Global Policy Spillovers: Evidence from the Multinational Automobile Industry*

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Abstract

In the globalized economy, a country's domestic policy can produce global spillover effects through products manufactured by multinational firms. However, standard economic analysis rarely incorporates this possibility, which could understate the impacts of many economic policies. We investigate this phenomenon in the context of environmental policies for automobiles. First, we empirically show that Japan's fuel economy subsidy led to improvements in fuel economy for cars sold in the U.S. market. Second, using a structural model of differentiated product markets, we demonstrate that cross-market links in revenues and costs could highlight the potential mechanism behind the global spillovers. Finally, we use the estimated model to conduct counterfactual policy simulations, quantifying the welfare effects of the global policy spillovers.

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1 Introduction

In the globalized economy, a country's domestic policy can produce global spillover effects through products manufactured by multinational firms. However, standard economic analysis rarely incorporate this possibility and therefore the impacts of many economic policies may have been understated.

We investigate this phenomenon in the context of environmental policies for automobiles. First, we empirically show that Japan's fuel economy subsidy led to improvements in fuel economy for cars sold in the U.S. market. Second, using a structural model of differentiated product markets, we demonstrate that cross-market links in revenues and costs could highlight the potential mechanism behind the global spillovers. Finally, we use the estimated model to conduct counterfactual policy simulations, quantifying the welfare effects of the global policy spillovers.

We begin with the difference-in-differences strategy to test whether the Japanese fuel economy subsidy policy in 2009 generated international spillover effects through products designed and sold by multinational firms. We exploit the fact that many models that were sold in Japan were also sold in other countries (e.g. sold in Japan and the United States), while many other models were not sold in Japan at all (e.g. sold in the United States but not in Japan) and were therefore unaffected by the subsidy policy. Consider data from the US market.

The difference-in-differences analysis provides empirical evidence that the Japanese fuel-economy subsidy induced international spillover effects to the US market through products sold by Japanese automakers. The spillover effects were economically significant, ranging between 8 and 11%.

A key question is whether this spillover effect improved or lowered consumer and producer welfare as well as environmental externalities in the US. The improvement in fuel economy suggests that consumers were likely to benefit from it. However, this does not necessarily imply a higher consumer surplus. F Firms may have increased prices and markups. Furthermore, there could be indirect equilibrium effects on unaffected cars through their oligopolistic competition.

To answer these questions, we build a model of multinational car markets. Our model has two goals. First, we aim to model and estimate a potential mechanism of global policy spillovers. To do so, we extend a standard differentiated-product market model (Berry, Levinsohn and Pakes, 1995) to incorporate firms selling products in multinational markets and incorporate firms' endogenous attribute choices. This allows us to estimate potential cross-market links in revenues and costs.

The second objective of our model is to investigate the welfare implications of the global policy spillover effect. The equilibrium model allows us to examine the welfare implications of the global spillover effects by quantifying consumer surplus, producer surplus, and environmental externalities.

Our structural estimation results suggest evidence of cross-market complementarity in the fixed cost of redesigning car attributes. Furthermore, our findings suggest that the cross-market complementarity is likely to come from cars that are produced in a common plant and export to both countries.

Finally, to investigate the welfare impact of the global policy spillover, we use our structural model and parameter estimates to simulate two scenarios. The first scenario is Actual scenario, where we include the fuel- economy subsidy policy in the Japanese market. The second scenario is a counterfactual scenario, where we remove the fuel-economy subsidy policy and compute an equilibrium.

Our preliminary results suggest that Japan's fuel-economy subsidy resulted in welfare effects in the US. The spillover effect increased average fuel economy and price. As a result, it reduced environmental externality cost. Our results also suggest that the spillover effects increased consumer surplus, producer surplus, and social welfare in the US market.

2 Background

2.1 Japanese government's subsidy for fuel-efficient cars

Starting in 2009, the Japanese government provided a subsidy for consumers purchasing a new car with fuel economy in excess of the fuel economy target. There are three unique features of this policy that will help my empirical analysis. First, the subsidy ranged approximately between $700 and $1,500, which was a significant amount for consumers (about 5 to 10% of an average new car price).

Second, this subsidy was based on each vehicle's own fuel economy, rather than a corporate average fuel economy. A model was qualified for the subsidy if the model's fuel economy (e) was above the fuel economy target ($\bar{e}(w)$) given the model's weight w. This allows me to exploit variation at the model level rather than at the corporate level.

Third, because the fuel economy target ($\bar{e}(w)$) was designed as a step function of weight, the policy created variation across models in the difficulty of meeting the fuel economy target. For example, if a model's combination of fuel economy and weight before the policy was enacted (i.e., the pre-policy period) was already close to the target, the model would be able to qualify for the subsidy with small changes in its

product attributes. In contrast, if a model was located far from the target function, it would need relatively larger changes in its product attributes in order to qualify for the consumer subsidy.

