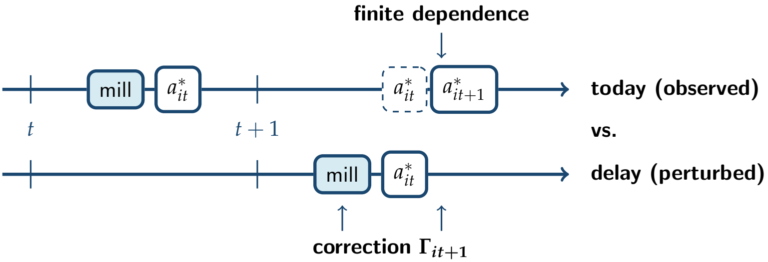
Extensive-margin discrete choice (mills)



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

Value function Regression

Extensive-margin discrete choice (mills)



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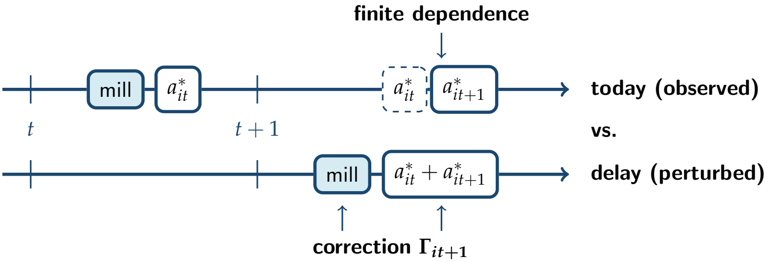

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Value function Regression

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

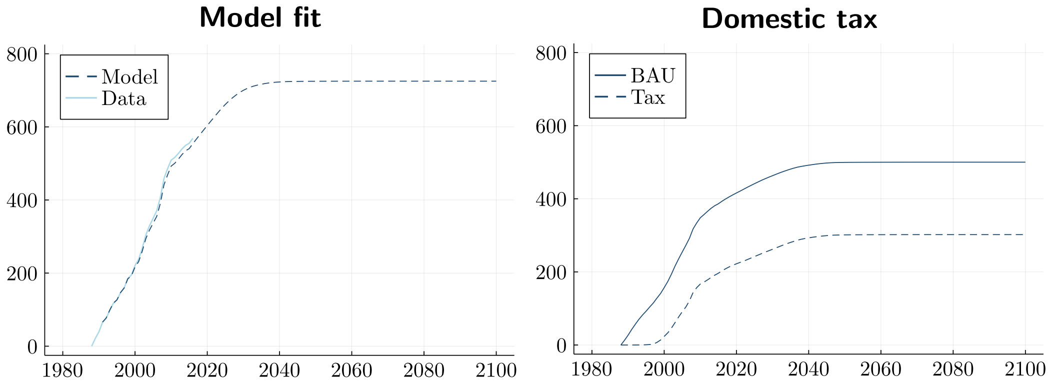
Solving the model

- **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
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

	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

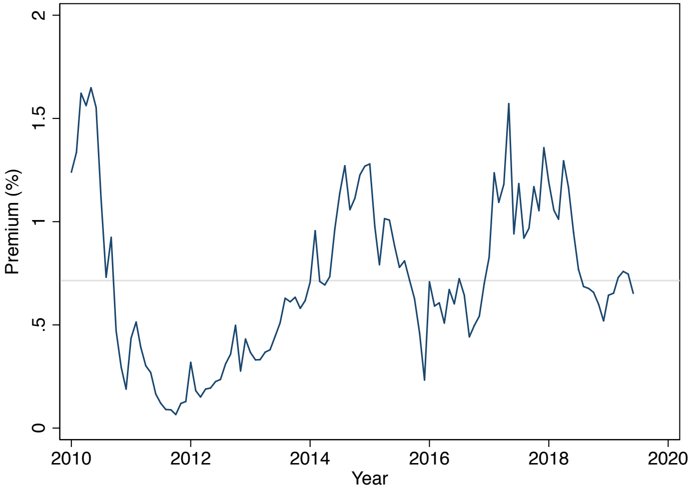
Summary

- **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

Appendix

Price premiums for certified palm oil are very small



Back

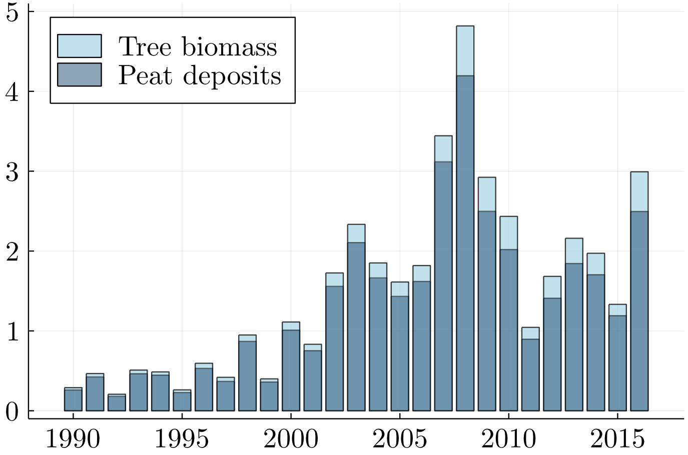
Shapiro (2020): The Environmental Bias of Trade Policy

