Global Policy Spillovers:

Evidence from the Multinational Automobile Industry

Koichiro Ito[1] James M. Sallee[2] Andrew Smith[3]

[1]University of Chicago and NBER (ito@uchicago.edu)

[2]University of California, Berkeley and NBER

[3]University of Wisconsin–Madison

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Motivation and research question

- Motivation: A country's policy affects multinational firms' products
  - Environmental regulations on cars, electric appliances, etc.
  - Safety regulations on equipment, medications, etc.
  - Firms may change product designs in response to policies

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  - Firms may change product designs in response to policies
- Do policy impacts spillover globally though product markets?
  - A country's policy affects products produced by multinational firms
  - If a product is sold worldwide, one country's policy may affect individuals in the rest of the world through the product market
- Economic analysis usually do not incorporate this possibility
  - Evaluations of domestic policies usually focus on domestic benefits
  - Many economic policies' impacts may have been understated

We examine this question in the international car markets

- Automakers often sell common models in many countries
  - The world best selling models (Toyota Carolla, Rav4, Honda Civic, CR-V etc.) are sold in many countries
  - A country's environmental policy might affect these products worldwide

Related literature

- Our focus is global spillover effects through the policy impact on product designs

- Related literature

  1. Spillover effects through the relocation of production
     - Pollution haven hypothesis—countries with weaker environmental regulations attract polluting industries, including local pollution

  2. Spillover effects through the exports of used products
     - Used cars (Davis and Kahn, 2010)
     - Used batteries (Tanaka, Teshima, and Verhoogen, 2022)

Outline

1. Introduction
2. Background
3. Difference-in-Differences Estimation
4. Structural Model
5. Counterfactual Policy Simulation
6. Conclusion

Background

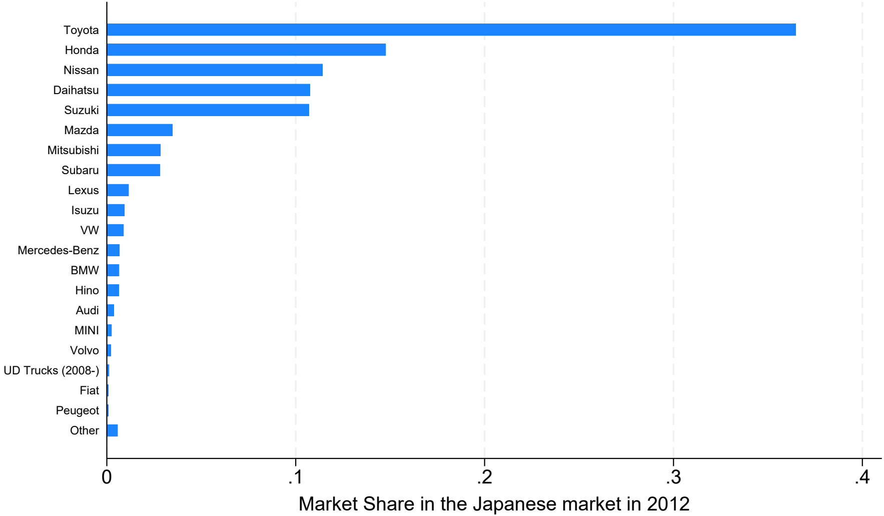
Policy: JPN government's subsidy for fuel-efficient vehicles

- "Eco-car" subsidy started in April, 2009
  - Consumers received a $1,000 subsidy for a new car purchase if the model exceeds its 2015 fuel economy target
  - A stronger incentive for automakers to improve each model's fuel economy than the CAFE b/c the incentive was at the model level
  - Firms responded to it by improving fuel economy
- However, it was considered as an "expensive" policy
  - The government spent $6.3 billion for the subsidy

Hypothesis: did the policy generate global spillovers?