Fourth, many models sold in the US market were also possibly affected by Japan's policy because they were sold in both countries, whereas there were many other models in the US market that were not sold in Japan. This provides another source of variation to conduct difference-in-differences (DID) estimation. we take advantage of these four features to analyze data with three empirical methods.

2.2 Potential global spillover effects

Our question is whether the Japan's fuel-economy subsidy policy generated global spillover effects through products sold by multinational firms. Before we begin with empirical analysis, it is helpful to see key descriptive statistics in the Japanese and global car markets to hypothesize which automakers are more likely to potentially generate global spillover effects than others.

Panel A of Figure 1 shows the market shares for new car sales in the Japanese car market in 2012. The top 10 were all Japanese automakers, and about 80% of new car sales were from Japanese firms. In contrast, while American firms sold a variety of cars in Japan, their sales quantities were extremely small. This statistics imply that qualifying for the fuel-economy subsidy was likely to be important for Japanese firms but not for American firms—it is unlikely to make sense for American firms to spend a fixed cost to change their car designs to quality for the subsidy as the sales quantities were low.

[Figure 1 about here]

Panel B of Figure 1 illustrates the extent to which the Japanese market is important for each automaker relative to their worldwide sales. This figure shows again that Japan is a key market for Japanese firms but not for American firms. In addition, this figure suggests that for most of the major Japanese firms, such as Toyota, Honda, Nissan, Suzuki, Subaru, and Mitsubishi, Japan is a major market but Japan's share relative to these firms' worldwide sales are around 15-20%, which implies that these firms have high sales quantities in the rest of the world.

Overall, these descriptive statistics suggest that the global spillover effects can be heterogeneous among automakers, depending on their market share in Japan and the rest of the world. We provide our empirical analysis in Section 3 to test this hypothesis.

2.3 Data

We use three primary datasets. The first dataset is car spec data from Japan and the United States. The data sources are Car Sensor for Japan and Wards Auto data for the United States. The second dataset is monthly car sales quantify data from the Marklines. The third dataset is monthly car production data from the Marklines. Our dataset covers all car models sold in Japan and the United States between 2004 and 2018 model years.

3 Difference-in-Differences Estimation

3.1 Global spillover effects in the US market

We begin with the difference-in-differences strategy to test whether the Japanese fuel economy subsidy policy in 2009 generated international spillover effects through products designed and sold by multinational firms. We exploit the fact that many models that were sold in Japan were also sold in other countries (e.g. sold in Japan and the United States), while many other models were not sold in Japan at all (e.g. sold in the United States but not in Japan) and were therefore unaffected by the subsidy policy. Consider data from the US market. We estimate the equation below using OLS:

$$\ln e_{it} = \alpha_1 Treated_i \times Post_t + \alpha_2 Treated_i + \alpha_3 Post_t + \alpha_4 X_{it} + \epsilon_{it}, \tag{1}$$

where e_{it} denotes the fuel economy in miles per gallon (MPG) for vehicle model i in model-year t in the US market, $Treated_i$ equals 1 if model i is also sold in Japan, $Post_t$ equals 1 after the introduction of the fuel economy subsidy program in Japan, and X_{it} is a vector of control variables (e.g., model and time fixed effects). We cluster standard errors at the model level to adjust for serial correlation.

Figure 2 shows the time trends of sales-weighted average fuel economy (miles per gallon) for the treated and untreated groups for Japanese cars sold in the the US market. The figure suggests that the treated models (i.e., models sold both in the US and Japan) and untreated models (i.e., models sold in the US but not in Japan) have similar time trends during the pre-policy period. Between the two groups, fuel economy diverged after the start of the subsidy policy in 2009.

[Figure 2 about here]

Panel A of Table 1 shows the regression results for Japanese cars sold in the the US market. The DID estimate suggests that the Japanese subsidy policy generated an international spillover effect on fuel economy in the US market. The improvement in fuel economy is between 8% and 11%.

[Table 1 about here]

Panel B of Table 1 shows the results for American cars sold in the the US market. Recall that American automakers sell a variety of cars both in Japan and US, but their sales quantities are very low in Japan, and therefore, we hypothesize that American automakers are unlikely to respond to the subsidy incentive in Japan. Our empirical results are consistent with this prediction.

In Table 2, we use the same identification strategy to test whether the Japan's subsidy policy had spillover effects on other car attributes in the US market. Panel A results suggest that the Japanese automakers are likely to trade-off fuel economy and horsepower to qualify the subsidy. Consistent with our prediction, none of the car attribute shows statistically significant spillover effects for American automakers.

[Table 2 about here]

3.2 Heterogeneity in the spillover effects by product differentiation

Our dataset allows us to observe differences and similarities in vehicle characteristics *within* a model between countries. Notably, there is substantial variation in the product differentiation within the same model across countries. For example, some models have nearly identical product characteristics between markets, whereas some models are quite different in some attributes between countries even though they share the same model name and basic characteristics such as wheelbase.