- Normative: what optimal, emission-based trade policy can achieve
- One industry: capture dynamic entry/investment, spatial heterogeneity

- Tension? Dirty industries have lower tariffs
  - Because clean, downstream industries do not lobby – dispersed, poorly organized
  - But EU palm oil consumers are downstream and dispersed

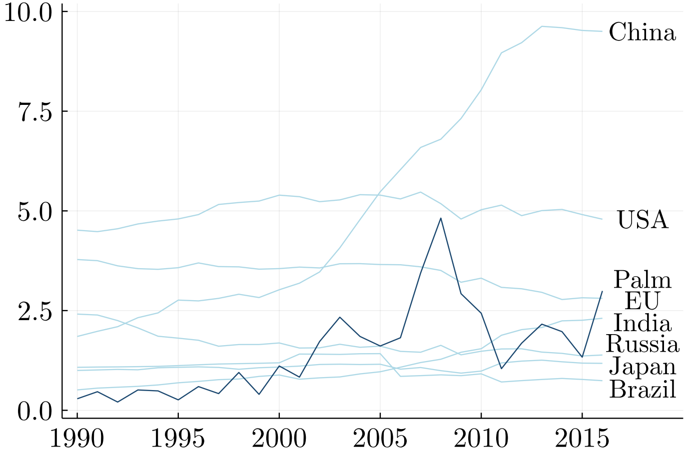
Back

Peatlands magnify emissions from deforestation



Back

Palm emissions exceed Indian emissions



Back

Market concentration is low

Producers	Ratio
Top one	0.04
Top five	0.15
Top ten	0.21
Top twenty	0.27

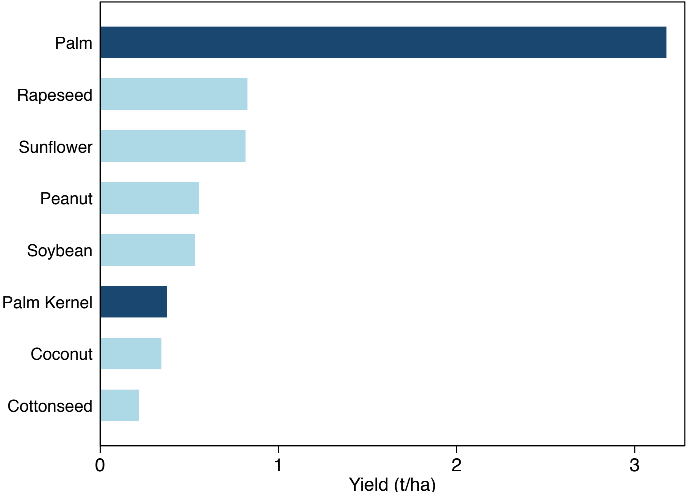
Biggest: FGV Holdings

Consumers	Ratio
Top one	0.02
Top five	0.04
Top ten	0.06
Top twenty	0.07

Biggest: Unilever

Back (setting) Back (demand) Back (supply)

Palm oil has high yields



Back

Carbon costs are large relative to palm oil revenues

	\$1,000/ha
Palm revenues (NPV)	23
Development costs	3.6
Carbon costs, average	98
Carbon costs, no peat	18
Carbon costs, mean peat depth	532
Carbon costs, 90th-percentile peat depth	974
If biodiesel, gasoline emissions averted (NPV)	3.0

Back

“Rest of world” by country

	Production
Rest of world	0.16
Thailand	0.03
Nigeria	0.02
Colombia	0.02
Papua New Guinea	0.01
Côte d’Ivoire	0.01
Ecuador	0.01
Ghana	0.01
Honduras	0.01
Cameroon	0.01
Brazil	0.01

	Consumption
Rest of world	0.45
Pakistan	0.05
Nigeria	0.03
Thailand	0.03
Egypt	0.02
Bangladesh	0.02
United States	0.02
Colombia	0.02
Japan	0.01
Russia	0.01
Kenya	0.01

Back

AIDS (for a given region r)