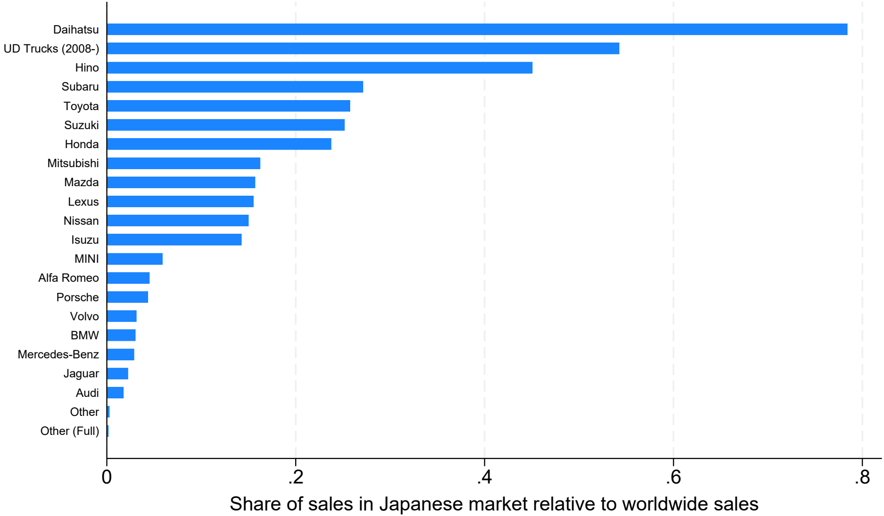
- What could be important factors for the potential spillover effect?
  - Firms face fixed costs of changing each model's product design
  - The subsidy incentive needs to be large enough to cover the fixed cost
- Conditions for home country:
  - The market has to be big enough for the model, otherwise it makes little sense for firms to respond to the subsidy's incentive
- Conditions for spillovered country:
  - Spillover impact is economically significant if the model's market share in the spillovered country is also larger

Which firms sell the most in the Japanese market?



- JPN firms dominate, European firms are second, and almost no American cars

Market share in Japan relative to a firm's worldwide sales



- JPN market is important for JPN & European firms, not so for American firms

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Difference-in-Differences Estimation

Identification strategy and data

- Identification strategy
  - Want to estimate JPN policy's impact on MPG of cars sold outside JPN
  - We use the difference-in-differences (DID) method
  - Time: before and after the policy introduction
  - Treated: models sold in home county (JPN) and spillovered country (US)
  - Control: the same firms' models sold in the US but NOT sold in JPN

- Data
  - Car characteristics data and sales data at the model level
  - Data sources: web-scraped car characteristics, sales from Marklines
  - Currently collected data for Japan, US, Germany, India
  - Linking models between countries is not obvious and needs careful work

Difference-in-differences for cars sold by JPN automakers

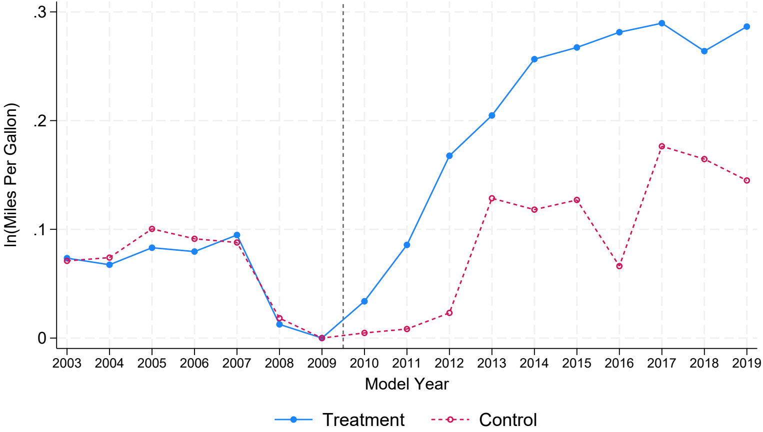
$$\ln MPG_{it} = \alpha Treated_i \times Post_t + \beta Treated_i + \gamma Post_t + \delta X_{it} + \epsilon_{it}$$

- Variables:
  - MPG_{it} is miles per gallon for vehicle i and model year t in the US market
  - $Treated_i = 1$ if model i is also sold in Japan
  - $Post_t = 1$ after the introduction of the fuel-efficiency subsidy in Japan
  - X_{it} is a set of control variables (e.g, model and time fixed effects)
  - Standard errors clustered at the model level to adjust for serial correlation
- Identification assumption:
  - Parallel trend of MPG between 1) models sold in both countries and 2) models not sold in Japan

Japanese cars in the US market

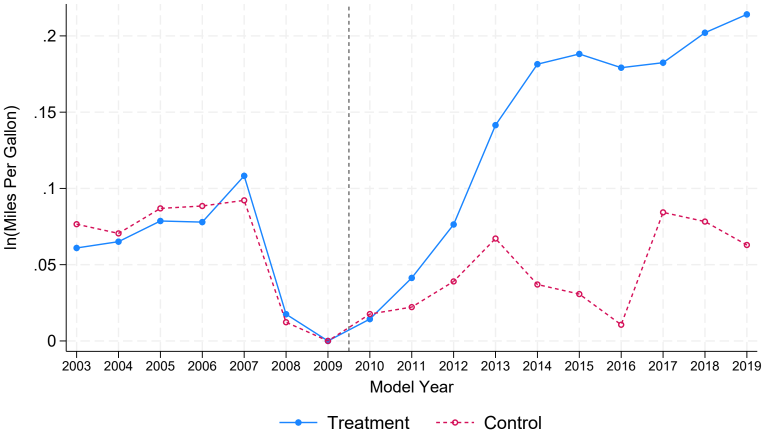
- US is the top 2 country in car sales (18.5% of the world sales)
- Japanese automakers have a 36.5% market share in the US