We hypothesize that the degree of pre-existing product differentiation might affect the size of global policy spillovers. Car models that are almost identical between countries might share the same product design and production scheme, which implies that they are likely to share the fixed cost of product redesign. Car models that are quite different between countries might be based on different product design, which implies that their fixed cost of product redesign might be independent or less related to that of the same model in other markets.

To test this hypothesis, we create two measures of pre-existing product differentiation based on fuel economy data in 2008 (i.e., before the introduction of the subsidy policy). The first measure (Differentiation

1) is the absolute value of the difference in log fuel economy for car model i in 2008, $|\ln(MPG_{i,JP,2008}) - \ln(MPG_{i,US,2008})|$. The secome measure (Differentiation 2) is the quadratics of the difference in fuel economy for car model i in 2008, $(MPG_{i,JP,2008} - MPG_{i,US,2008})^2$.

In Table 3, we interact each of the differentiation measures with the treatment variable to estimate the heterogeneity in the spillover effects by product differentiation. With both of the two measures, the results suggest provides empirical evidence that supports our hypothesis. The negative coefficients on the interaction terms imply that the global spillover effects are smaller for the cars that have higher degree of pre-existing product differentiation.

[Table 3 about here]

3.3 Pass-through rate of the spillover effects

Our results in Table 1 shows that the spillover effect of the Japanese subsidy policy on fuel economy in the US market is an improvement in fuel economy by a 0.073 log point. A natural question is how large this spillover effect is when it is compared to the direct effect—the effect of the subsidy on fuel economy in the Japanese market.

Suppose that we use fuel economy *in Japan* for the treated cars in equation (1). Given the assumption that the control group's trend of the fuel economy in the US provides a credible estimate of the counterfactual trend of fuel economy in Japan for the treated cars, we can run the DID estimation in equation (1) to estimate the direct effect of the subsidy policy on the treated cars in Japan.

In Table 4, we show this result (the direct effect) in Column 2 and compare it to column 1 (the spillover effect), which is replicated from Table 1. In column 3, we stacked these observations to estimate the difference and ratio of the direct and spillover effects.

Our results suggest that the direct effect is an improvement in fuel economy by a 0.207 log point. This implies that the spillover effect on fuel economy in the US is approximately 35% of the direct effect, which can be interpreted as the pass-through rate of the spillover effects.

[Table 4 about here]

4 A Model of Multinational Car Markets

Overall, the difference-in-differences analysis provides empirical evidence that the Japanese fuel-economy subsidy induced international spillover effects to the US market through products sold by Japanese automakers. The spillover effects were economically significant, ranging between 8 and 11%.

A key question is whether this spillover effect improved or lowered consumer and producer welfare as well as environmental externalities in the US. The improvement in fuel economy suggests that consumers were likely to benefit from it. However, this does not necessarily imply a higher consumer surplus. Firms may have increased prices and markups. Furthermore, there could be indirect equilibrium effects on unaffected cars through their oligopolistic competition. To answer these questions, we build a model of multinational car markets in this section.

Our model has two goals. First, we aim to model and estimate a potential mechanism of global policy spillovers. To do so, we extend a standard differentiated-product market model Berry, Levinsohn and Pakes (1995) to incorporate firms selling products in multinational markets and incorporate firms' endogenous attribute choices. This allows us to estimate potential cross-market links in revenues and costs.

The second objective of our model is to investigate the welfare implications of the global policy spillover effect. The equilibrium model allows us to examine the welfare implications of the global spillover effects by quantifying consumer surplus, producer surplus, and environmental externalities.

4.1 Demand

We follow Berry, Levinsohn and Pakes (1995) to model a consumer's new car purchase with a random utility model. We use p_{jc} to denote price for product j in market c and x_{jc} for a vector of product characteristics for product j in market c. Conditional indirect utility of consumer i who purchases product j can be written by:

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

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

We begin by describing a standard logit demand approach with no random-coefficient.

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

We ssume that β and α do not depend on i. Then, the probability that consumer i in market c chooses product j is:

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

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

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

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 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. With this setup, we have:

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

Then, the log market share for j minus log market share for outside option is:

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

An advantage of this method is that it can be estimated as a linear equation An disadvantage is that it assumes restrictive substitution patterns: the Independence of Irrelevant Alternatives (IIA) assumption.