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

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

$$\ln P_t = \alpha_0 + \sum_j (\alpha_j^0 + \alpha_j^1 t) \ln p_{jt} + \frac{1}{2} \sum_j \sum_k \gamma_{jk} \ln p_{jt} \ln p_{kt}$$

- Expenditure shares $\omega_{it} = p_{it} q_{it} / X_t$, expenditures $X_t = Q_t P_t$
- Restrictions: adding up, homogeneity, symmetry
- Serial autocorrelation: Newey-West

$$e_{ijt} = -\delta_{ij} + \frac{\gamma_{ij}}{\omega_{it}} + \left(\frac{\beta_i \gamma}{\omega_{it}} + \gamma + 1 \right) \underbrace{\left(\frac{\partial \ln P_t}{\partial \ln p_{jt}} \right)}_{\alpha_j^0 + \alpha_j^1 t + \sum_k \gamma_{kj} \ln p_{kt}}$$

Back

Weather shocks as price instruments

	All	All	Palm	Other
Rainfall shocks (100 mm)	0.208***	0.212***	0.139***	0.224***
	(0.0317)	(0.0278)	(0.0325)	(0.0318)
Temperature shocks ($^\circ$C)	0.297***	0.308***	0.681	0.315***
	(0.0335)	(0.0315)	(0.804)	(0.0334)
Oil FE	x	x		
Oil-year trend		x		
Year trend			x	x
Observations	174	174	29	145
F-statistic	40.94	49.25	10.56	48.90

Foreign shocks Back

Foreign weather shocks as price instruments

	European Union	China	India	Other importers	Indonesia	Malaysia
Rainfall shocks (100 mm)	0.000499	0.217***	0.197***	0.111**	0.185***	0.199***
	(0.0419)	(0.0179)	(0.0307)	(0.0443)	(0.0236)	(0.0297)
Temperature shocks ($^{\circ}$C)	0.150***	0.343***	0.275***	0.240***	0.295***	0.300***
	(0.0523)	(0.0178)	(0.0356)	(0.0514)	(0.0302)	(0.0327)
Observations	174	174	174	174	174	174
F-statistic	12.76	200.5	30.12	12.22	48.22	45.83

Back

Weather shocks do not affect overall incomes or expenditures

		Rainfall		Temperature		
Market	Outcome	Estimate	SE	Estimate	SE	Obs
European Union	CPI	0.00362	(0.00275)	0.00264	(0.00245)	174
	GDP	0.00530	(0.00762)	0.00408	(0.00736)	174
	GDE	0.00587	(0.00783)	0.00437	(0.00748)	174
	GDE (hh)	0.000190	(0.000257)	0.000147	(0.000245)	174
	GDE (gov)	0.000241	(0.000303)	0.000169	(0.000292)	174
China/India	CPI	0.00632	(0.0109)	0.00346	(0.0113)	174
	GDP	8.10e-05	(0.0103)	-0.00344	(0.00986)	174
	GDE	-0.00163	(0.00969)	-0.00434	(0.00922)	174
	GDE (hh)	-5.51e-05	(0.000343)	-0.000148	(0.000327)	174
	GDE (gov)	4.56e-05	(0.000281)	-6.68e-05	(0.000263)	174
Other importers	CPI	0.00571	(0.00776)	0.000995	(0.00787)	174
	GDP	0.00360	(0.00448)	0.00180	(0.00411)	174
	GDE	0.00429	(0.00415)	0.00235	(0.00373)	174
	GDE (hh)	0.000138	(0.000130)	8.12e-05	(0.000117)	174
	GDE (gov)	0.000181	(0.000182)	9.07e-05	(0.000162)	174
Indonesia/Malaysia	CPI	-0.0231	(0.0246)	-0.0221	(0.0242)	174
	GDP	0.0113	(0.0154)	0.00539	(0.0157)	174
	GDE	0.00920	(0.0147)	0.00424	(0.0152)	174
	GDE (hh)	0.000384	(0.000536)	0.000202	(0.000555)	174
	GDE (gov)	0.000283	(0.000769)	5.96e-05	(0.000798)	174

Back

Static demand

- **Stockpiling:** observed and small (aggregation helps)
- **Taste preferences:** palm, soybean, rapeseed, and sunflower oils are similar
  - But miss stickiness from long-term contracts or firm relationships
- **Short-run elasticities:** capture year-to-year substitution
  - But miss long-run response of competing oil industries
  - And also of downstream, palm-related industries

Back

CO_2 emissions from other oils are limited

Oil	Ratio
Palm	0.35
Soybean	0.32
Rapeseed	0.16
Sunflower	0.11
Coconut	0.04
Olive	0.03

Soybean origin	Ratio
Brazil	0.17
Argentina	0.13
Rest of South America	0.02
United States	0.28
China	0.16
European Union	0.10
Rest of world	0.15

Back

Product- vs. characteristic-space demand estimation

Product space (AIDS)

- Flexible substitution patterns
- Without specifying product attributes (e.g., smoke point?)