Average ln(MPG) in the US market: Unweighted



- Treatment: Japanese cars sold in the US and Japan (90 models)
- Control: Japanese cars sold in the US but not in Japan (41 models)
- Vertical line: Introduction of the fuel-efficiency subsidy in Japan

Average ln(MPG) in the US market: Weighted by sales



- Treatment: Japanese cars sold in the US and Japan (90 models)
- Control: Japanese cars sold in the US but not in Japan (41 models)
- Vertical line: Introduction of the fuel-efficiency subsidy in Japan

Spillover effects for Japanese cars in the US market

$$\ln MPG_{it} = \alpha Treated_i \times Post_t + \beta Treated_i + \gamma Post_t + \delta X_{it} + \epsilon_{it}$$

	(1)	(2)	(3)	(4)
Treated × Post	0.112	0.108	0.085	0.080
	(0.042)	(0.041)	(0.025)	(0.025)
Treated	0.298	0.299		
	(0.062)	(0.062)		
Post	-0.007		0.007	
	(0.037)		(0.016)	
N	1,178	1,178	1,176	1,176
Year FE	No	Yes	No	Yes
Model FE	No	No	Yes	Yes

- Spillover effects: 8∼11% increase in fuel economy

American cars in the US market

- American automakers have a 45.1% market share in the US.
- American automakers have a 0.2% market share in Japan.

Spillover effects for American cars in the US market

$$\ln MPG_{it} = \alpha Treated_i \times Post_t + \beta Treated_i + \gamma Post_t + \delta X_{it} + \epsilon_{it}$$

	(1)	(2)	(3)	(4)
Treated × Post	0.040	0.040	-0.019	-0.018
	(0.049)	(0.048)	(0.031)	(0.031)
Treated	-0.102	-0.102		
	(0.062)	(0.062)		
Post	0.093		0.093	
	(0.033)		(0.023)	
N	1,329	1,329	1,325	1,325
Year FE	No	Yes	No	Yes
Model FE	No	No	Yes	Yes

- Treatment: US cars sold in the US and Japan (59 models)
- Control: US cars sold in the US but not in Japan (144 models)
- Insignificant effects → could make sense b/c of the low market share in Japan

Japanese cars in the German market

- Germany is the top 5 country in car sales (3.9% of the world sales)
- Japanese automakers have a 9.8% market share in Germany

Spillover effects for Japanese cars in the German market

$$\ln MPG_{it} = \alpha Treated_i \times Post_t + \beta Treated_i + \gamma Post_t + \delta X_{it} + \epsilon_{it}$$

	(1)	(2)	(3)	(4)
Treated × Post	0.083	0.076	0.078	0.076
	(0.035)	(0.031)	(0.024)	(0.020)
Treated	-0.263	-0.263		
	(0.114)	(0.115)		
Post	0.061		0.047	
	(0.022)		(0.014)	
N	547	547	543	543
Year FE	No	Yes	No	Yes
Model FE	No	No	Yes	Yes

- Treatment: Japanese cars sold in Germany and Japan (84 models)
- Control: Japanese cars sold in Germany but not in Japan (7 models)
- Spillover effects: 8% increase in fuel economy

Japanese cars in the Indian market

- India is the top 4 country in car sales (4.6% of the world sales)
- Japanese automakers have a 49.2% market share in India

Spillover effects for Japanese cars in the Indian market

$$\ln MPG_{it} = \alpha Treated_i \times Post_t + \beta Treated_i + \gamma Post_t + \delta X_{it} + \epsilon_{it}$$

	(1)	(2)	(3)	(4)
Treated × Post	0.173	0.144	0.285	0.272
	(0.135)	(0.142)	(0.056)	(0.060)
Treated	-0.016	-0.016		
	(0.139)	(0.143)		
Post	0.115		-0.006	
	(0.123)		(0.009)	
N	147	147	145	145
Year FE	No	Yes	No	Yes
Model FE	No	No	Yes	Yes

- Treatment: Japanese cars sold in India and Japan (29 models)
- Control: Japanese cars sold in the India but not in Japan (13 models)

Heterogeneity in the spillover effects

- Car models that were similar between Japan and US before the policy shock may have shared more common design/platform/inputs
- These models may get larger spillover effects in the US market
- Hypothesis: "Differentiated" models may get less spillover effects