To address the issue with the IIA, we use a random-coefficient logit approach. We allow heterogeneity in β and α

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

where we model $\beta_i = \beta_0 + \beta_1 D_i + u_i$ and $\alpha = \alpha_0 + \alpha_1 D_i + e_i$, by explaining taste heterogeneity by demographic variables (D_i) and a random term $u_i \sim N(0, \sigma_\beta)$ and $e_i \sim N(0, \sigma_\alpha)$. An advantage of this appraoch is that it allows for flexible substitution patterns, less restrictive price elasticity, and heterogeneous tastes. A challenge is that the non-linear GMM requires numerical simulation and does not guarantees unique global

optimum, and therefore, we need careful implantation to obtain global optimal GMM estimates (Knittel and Metaxoglou, 2013; Conlon and Gortmaker, 2020).

4.2 Supply

We model multinational multi-product firm f's profit by:

$$\text{Japan: } \pi_f = \sum_{j \in J_f} \Big[\Big(p_j - c_j(e_j, x_j) \Big) \cdot q_j \big(p_j - \tau_j(e_j), e_j, x_j \big) \Big]$$
$$\text{US: } \hat{\pi}_f = \sum_{j \in \hat{J}_f} \Big[\Big(\hat{p}_j - \hat{c}_j(\hat{e}_j, \hat{x}_j) \Big) \cdot \hat{q}_j \big(\hat{p}_j, \hat{e}_j, \hat{x}_j \big) \Big]$$

where J_f is the set of cars sold by firm f, p_j is the price of car j, c_j is the marginal cost, e_j is the fuel economy, x_j is a vector of other attributes, q_j is the demand, $\tau_j(e_j)$ is the fuel-economy subsidy in Japan.

Firm f maximizes the joint profit: $\pi_f + \hat{\pi}_f - \sum_j FC(e_j, \hat{e}_j)$ with respect to three endogenous variables $(p_j, e_j, \hat{p}_j, \hat{e}_j)$, where $FC(e_j, \hat{e}_j)$ is the fixed cost of improving fuel economy.

4.2.1 Estimation of the marginal cost

The firm's first order condition with respect to price (p_j) implies:

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

This equation and demand estimation provides us an estimate of c_k. We then regress c_k on attributes to estimate the marginal cost function. We model the cost function with the Cobb-Douglas production function and estimate this separately for each country to allow heterogeneity.

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

4.2.2 Estimation of the slope of the fixed cost

Our approach builds on Fan (2013) and Barwick, Kwon and Li (2024). The 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 with respect to $\hat{e}_j$ provides an estimate of $\frac{\partial FC(e_j, \hat{e}_j)}{\partial \hat{e}_j}$.

We model the fixed cost function by:

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

where $\bar{e_j}$ = 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, $(e_j - \hat{e}_j)$ is the deviation of fuel economy between the two markets, and γ_1 is the marginal fixed cost of improving car j's average fuel economy.

Our hypothesis is that $\gamma_2 > 0$ if there is a cross-market complementarity. The derivatives with respect to e_j and $\hat{e}_j$ imply:

$$\begin{aligned} \frac{\partial FC(e_j, \hat{e}_j)}{\partial e_j} &= \gamma_1 w_j + 2\gamma_2 (e_j - \hat{e}_j) \\ \frac{\partial FC(e_j, \hat{e}_j)}{\partial \hat{e}_j} &= \gamma_1 \hat{w}_j - 2\gamma_2 (e_j - \hat{e}_j) \end{aligned} \tag{3}$$

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

4.3 Endogeneity and instruments

The standard BLP estimation considers that firms endogenously choose only p_j, taking other attributes exogenous. This approach is not appropriate in our context because we allow firms endogenously choose p_j and e_j.

Following Ito and Sallee (2018), we use a unique feature of the Japanese subsidy to create an instrumental variable for e_j. To be qualified for the subsidy, e_j needed to be above the target. As shown in Figure 3, the fuel-economy target was a non-linear step function. This created variation in easiness/difficulties to

qualify for the subsidy so that it 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.

Figure 3 visually shows the policy induced variation. We construct panel data of car models by linking cars sold in 2008 (before the policy change) and 2012 (three years after the policy introduction). Each dot in the figure shows a car's starting values of fuel economy and weight in 2008. For the cars that qualified for the new subsidy in 2012, we also show vectors connecting each car's starting position in 2008 to its final position in 2012.

[Figure 3 about here]

This figure provides several useful results. First, many of the cars that gained the subsidy were re-designed in a way that they were just above the subsidy cutoff. Second, cars that started closer to the new standard were more likely to get the subsidy; that is, the "distance" to the subsidy cutoff explains most of the variation in which cars obtained the subsidy.

5 Structural estimation results

In this section, we present the estimation results of our model described in the previous section. Table 5 shows the demand estimation results for Japan and US. In both markets, we find that consumers value fuel economy and horsepower. The sigma parameter is the standard deviation of the random-coefficient on price, suggesting that there is substantial unobseved heterogeniety in the price elasticity.

[Table 5 about here]

Table 6 shows the marginal cost estimation results for each market. We model the marginal cost function by the Cobb-Douglas function so that each coefficient implies the elasticity of inputs on the marginal cost.