Characteristic space (BLP)

- Accommodate many products
- Value new goods
- Use price variation of similar goods

Back

Mean demand elasticities

		Estimates		SEs	
Market		Palm	Other	Palm	Other
European Union	Palm	-0.510***	0.290	(0.181)	(0.206)
	Other	0.105	-0.301*	(0.148)	(0.171)
China/India	Palm	-0.667***	0.172	(0.210)	(0.302)
	Other	0.187	-0.584***	(0.159)	(0.224)
Other importers	Palm	-0.558***	0.454**	(0.134)	(0.180)
	Other	0.350***	-0.436***	(0.113)	(0.149)
Indonesia/Malaysia	Palm	-0.026	0.234*	(0.171)	(0.120)
	Other	0.707	-0.416	(0.474)	(0.478)

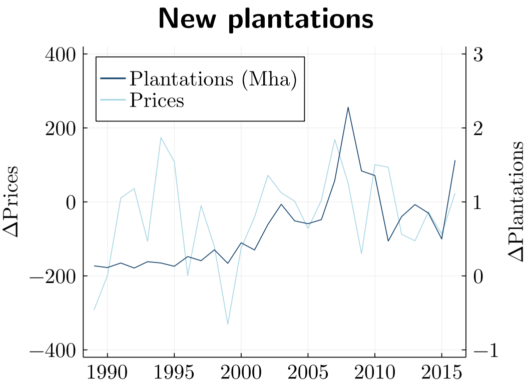
Back

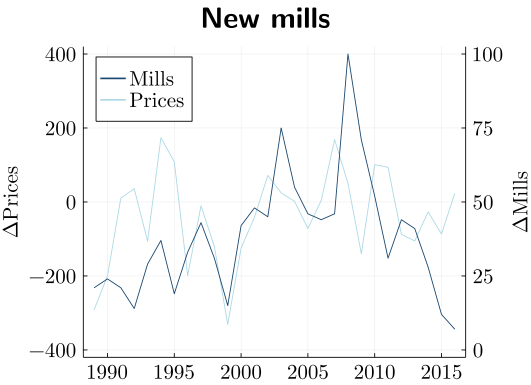
Mean demand elasticities without price instruments

		Estimates		SEs	
Market		Palm	Other	Palm	Other
European Union	Palm	-0.075	0.018	(0.116)	(0.150)
	Other	-0.347**	0.196	(0.149)	(0.184)
China/India	Palm	0.606	-0.113	(0.693)	(0.556)
	Other	0.850**	-0.617*	(0.342)	(0.359)
Other importers	Palm	-0.484***	0.224	(0.051)	(0.143)
	Other	-0.279**	-0.139	(0.135)	(0.221)
Indonesia/Malaysia	Palm	0.730*	-0.685*	(0.424)	(0.403)
	Other	0.417	-0.477	(0.576)	(0.518)

Back

Historical price variation





Back

Reduced-form supply

$$\ln S_t = \beta_1 \ln P_t + \beta_2 \ln P_{t+1} + \varepsilon_t$$

- Short-run observed variation, but long-run counterfactual tariffs
  - So add more regressors: futures prices, leads/lags

- Problems
  - For estimation, impose that P_{t+2} does not enter
  - For counterfactuals, tariffs change P_{t+2}

Back

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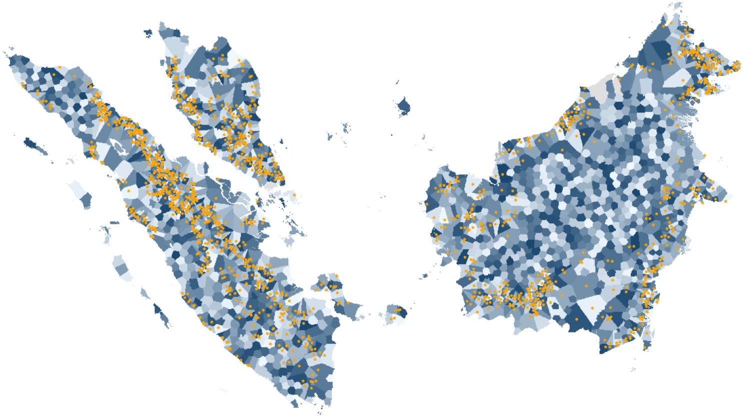
Back

Defining sites by k-means clustering



1. Choose k based on "mature" provinces
2. Apply clustering, imposing max one observed mill/site
3. Lightly harmonize observed mills and plantations