Heterogeneity in the spillover effects

Dependent variable: ln MPG_{it}			
	(1)	(2)	(3)
Treated × Post	0.073	0.119	0.088
	(0.024)	(0.027)	(0.025)
Treated × Post × Differentiation 1		-0.218	
		(0.071)	
Treated × Post × Differentiation 2			-0.184
			(0.072)
N	9,098	7,159	7,159
Year FE	Yes	Yes	Yes
Model FE	Yes	Yes	Yes

- Differentiation 1 $= |ln(MPG_{i,JP,2008}) - ln(MPG_{i,US,2008})|$
- Differentiation 2 $= (MPG_{i,JP,2008} - MPG_{i,US,2008})^2$
- Confirms that models with higher differentiation between Japan and US experienced smaller spillover effects

Pass-through rate of the spillover effects

- How large was the spillover effects relative to the "direct effects" of the policy in the home country?

Pass-through rate of the spillover effects

Dependent variable: ln MPG_{it}

	JPN models in US	JPN models in JPN	Stacked regression
Treated in Japan × Post		0.207	0.207
		(0.080)	(0.082)
Treated in US × Post	0.073		0.073
	(0.024)		(0.024)
Year FE	Yes	Yes	Yes
Model FE	Yes	Yes	Yes
Difference in Japan-US coefficients			0.134
Standard error of difference			0.082
Ratio of US-Japan coefficients			0.354
Standard error of ratio			0.169

- Control group: Japanese models sold in the US but not in Japan
- Result suggests that the spillover pass-though rate = 35.4%

Summary of the DID results and welfare implications

- The Japanese fuel-economy subsidy induced global spillover effects:
  - Mostly through products sold by Japanese automakers
  - Spillover effects were economically significant (e.g. 8∼11% increase in fuel economy in the US market)

- What were the welfare effects of this spillover for the US economy?
  - Consumers were likely to benefit from the improved fuel economy
  - However, this does not necessarily imply a higher consumer surplus
    - Firms may have increased prices
    - Firms may have increased markups
    - There could be indirect equilibrium effects on unaffected cars

- We build a model of multinational car markets to study these questions

Impact on other attributes: JPN cars in US market

$$\ln Attribute_{it} = \alpha Treated_i \times Post_t + \beta Treated_i + \gamma Post_t + \delta X_{it} + \epsilon_{it}$$

	(1) MPG	(2) Horsepower	(3) Price	(4) Wheelbase	(5) Footprint	(6) Weight
Treated × Post	0.073	-0.080	-0.039	-0.010	-0.008	-0.025
	(0.024)	(0.030)	(0.024)	(0.008)	(0.010)	(0.019)
N	9,098	9,134	9,124	9,134	9,134	9,120

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A Model of Multinational Car Markets

Our model has two goals

1. Model and estimate a potential mechanism of global policy spillovers
   - Build on a standard differentiated-product market model (BLP, 1995)
   - Extend it to incorporate multinational markets
   - Extend it to incorporate firms' endogenous attribute choices
   - Model & estimate potential cross-market links in revenues and costs
2. Investigate the welfare implications of the global policy spillover effect
   - Consumer surplus
   - Producer surplus
   - Environmental externalities
   - Social welfare

Overview of the model

- Multinational firms maximize their profits in two countries
  - A home country where a policy intervention occurs (Japan in our case)
  - A spillovered country (United States in our case)
- Demand
  - A standard random-utility framework with random-coefficient logit
  - Consumer preferences are allowed to be different between countries
  - i.e. We estimate each country's demand system separately
- Supply
  - We consider a multinational multi-product firms that sell products $j \in J_f$
  - Marginal cost c_j is allowed to be different between countries
  - Firms also have fixed costs of improving fuel economy FC_j (Fang, 2013)
  - We allow FC_j to have cross-market complementarity

1) Demand—A random utility model for new car purchases

- p_{jc}: price for product j in market c
- x_{jc}: a vector of product characteristics for product j in market c

- Conditional indirect utility of consumer i who purchases product j

$$u_{ijc} = \beta_i x_{jc} + \alpha_i p_{jc} + \xi_{jc} + \epsilon_{ijc}$$

  - ξ_{jc}: unobserved factors at the market-product level
  - ϵ_{ijc}: unobserved factors at the market-product-consumer level (type-I extreme value)

1-1) Standard Logit Demand Approach

$$u_{ijc} = \beta_i x_{jc} + \alpha_i p_{jc} + \xi_{jc} + \epsilon_{ijc}$$

- First, assume that β and α do not depend on i
- The probability that consumer i in market c chooses product j is:

$$P_{ijc} = Pr(U_{ijc} > U_{ij'c}) \; \forall j' = \frac{\exp(\beta x_{jc} + \alpha p_{jc} + \xi_{jc})}{\sum_{j'=0}^{J} \exp(\beta x_{j'c} + \alpha p_{j'c} + \xi_{j'c})}$$