[Table 6 about here]

Finally, Table 7 shows the marginal fixed cost estimation results for each market. The parameters γ_1 and γ_2 correspond to the parameters in equation (3). $\gamma_2 > 0$ suggests the evidence of cross-market complementarity. To test the potential mechanism of the spillover effect, we use production location data to create a dummy variable $D_j = 1$ if both Japan and North America have plants that produce car j and zero otherwise.

The interaction effect (γ_3) suggest that the cross-market complementarity is likely to come from cars that are produced in a common plant and export to both countries.

[Table 7 about here]

6 Counterfactual Policy Simulation

To investigate the welfare impact of the global policy spillover, we use our structural model and parameter estimates to simulate two scenarios. The first scenario is Actual scenario, where we include the fuel-economy subsidy policy in the Japanese market. The second scenario is a counterfactual scenario, where we remove the fuel-economy subsidy policy and compute an equilibrium.

Our model predicts a few key possible changes if Japan *did not* implement the fuel-economy subsidy. First, it would lower demand for fuel-efficient cars in Japan. This would lower incentives for firms to improve fuel-economy, resulting in lower fuel-economy for some cars in the US market.

That is, each car model's optimal choices of e_j and p_j would change with this direct effect. In addition, the untreated cars might have indirect effects on the optimal choices of their e_j and p_j through oligopolistic competition (an indirect effect through the market equilibrium). Our aim is to estimate these effects on consumer and producer surplus and social welfare.

Table 8 shows our preliminary findings. The results imply that Japan's fuel-economy subsidy resulted in welfare effects in the US. The spillover effect increased average fuel economy and price. As a result, it reduced environmental externality cost. Our results also suggest that the spillover effects increased consumer surplus, producer surplus, and social welfare in the US market.

[Table 8 about here]

7 Conclusion

In the globalized economy, a country's domestic policy can produce global spillover effects through products manufactured by multinational firms. However, standard economic analysis rarely incorporate this possibility and therefore the impacts of many economic policies may have been understated.

In this paper, we investigated this phenomenon in the context of environmental policies for automobiles. First, we empirically show that Japan's fuel economy subsidy led to improvements in fuel economy for cars

sold in the U.S. market. Second, using a structural model of differentiated product markets, we demonstrate that cross-market links in revenues and costs could highlight the potential mechanism behind the global spillovers. Finally, we use the estimated model to conduct counterfactual policy simulations, quantifying the welfare effects of the global policy spillovers.

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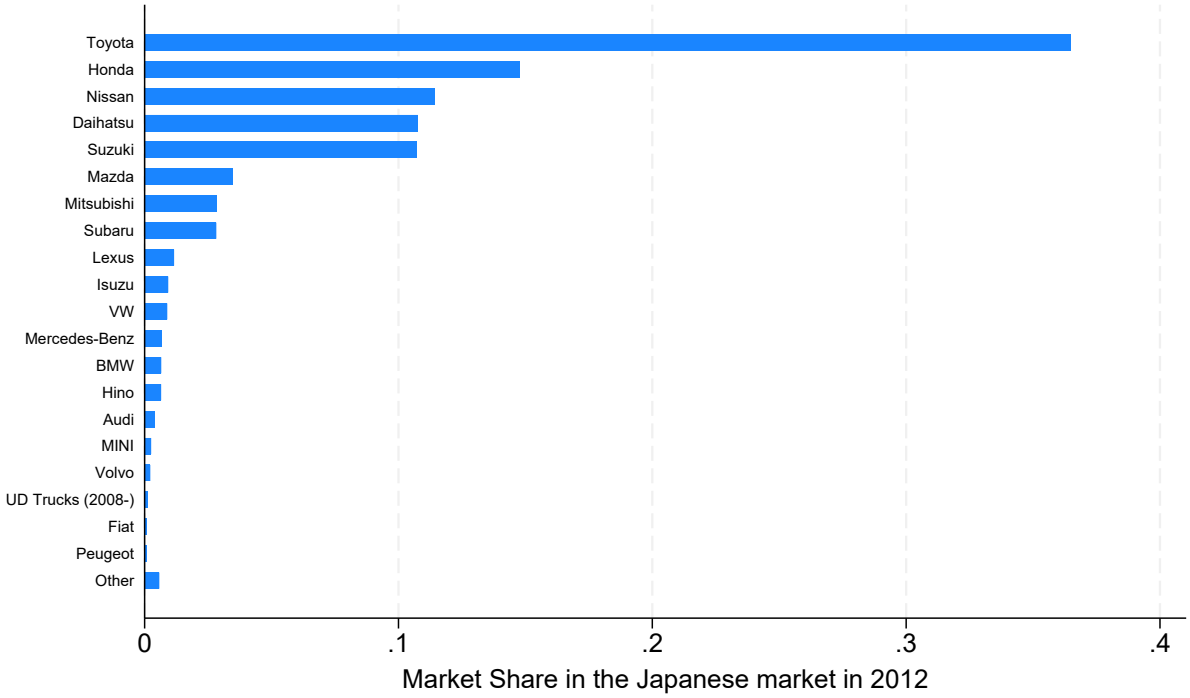
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Figures