Back

Smallholder farmers account for 40% of plantations

- But most bound to mills with **vertical contracts** (Cramb & McCarthy 2016)
  - Exclusive buying rights for investment support
- Assumption: mills extract all surplus (or need to estimate bargaining power)
  - Only matters for extensive margin, as long as intensive margin is efficient
- Credit constraints: quadratic costs capture soft constraints
- Risk aversion: for estimation, only short-term uncertainty
- Dynamic sophistication: for estimation, flexible long-term expectations

Back

Cost shocks $\varepsilon^e_{it}, \varepsilon_{it}$

- Assumptions
  1. Timing: ε_{it} realized after choice $a^e_{it}(\varepsilon^e_{it})$
  2. Uncorrelatedness
- Relaxing either breaks $\mathbb{E}^e_{it}[\varepsilon_{it}|\varepsilon^e_{it}] = 0$
  - Extensive: omitted variable bias since π_{it} and ε_{it} correlated
  - Intensive: sample selection bias since observed data have high ε_{it}

Back

Site-level unobserved heterogeneity

- Need multiple choices per site, but only build a mill once
- Otherwise, expectation maximization algorithm (Arcidiacono & Miller 2011, Scott 2013)
  - Finite unobserved types $\zeta_i \in \{0, 1\}$
  - E step: update posterior for ζ given CCPs and prior
  - M step: update CCPs and prior given posterior
  - Continue until convergence

Back

Introducing market power

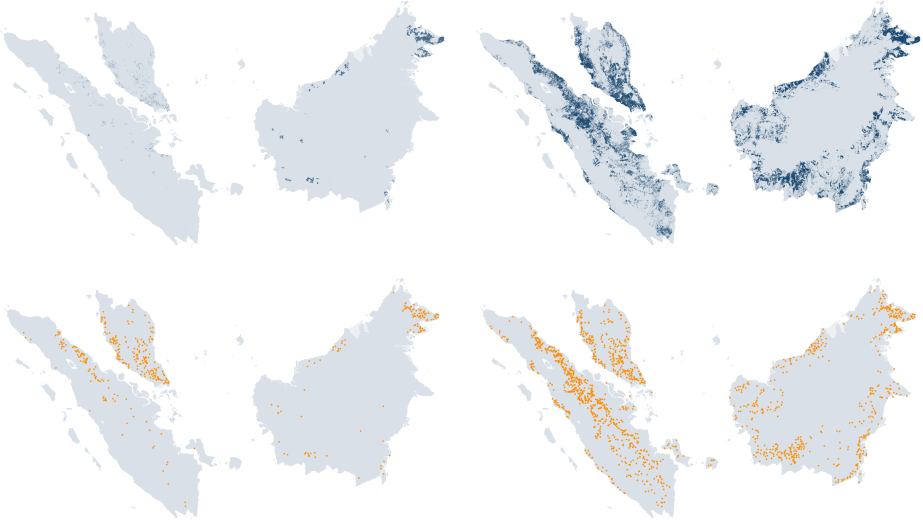
- Breaks finite dependence
  - If price-maker delays, then others respond – economy evolves differently
- Typical effect: market power lowers output (Ryan 2012)
  - Here, production is fixed after sunk investment, and land is scarce
  - So may preemptively invest to deter competitors

Back

Satellite data on plantations and mills over time

Plantations (1988)

Plantations (2016)

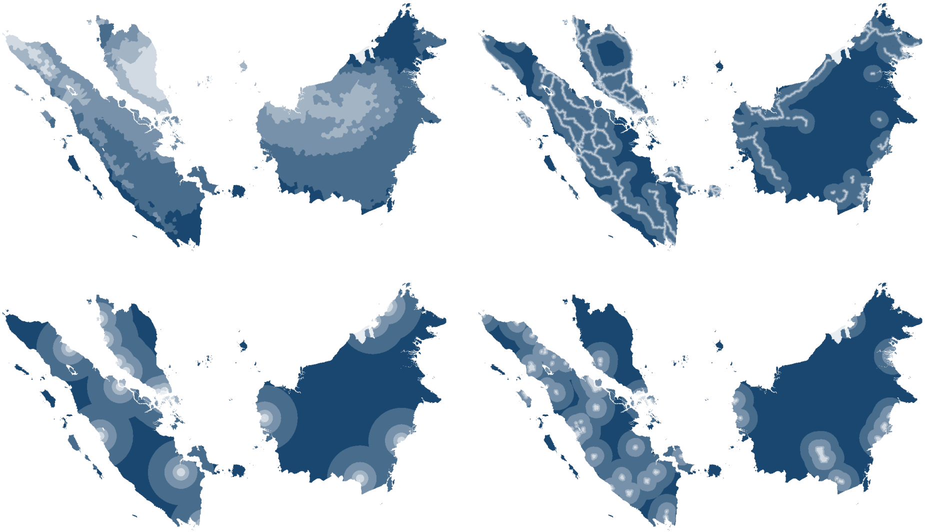


Mills (1988)