- Note that P_{ijc} does not depend on i. Then, the sum over i will be:

$$\sum_{i=1}^{N_c} P_{ijc} = N_c \cdot \frac{\exp(\beta x_{jc} + \alpha p_{jc} + \xi_{jc})}{\sum_{j'=0}^{J} \exp(\beta x_{j'c} + \alpha p_{j'c} + \xi_{j'c})}$$

1-1) Standard Logit Demand Approach

- The market share for product j in city c is:

$$s_{jc} \equiv \frac{1}{N_c} \sum_{i=1}^{N_c} P_{ijc} = \frac{\exp(\beta x_{jc} + \alpha p_{jc} + \xi_{jc})}{\sum_{j'=0}^{J} \exp(\beta x_{j'c} + \alpha p_{j'c} + \xi_{j'c})}$$

- The market share for the outside option S_{0c}
  - The outside option is not to buy product $j = 1, ..., J$
  - This market share is usually unobservable from a dataset
  - A typical approach is to assume that S_{0c} is the number of consumers (households) in market c that did not buy any product j
  - Consumers obtain zero utility if they do not purchase any of product j

$$s_{0c} = \frac{\exp(0)}{\sum_{j'=0}^{J} \exp(\beta x_{j'c} + \alpha p_{j'c} + \xi_{j'c})}$$

1-1) Standard Logit Demand Approach

- Log market share for j minus log market share for outside option:

$$\ln s_{jc} - \ln s_{0c} \quad = \quad \beta x_{jc} + \alpha p_{jc} + \xi_{jc}$$

- An advantage of this method is that it is just a linear equation
- An disadvantage is that it assumes restrictive substitution patterns: the Independence of Irrelevant Alternatives (IIA) assumption

1-2) Random Coefficient Logit Approach

- Allow heterogeneity in β and α

$$u_{ijc} = \beta_i x_{jc} + \alpha_i p_{jc} + \xi_{jc} + \epsilon_{ijc}$$

  - e.g. $\beta_i = \beta_0 + \beta_1 D_i + u_i$
  - e.g. $\alpha = \alpha_0 + \alpha_1 D_i + e_i$,
  - Explain taste heterogeneity by demographic variables (D_i) and a random term $u_i \sim N(0, \sigma_\beta)$ and $e_i \sim N(0, \sigma_\alpha)$

- Advantage: Allow for flexible substitution patterns, less restrictive price elasticity, and heterogeneous tastes

- Challenge: Non-linear GMM requires numerical simulation. Need careful implantation to obtain global optimal GMM estimates (Knittel and Metaxoglou 2013, Conlon and Gortmaker 2020)

2) Supply

- Multinational multi-product firm f's profit can be written by:

$$\text{Japan: } \pi_f = \sum_{j \in J_f} \left[\Big(p_j - c_j(e_j, x_j) \Big) \cdot q_j\big(p_j - \tau_j(e_j), e_j, x_j \big) \right]$$

$$\text{US: } \hat{\pi}_f = \sum_{j \in \hat{J}_f} \left[\Big(\hat{p}_j - \hat{c}_j(\hat{e}_j, \hat{x}_j) \Big) \cdot \hat{q}_j\big(\hat{p}_j, \hat{e}_j, \hat{x}_j \big) \right]$$

  - J_f: the set of cars sold by firm f
  - p_j: the price of car j
  - c_j: marginal cost
  - e_j: fuel economy
  - x_j: a vector of other attributes
  - q_j: demand $=$ (market size) $\cdot s_j$
  - $\tau_j(e_j)$: the fuel-economy subsidy in Japan

- Firm f maximizes $\pi_f + \hat{\pi}_f - \sum_j FC(e_j, \hat{e}_j)$ w.r.t. $(p_j, e_j, \hat{p}_j, \hat{e}_j)$
  - $FC(e_j, \hat{e}_j)$ is the fixed cost of improving fuel economy

2-1) Estimation of the marginal cost

- Our approach builds on Berry, Levinson, and Pakes (1995)
- Firm's first order condition with respect to price (p_j) implies:

$$q_j + \sum_{k \in J_f} \left[\left(p_k - c_k(e_k, x_k) \right) \cdot \frac{\partial q_k}{\partial p_j} \right] = 0$$