Figure 1: Market Shares

Panel A: Market Share in the Japanese market in 2012



Panel B: Each firm's Japanese market share relative to its worldwide sales

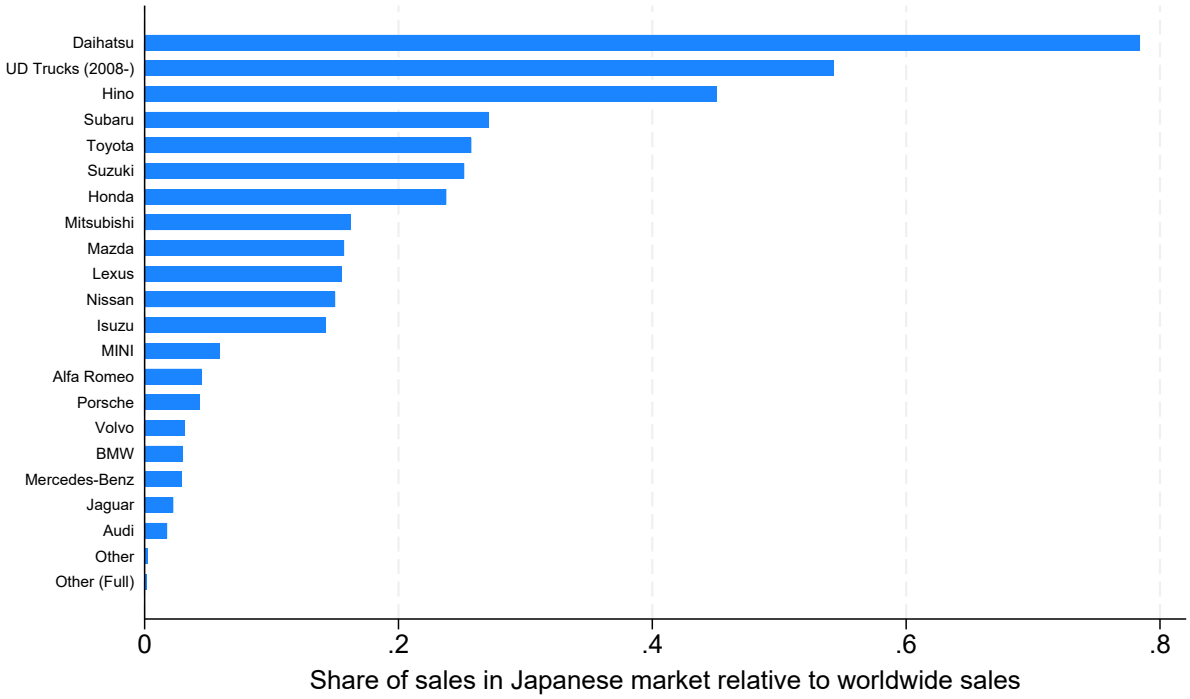
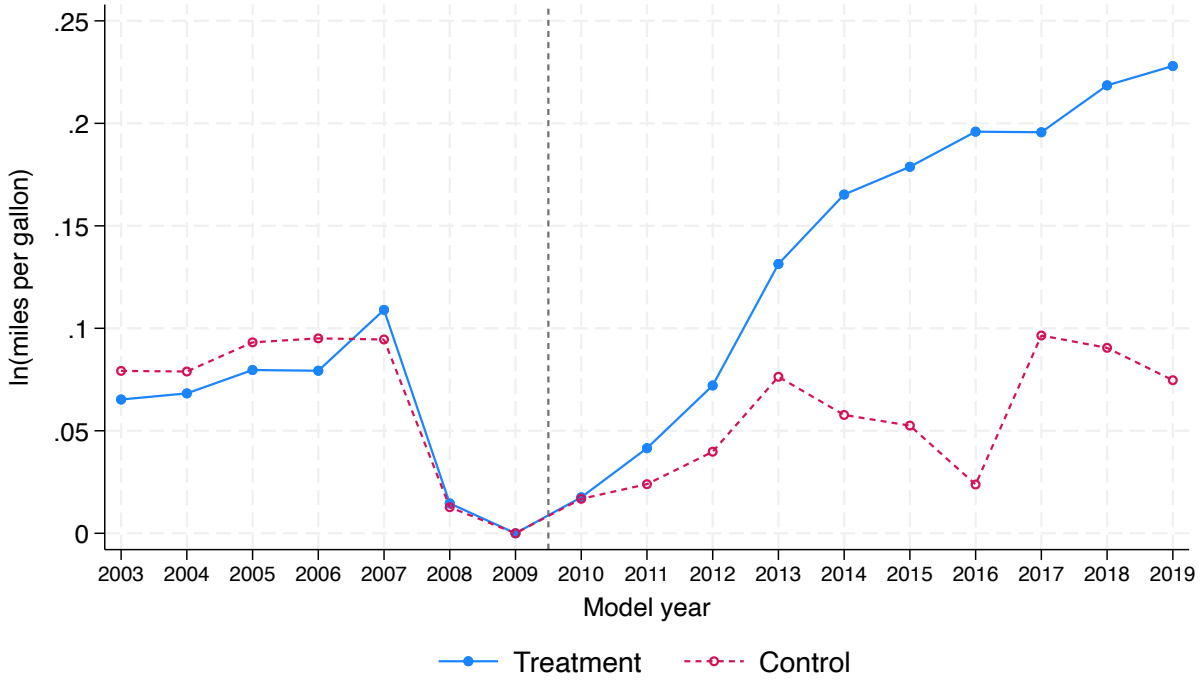
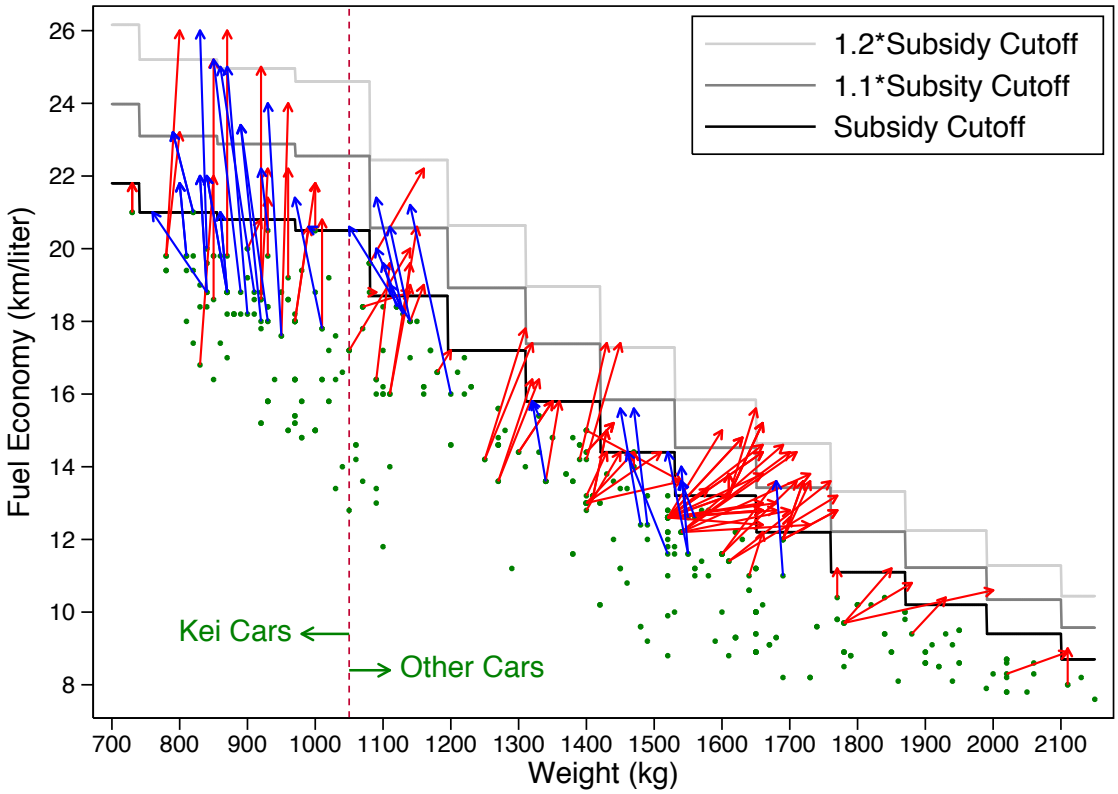