Mills (2016)

Back

Spatial data on yields and cost factors



Palm yields

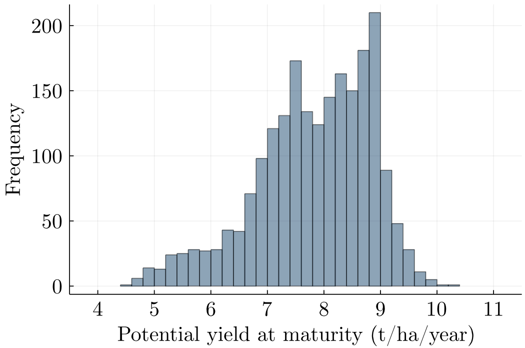
Road distance

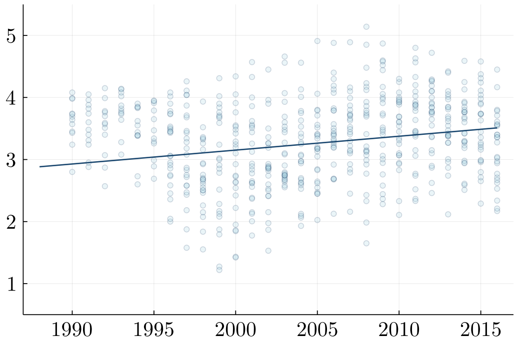
Port distance

Urban distance

Back

Yields Y_{it}: PALMSIM (Hoffmann et al. 2014)





Back

Intensive-margin value function

- Plantation development a_{it} increases size $s_{it+1} = s_{it} + a_{it}$
    - States $\boldsymbol{w}_{it} = \{Y_{it}, x_i, s_t, d_t\}$, ε_{it} for $s_t = \sum_i Y_{it} s_{it}$

$$V(s_{it}; \boldsymbol{w}_{it}, \varepsilon_{it}) = \max_{a_{it}} \left\{ r(s_{it}; \boldsymbol{w}_{it}) - c(a_{it}; \boldsymbol{w}_{it}, \varepsilon_{it}) + \beta \mathbb{E}_{it}\left[V(s_{it+1}; \boldsymbol{w}_{it+1}, \varepsilon_{it+1}) \right] \right\}$$

$$r(s_{it}; \boldsymbol{w}_{it}) = Y_{it} P(s_t, d_t) s_{it}, \quad c(a_{it}; \boldsymbol{w}_{it}, \varepsilon_{it}) = \left(\frac{1}{2} \delta a_{it} + x_i \gamma + \kappa_m + \alpha_m t + \varepsilon_{it} \right) a_{it}$$

Back

Intensive-margin regression

$$a_{it} - \beta a_{it+1} = \frac{\beta}{\delta} Y_{it+1} P_{t+1} - x_i \tilde{\gamma} - \tilde{\kappa}_m - \tilde{\alpha}_m \tilde{t} - \tilde{\varepsilon}_{it} + \eta_{it}$$

- Plantation development a_{it}, a_{it+1}
- Yields Y_{it+1}, prices P_{t+1}
- Cost factors x_i
- Province fixed effects $\tilde{\kappa}_m$
- Province-year trends $\tilde{\alpha}_m$
- Unobserved cost shocks $\tilde{\varepsilon}_{it}$

- Expectational errors $\eta_{it} = \mathbb{E}_{it}[c'_{it+1} + r'_{it+1}] - c'_{it+1} - r'_{it+1}$
- Notation: $\tilde{\gamma} = \frac{1-\beta}{\delta}\gamma$, $\tilde{\kappa}_m = \frac{1-\beta}{\delta}\kappa_m$, $\tilde{\alpha}_m = \frac{1}{\delta}\alpha_m$, $\tilde{t} = t - \beta(t+1)$, $\tilde{\varepsilon}_{it} = \frac{1}{\delta}\varepsilon_{it}$

Back

Intensive-margin IV estimates

	OLS	IV	First stage
	$a_{it} - \beta a_{it+1}$	$a_{it} - \beta a_{it+1}$	$Y_{it+3}P_{t+3}$
Yield $\times$ price ($Y_{it+3}P_{t+3}$)	0.111***	0.279**	
	(0.00677)	(0.117)	
Potential yield $\times$ demand ($Y_i^p d_t$)			17.53***
			(0.719)
Province FE	x	x	x
Province-year trend	x	x	x
Observations	22,914	22,914	22,914
F-statistic			594