- This equation and demand estimation provides us an estimate of c_k
- We regress c_k on attributes to estimate the marginal cost function
- We model the cost function with the Cobb-Douglas production function

$$\ln c_k = \beta_1 + \beta_2 \ln e_j + \beta_3 \ln x_j + \eta_j$$

- We estimate this separately for each country to allow heterogeneity

2-2) Estimation of the slope of the fixed cost

- Our approach builds on Fan (2013) and Barwick, Kwon, and Li (2024)
- Firm's first order condition with respect to fuel economy (e_j) implies:

$$-\frac{\partial c_j}{\partial e_j} \cdot q_j + \sum_{k \in J_f} \left[\Big(p_k - c_k(e_k, x_k) \Big) \cdot \frac{\partial q_k}{\partial e_j} \right] = \frac{\partial FC(e_j, \hat{e}_j)}{\partial e_j}$$

- This equation provides an estimate of the marginal fixed cost $\frac{\partial FC(e_j, \hat{e}_j)}{\partial e_j}$
- Similarly, the FOC w.r.t. $\hat{e}_j$ provides an estimate of $\frac{\partial FC(e_j, \hat{e}_j)}{\partial \hat{e}_j}$

2-2) Estimation of the slope of the fixed cost

- Model the fixed cost function by $FC(e_j, \hat{e}_j) = \gamma_0 + \gamma_1 \bar{e}_j + \gamma_2 (e_j - \hat{e}_j)^2$
  - $\bar{e}_j$ = car j's average fuel economy across the two countries $\equiv w_j e_j + \hat{w}_j \hat{e}_j$
  - w_j and $\hat{w}_j$ are car j's sales shares between Japan and US
  - $(e_j - \hat{e}_j)$: the deviation of fuel economy between the two markets
  - γ_1 is the marginal fixed cost of improving car j's average fuel economy
  - Hypothesis: $\gamma_2 > 0$ if there is a cross-market complementarity

- The derivatives with respect to e_j and $\hat{e}_j$ imply:

$$\frac{\partial FC(e_j, \hat{e}_j)}{\partial e_j} = \gamma_1 w_j + 2\gamma_2 (e_j - \hat{e}_j)$$

$$\frac{\partial FC(e_j, \hat{e}_j)}{\partial \hat{e}_j} = \gamma_1 \hat{w}_j - 2\gamma_2 (e_j - \hat{e}_j)$$

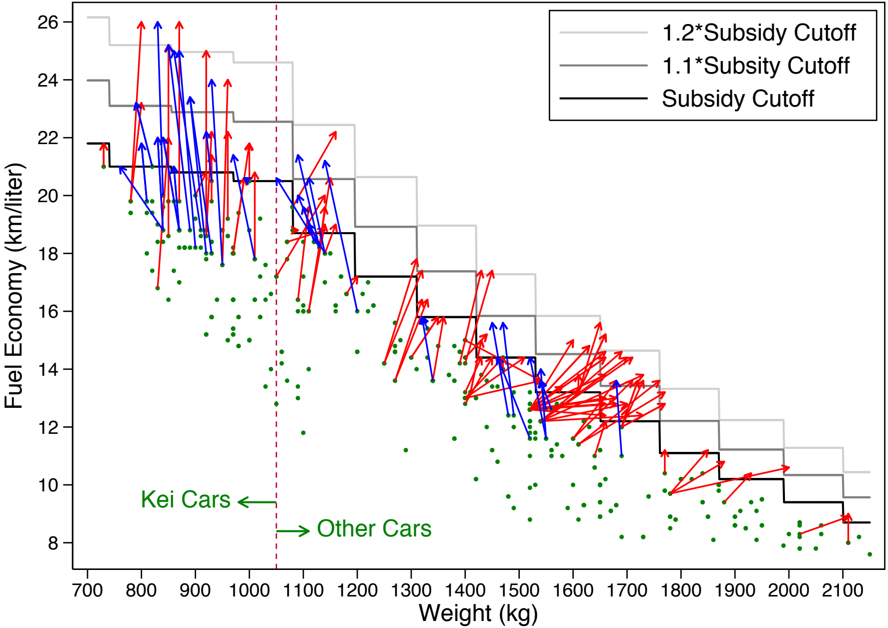
- We fit data to these equations to estimate γ_1 and γ_2

Instruments

- Standard BLP considers that firms endogenously choose p_j only
  - BLP uses rivals' product characteristics as instruments for p_j

- In our model, we allow firms endogenously choose p_j and e_j
  - This means that we need an instrument for e_j
  - The instrument needs to be correlated with e_j
  - The instrument needs to be uncorrelated with the error terms

- We use a unique feature of the Japanese subsidy to create an IV
  - To be qualified for the subsidy, e_j needed to be above the target
  - The fuel-economy target was a non-linear step function (next page)
  - This created variation in easiness/difficulties to qualify for the subsidy
  - This variation created a policy-induced change in e_j in policy period
  - Recall that the subsidy was introduced in 2009
  - We create $\tilde{\Delta} e_j = e_j^{\text{target}} - e_{j,2008}$ as an instrument for e_j