Figure 2: Average Fuel Economy of Japanese Vehicles in the US market



Note: Each dot shows the log of fuel economy in the US auto market for each group, normalized at their 2009 level so that it shows the changes in the log of fuel economy relative to 2009. The treatment group includes Japanese automakers' vehicles that were sold in both the United Sates and Japan. The control group includes Japanese automakers' vehicles that were sold in the United Sates but not in Japan. Treatment group includes 90 models, and control group includes 41 models. Panel B uses the average annual model-level sales as a weight to calculate weighted averages. We include both hybrid and non-hybrid cars.

Figure 3: Subsidy take-up



Note: This figure shows the policy induced variation. We construct panel data of car models by linking cars sold in 2008 (before the policy change) and 2012 (three years after the policy introduction). Each dot in the figure shows a car's starting values of fuel economy and weight in 2008. For the cars that qualified for the new subsidy in 2012, we also show vectors connecting each car's starting position in 2008 to its final position in 2012.

Tables

Table 1: International Spillover Effects of Japan's Fuel Economy Subsidy on the US Automobile Market

Panel A: Japanese cars in the US market. Dependent variable is the log of fuel economy (miles per gallon).

	(1)	(2)	(3)	(4)
Treated × Post	0.106	0.101	0.078	0.073
	(0.040)	(0.039)	(0.024)	(0.024)
Treated	0.297	0.298		
	(0.056)	(0.056)		
Post	0.001		0.007	
	(0.033)		(0.016)	
N	9,099	9,099	9,098	9,098
Year FE	No	Yes	No	Yes
Model FE	No	No	Yes	Yes

Panel B: American cars in the US market. Dependent variable is the log of fuel economy (miles per gallon).

	(1)	(2)	(3)	(4)
Treated × Post	0.026	0.025	-0.027	-0.027
	(0.049)	(0.049)	(0.030)	(0.030)
Treated	-0.100	-0.099		
	(0.063)	(0.063)		
Post	0.094		0.090	
	(0.033)		(0.023)	
N	21,569	21,569	21,567	21,567
Year FE	No	Yes	No	Yes
Model FE	No	No	Yes	Yes

Note: This table shows the OLS regression results of equation (1). The dependent variable is the log of fuel economy (miles per gallon) at the make-model-trim level between model years 2003 and 2019. All regressions are weighted by the average annual sales. Standard errors are clustered at the model level. Panel A includes vehicles sold by Japanese automakers (Honda, Isuzu, Lexus, Mazda, Mitsubishi, Nissan, Subaru, Suzuki, and Toyota). Panel B includes vehicles sold by American automakers (Buick, Cadillac, Chevrolet, Chrysler, Dodge, Fisker, Ford, GMC, Hummer, Jeep, Lincoln, Mercury, Oldsmobile, Pontiac, Saturn, Tesla, and Wheego).

Table 2: International Spillover Effects of Japan's Fuel Economy Subsidy on the US Automobile Market

Panel A: Japanese cars in the US market. Dependent variable is the log of each attribute.

	(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

Panel B: American cars in the US market. Dependent variable is the log of each attribute.

	(1) MPG	(2) Horsepower	(3) Price	(4) Wheelbase	(5) Footprint	(6) Weight
Treated × Post	-0.027	0.053	0.013	-0.004	-0.003	-0.013
	(0.030)	(0.034)	(0.024)	(0.007)	(0.010)	(0.016)
N	21,567	21,752	21,661	21,762	21,762	21,719

Note: This table shows the OLS regression results of equation (1). The dependent variable is the log of each car attribute at the make-model-trim level between model years 2003 and 2019. All regressions are weighted by the average annual sales. Standard errors are clustered at the model level. Panel A includes vehicles sold by Japanese automakers (Honda, Isuzu, Lexus, Mazda, Mitsubishi, Nissan, Subaru, Suzuki, and Toyota). Panel B includes vehicles sold by American automakers (Buick, Cadillac, Chevrolet, Chrysler, Dodge, Fisker, Ford, GMC, Hummer, Jeep, Lincoln, Mercury, Oldsmobile, Pontiac, Saturn, Tesla, and Wheego).

Table 3: Heterogeneity in the Spillover Effects by Product Differentiation

Dependent variable is the log of fuel economy (miles per gallon)			
	(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

Note: We define Differentiation 1 by $|\ln(MPG_{i,JP,2008}) - \ln(MPG_{i,US,2008})|$ and Differentiation 2 = $(MPG_{i,JP,2008} - MPG_{i,US,2008})^2$. Standard errors are clustered at the model level.

Table 4: Pass-through Rate of the Spillover Effects

Dependent variable is the log of fuel economy (miles per gallon)			
	Fuel economy in the US	Fuel economy in Japan	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)

Note: Standard errors are clustered at the model level.

Table 5: 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

Note: This table shows the demand estimation results of our structural model.

Table 6: Marginal cost estimation results

	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 hp_j	0.405	0.237	2.396	1.745
	(0.036)	(0.037)	(0.129)	(0.120)
ln 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

Note: This table shows the marginal cost estimation results of our structural model.

Table 7: Marginal fixed cost estimation results

	(1)	(2)	(3)	(4)
γ_1	5.87	5.29	6.76	5.71
	(0.180)	(0.185)	(0.253)	(0.268)
γ_2	0.079	0.298	0.115	0.315
	(0.016)	(0.023)	(0.018)	(0.024)
γ_3		-0.310		-0.325
		(0.041)		(0.040)
Firm FE	No	No	Yes	Yes
Observations	4281	3622	4281	3622

Note: This table shows the fixed cost estimation results of our structural model.

Table 8: Counterfactual simulation results

	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

Note: This table shows the counterfactual simulation results in Section 6.