Back

Extensive-margin value function

- Mill construction a_{it}^e (if $s_{it}^e = 0$)
  - States $\boldsymbol{w}_{it} = \{Y_{it}, x_i, s_t, d_t\}$, ε_{it}^e for $s_t = \sum_i Y_{it} s_{it}$

$$V^e(\boldsymbol{w}_{it}) = \mathbb{E}_{it}^e[\max\{v^e(0; \boldsymbol{w}_{it}) + \varepsilon_{it0}^e, v^e(1; \boldsymbol{w}_{it}) + \varepsilon_{it1}^e\}]$$

$$v^e(0; \boldsymbol{w}_{it}) = \beta \mathbb{E}_{it}^e[V^e(\boldsymbol{w}_{it+1})], \quad v^e(1; \boldsymbol{w}_{it}) = -\underbrace{c^e(\boldsymbol{w}_{it})}_{x_i\gamma^e + \kappa_m^e + \alpha_m^e t} + \mathbb{E}_{it}^e[V(0; \boldsymbol{w}_{it}, \varepsilon_{it})]$$

Back

Extensive-margin regression

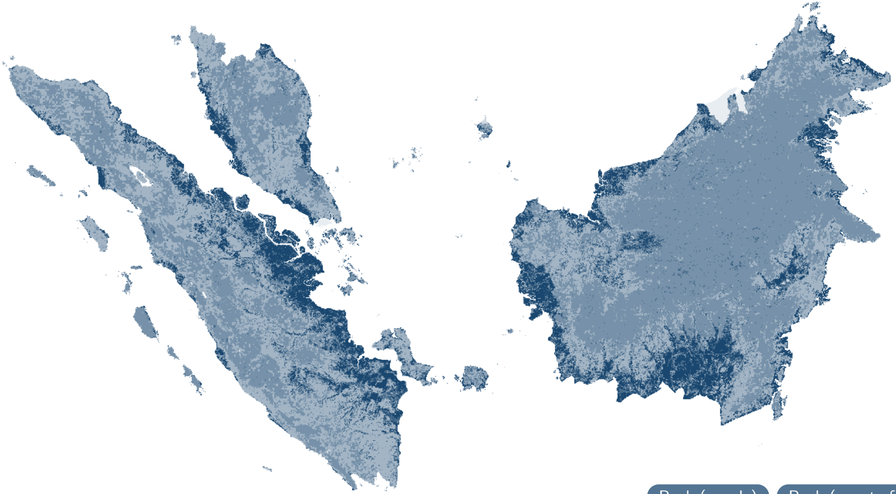
$$\ln\left(\frac{\widehat{p^e}(\boldsymbol{w}_{it})}{1-\widehat{p^e}(\boldsymbol{w}_{it})}\right) - \beta \ln \widehat{p^e}(\boldsymbol{w}_{it+1}) = \widehat{I}_{it+1} - (1-\beta)x_i\gamma^e - (1-\beta)\kappa_m^e - \alpha_m^e\tilde{t} + \eta_{it}^e$$

$$\widehat{I}_{it+1} = [\beta Y_{it+1}P_{t+1} - (1-\beta)x_i\widehat{\gamma} - (1-\beta)\widehat{\kappa}_m - \widehat{\alpha}_m\tilde{t}]a_{it}^* + \widehat{\delta}[-\frac{1}{2}a_{it}^{*\,2} + \beta a_{it}^* a_{it+1}^*]$$

- Mill development probability p^e
- Intensive-margin profits I_{it+1}
- Cost factors x_i
- Province fixed effects κ_m^e
- Province-year trends α_m^e
- Expectational errors η_{it}^e

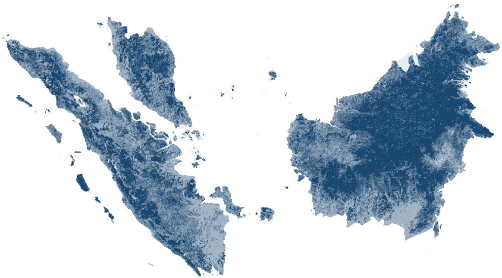
Back

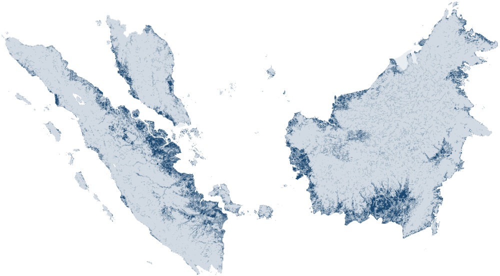
Spatial data on carbon stocks: trees + peat (Zarin et al. 2016, Gumbricht et al. 2017)



Back (supply) Back (counterfactuals)

Spatial data on carbon stocks: trees + peat (Zarin et al. 2016, Gumbricht et al. 2017)