- This figure is from Ito and Sallee (2018)

1) Demand estimation results

	Japan	US
Price/Income (USD)	-1.513	-2.005
	(0.379)	(0.180)
Fuel economy (mpg)	0.174	0.049
	(0.019)	(0.008)
Horsepower	0.008	0.005
	(0.003)	(0.001)
Vehicle weight (US tons)	1.459	0.023
	(0.215)	(0.070)
sigma	22.799	29.479
	(.0004)	(0.0001)
Observations	2142	2139

- Sigma is the standard deviation for the log-normal random-coefficient for price

2) Marginal cost estimation results

$$\ln c_k = \beta_1 + \beta_2 \ln e_j + \beta_3 \ln x_j + \eta_j$$

	Japan		US	
	(1)	(2)	(3)	(4)
$\ln\ e_j$	0.470	0.509	1.339	1.140
	(0.026)	(0.029)	(0.189)	(0.175)
$\ln\ \text{hp}_j$	0.405	0.237	2.396	1.745
	(0.036)	(0.037)	(0.129)	(0.120)
$\ln\ \text{weight}_j$	2.294	2.467	2.125	2.651
	(0.054)	(0.053)	(0.160)	(0.157)
Constant	-9.903		-24.780	
	(0.270)		(1.779)	
Firm FE	No	Yes	No	Yes
Observations	2142	2142	1707	1707

3) Estimation results of marginal fixed cost

$$FC(e_j, \hat{e}_j) = \gamma_0 + \gamma_1 \bar{e}_j + \gamma_2 (e_j - \hat{e}_j)^2 \quad (1)$$

	(1)	(2)
γ_1	5.87	6.76
	(0.180)	(0.253)
γ_2	0.079	0.115
	(0.016)	(0.018)
Firm FE	No	Yes
Observations	4281	4281

- The monetary unit is one million USD. The unit of e_j is miles/gallon.
- $\gamma_2 > 0$ suggests the evidence of cross-market complementarity

3) (Preliminary) Investigating potential heterogeneity

$$FC(e_j, \hat{e}_j) = \gamma_0 + \gamma_1 \bar{e}_j + (\gamma_2 + \gamma_3 D_j)(e_j - \hat{e}_j)^2 \quad (2)$$

	(1)	(2)
γ_1	5.29	5.71
	(0.185)	(0.268)
γ_2	0.298	0.315
	(0.023)	(0.024)
γ_3	-0.310	-0.325
	(0.041)	(0.040)
Firm FE	No	Yes
Observations	3622	3622

- $D_j = 1$ if both Japan and North America have plants that produce car j
- Results are preliminary as we keep collecting production information
- This suggests the cross-market complementarity is likely to come from cars that are produced in a common plant and export to both countries

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Counterfactual Policy Simulation

Counterfactual policy simulation

- What if Japan *did not* implement the fuel-economy subsidy?
  - Lowers demand for fuel-efficient cars in Japan
  - Lowers incentives for firms to improve fuel-economy
  - Lowers fuel-economy in the US
  - Firms' optimal choices of e_j & p_j would change
  - What are the effects on consumer & producer surplus and social welfare?

- We use our model to simulate two scenarios:
  - Actual scenario (with the fuel-economy subsidy in Japan)
  - Counterfactual scenario (remove the fuel-economy subsidy in Japan)
  - Quantify the Japanese policy's global spillover effects on the US market

Global spillover effects on the US car market

	Actual scenario	Counterfactual scenario	Spillover impact (level)	Spillover impact (%)
Fuel economy subsidy in Japan	Yes	No		
Average fuel economy (miles per gallon)	24.05	22.40	1.65	7.39
Average price (USD/car)	34,077	32,987	1,090	3.31
Consumer surplus (billion USD/year)	420.43	407.36	13.07	3.21
Producer surplus (billion USD/year)	357.99	345.78	12.21	3.53
Environmental externality cost (billion USD/year)	21.17	22.83	-1.66	-7.25
Social welfare (billion USD/year)	757.25	730.31	26.94	3.69

- Japan's fuel-economy subsidy resulted in welfare effects in the US:
  - Increased average fuel economy and price
  - Reduced environmental externality cost
  - Increased consumer surplus, producer surplus, and social welfare

Conclusion

Conclusion

- We study global policy spillovers through multinational firms
  - Policy impacts may spillover globally through multinational firms
  - This effect may spillover globally if the product is sold worldwide
  - We examine this question in the international car markets

- Difference-in-differences estimation
  - The Japanese fuel-economy subsidy induced global spillover effects
  - Spillover effects were economically significant (e.g. 8∼11% increase in fuel economy in the US market)

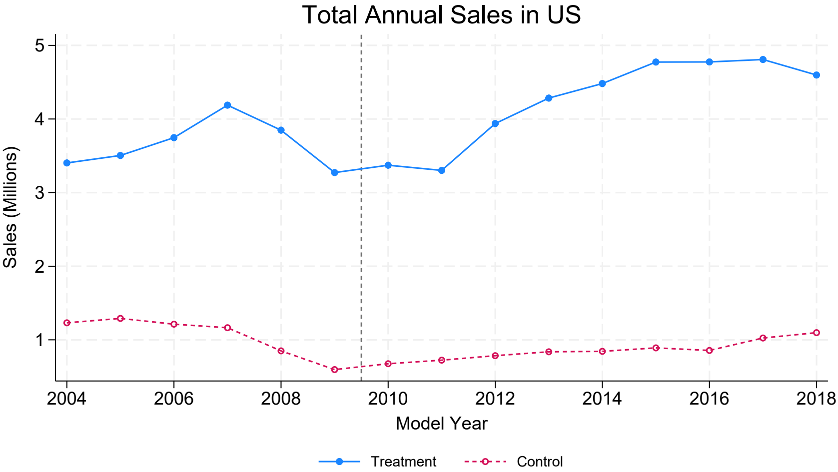
- A Model of multinational car markets and policy simulations
  - Japan's fuel-economy subsidy induced welfare effects in the US
  - Increased average fuel economy and price
  - Reduced environmental externality cost
  - Increased consumer surplus, producer surplus, and social welfare

Thank you!

Feedback/suggestions? ito@uchicago.edu

Appendix

Sales over time



- Electricity is a major source of GHG emissions (e.g., 25% in the US)
- Another large source is transportation, which can be electrified soon

Spillover effects for Japanese cars in the US market (Unweighted)

$$\ln MPG_{it} = \alpha Treated_i \times Post_t + \beta Treated_i + \gamma Post_t + \delta X_{it} + \epsilon_{it}$$

	(1)	(2)	(3)	(4)
Treated $\times$ Post	0.118	0.114	0.063	0.061
	(0.061)	(0.059)	(0.017)	(0.016)
Treated	0.216	0.217		
	(0.043)	(0.043)		
Post	0.053		0.013	
	(0.050)		(0.013)	
N	1,245	1,245	1,238	1,238
Year FE	No	Yes	No	Yes
Model FE	No	No	Yes	Yes

- Spillover effects: 6∼11% increase in fuel economy

JPN cars in Germany market (Control: US)

	(1)	(2)	(3)	(4)
Treated × Post	0.147	0.112	0.115	0.081
	(0.046)	(0.040)	(0.025)	(0.023)
Treated	0.595	0.628	-0.106	-0.080
	(0.062)	(0.056)	(0.022)	(0.020)
Post	-0.003		0.010	
	(0.037)		(0.017)	
N	793	793	790	790
Year FE	No	Yes	No	Yes
Model FE	No	No	Yes	Yes

- Treatment: Japanese cars sold in Germany and Japan (84 models)
- Control: Japanese cars sold in the US but not in Japan (41 models)

JPN cars in India market (Control: US)

	(1)	(2)	(3)	(4)
Treated × Post	0.382	0.365	0.319	0.286
	(0.050)	(0.050)	(0.035)	(0.031)
Treated	0.481	0.491	-0.107	-0.042
	(0.066)	(0.069)	(0.028)	(0.029)
Post	-0.016		0.010	
	(0.036)		(0.017)	
N	424	424	423	423
Year FE	No	Yes	No	Yes
Model FE	No	No	Yes	Yes

- Treatment: Japanese cars sold in India and Japan (29 models)
- Control: Japanese cars sold in the US but not in Japan (41 models)

European cars in the US market

- European automakers have a 8.5% market share in the US.
- European automakers have a 4.6% market share in Japan.

Spillover effects for European cars in the US market

$$\ln MPG_{it} = \alpha Treated_i \times Post_t + \beta Treated_i + \gamma Post_t + \delta X_{it} + \epsilon_{it}$$

	(1)	(2)	(3)	(4)
Treated × Post	0.069	0.072	0.108	0.095
	(0.049)	(0.052)	(0.016)	(0.022)
Treated	-0.151	-0.153		
	(0.075)	(0.074)		
Post	0.055		0.009	
	(0.045)		(0.012)	
N	962	962	959	959
Year FE	No	Yes	No	Yes
Model FE	No	No	Yes	Yes

- Treatment: EU cars sold in the US and Japan (95 models)
- Control: EU cars sold in the US but not in Japan (43 models)