Back (supply) Back (counterfactuals)

Own-surplus maximization has two effects

Own-surplus results

1. Terms-of-trade effects: tariffs $\uparrow$
   - Tariffs improve terms of trade at expense of partner countries (Johnson 1953)
2. Smaller emission damages: tariffs $\downarrow\downarrow$
   - EU cost of carbon $\ll$ social cost of carbon

Back (counterfactuals)

Uniform tax less effective than Pigouvian

Non-uniform results

- "Second-best": average emissions, weighted by supply elasticities (Diamond 1973)
- But more practical
  - No monitoring production or tracking histories
  - No "green-washing" concerns (commitment)
  - No fine vs. coarse differentiation concerns
- And common
  - Uniform gas tax for all vehicles (Knittel & Sandler 2018)
  - Stimulus checks for households with income under $150,000
  - Any national regulation without regional differentiation

Back (supply) Back (counterfactuals)

Non-palm land use (outside option)

- Assumptions
  - For estimation, palm tariffs do not affect outside utility
  - For counterfactual emissions, palm tariffs do not increase non-palm deforestation
- Threats

Acacia regression

  - Mining: exogenous deposits; selective logging: not slash-and-burn
  - **Acacia:** low palm-acacia sub. in reduced form (GE: nested model, acacia tariffs)
- But non-palm crops less profitable (Sofiyuddin et al. 2012)
  - Palm profits: 10x coconut, 10x maize, 7x acacia, 7x rice, 3x rubber, 2x jelutung

Back (setting) Back (supply) Back (counterfactuals)

Palm-acacia substitution is small

$$\text{acacia}_{it} = \beta \text{palm}_{it} + \alpha_i + \alpha_{mt} + \varepsilon_{it}$$

	Acacia	Acacia	Acacia	Acacia
Palm development (ha)	0.0221***	0.0155**	0.0113	0.0115
	(0.00682)	(0.00776)	(0.00782)	(0.00792)
Site FE		x	x	x
Year FE			x	
Province-year FE				x
Observations	6,018	6,018	6,018	6,018

Back

EU motivations for tariffs

- In the model, reducing global damages from CO_2
  - Otherwise not willing to sacrifice consumer surplus
- In reality, CO_2 agenda of the European Commission
  - Given carbon regulation (EU cap-and-trade), carbon tariffs help EU competitiveness

Back

GATT/WTO considerations

- Carbon tariffs motivated by emission reductions
  - Not terms-of-trade manipulation (Bagwell & Staiger 1999/2011, Broda et al. 2008)
  - Or production relocation (Krugman 1980, Venables 1987, Ossa 2011)
- Compliance: "conservation of exhaustible natural resources" (GATT art. XX(g))
  - For palm oil, implementable as a consumption tax (nondiscrimination)
  - More broadly, carbon taxes call for carbon tariffs

Back (introduction) Back (counterfactuals)

Tariff lobbying (Grossman & Helpman 1994/1995, Maggi & Rodríguez-Clare 1998/2007)

- Emissions aside, EU tariffs hurt EU palm oil consumers
  - Quantified in aggregate; dispersed, downstream actors
- But help EU non-palm oil producers
  - Need EU supply model to quantify; organized, upstream actors
  - Mitigated by lower export revenues
- Helps commitment if strong enough
  - 2018 US tariffs (no retaliation): EV^M -0.27% GDP, EV^X +0.09%, ΔR +0.19% (Fajgelbaum et al. 2020)

Back

Tariff retaliation by Indonesia/Malaysia

- Not modeled and indeed likely
  - WTO lawsuits, canceled Airbus orders following EU biofuel reforms
- But can quantify losses and thus transfers
  - Following EU tariffs, Indonesia/Malaysia producer surplus $\downarrow\downarrow$ (although CS $\uparrow$)
- And counterfactuals roll back to 1988
  - Malaysian industry small, Indonesian very small

Back

Quotas instead of tariffs

- Emissions only from "new" plantations, so set quota at last year's quantity
  - Prices vs. quantities aside (Weitzman 1974)
- But importers still have leakage and commitment problems
  - In unregulated markets, "old" and "new" palm oil are perfect substitutes
  - Ex-post temptation to revise quota after "new" palm oil becomes "old"

Back

Special features of palm oil

- Production concentrated in two countries and largely exported
  - Regulation by non-producers is enough, although I do quantify producer surplus
- Once land is developed, keeps producing
  - Production is a function of land, so can "observe" production via satellite
- Emissions all upfront
  - Without growing demand, existing plantations are enough
  - Ideally, regulation distinguishes between old and new plantations
  - But sunk investment drives the commitment problem (not sunk emissions per se)