**Proposal for**: NBER Call for Proposals: Economics of Transportation in the 21st Century (Date: March 30, 2024)
**Project title**: The Global Impact of Transportation Policy: Evidence from the Multinational Automobile Industry
**PI**: Koichiro Ito, Associate Professor, Harris School of Public Policy, University of Chicago

## 1. Research question

In this project, I theoretically and empirically investigate whether and how one country's transportation policy may induce global policy impacts through multinational firms' responses to the policy.

In environmental economics, a conventional approach to studying transportation and environmental policies is to investigate a policy's domestic impact. For example, when researchers study US transportation policies, such as fuel economy regulations and various tax and subsidy programs, they generally focus on each policy's potential benefits and costs for consumers and producers in the United States.

However, in the globalized economy, a transportation policy may have global impact through multinational firms' responses to the policy, and this point has been largely unstudied in economics. An important example and the focus of this study is the automobile industry in the transportation sector. The automobile industry is highly multinational—for example, about half of the US automobile market share is covered by foreign automakers. This market environment could imply two possible phenomena. First, a foreign country's transportation policy might affect consumers in the United States. This is because a foreign policy might affect products sold by foreign firms that are also sold in the United States. Second, conversely, US transportation policies might affect consumers in other countries. This is because a US policy may affect products sold by multinational firms that are also sold in other countries. In fact, many of the best selling cars in the United States, such as Toyota Corolla and Ford F-Series, are also sold worldwide. If a country's transportation policy affects the innovations of these cars, the policy impact might be spillovered to the global markets.

In this project, I will develop a simple model of differentiated products in multiple markets to characterize how a country's transportation policies could affect multinational firms and the supply & demand of their products. Then, I will empirically test predictions from the theoretical model by exploiting a quasi-experimental variation created by the Japanese government's fuel economy subsidy, which started in 2009. In this proposal, I will describe data, methods, and preliminary findings below.

## 2. Data, Methods, and Preliminary Findings

**Data**: This project requires the collection of automobile market data in many countries. I have already collected panel data on 1) model-by-year level product characteristic information and 2) model-by-year level sales for the United States, Japan, Germany, and India based on various data sources in each country. I plan to complete collecting the same information for other countries. Another key dataset is the information about production networks, which include each model's production location and its market. I plan to collect these datasets in this project.

**Fuel economy subsidy policy**: I exploit a quasi-experimental variation created by the Japanese government's fuel economy subsidy policy. Starting in 2009, the Japanese government provided a subsidy for consumers who purchased a new car whose fuel economy exceeded the fuel economy target. There are three unique features of this policy that help my empirical analysis. First, the subsidy was between about \$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 of fuel economy. A model was qualified for the subsidy if the model's fuel economy ($e$) is above the fuel economy target ($\bar{e}(w)$) for the model's weight $w$. This allows me to exploit variation at the model-level rather than at the cooperate level. Third, because the fuel economy target ($\bar{e}(w)$) was a step function of weight, the policy created variation in difficulty in meeting the target across models. For example, if a model's fuel economy and weight before the policy period were already close to the target, the model was able to qualify for the subsidy with small changes in its product attributes. In contrast, if a model is located far from the target function, it needed large changes in product attributes. Fourth, many models were sold in both Japan and the United States, whereas many other models were sold only in the United States. This provides another source of variation to conduct a difference-in-differences (DID) strategy. I take advantage of these features to conduct three empirical methods below.

**Method 1**: I begin with the DID strategy to test if the Japanese fuel economy subsidy in 2009 generated international spillover effects through multinational firms. I exploit the fact that many models were sold in Japan and other countries (e.g. sold in Japan and the United States), while many other models were not sold in Japan (e.g. sold in the United States but not in Japan).

Consider data from the US market. I estimate the equation below by the OLS:

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

where $e_{it}$ is the miles per gallon (MPG) 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-economy subsidy program in Japan, and $X_{it}$ is a set of control variables (e.g, model and time fixed effects). I cluster standard errors at the model level to adjust for serial correlation.

Figure 1 shows preliminary results in Panels A (unweighted) and B (weighted by vehicle sales). The figure suggests that the treatment models (models sold both in the US and Japan) and control models (models sold in the US but not in Japan) had similar time trends during the pre-policy period. The MPG diverged after the start of the Japanese subsidy policy in 2009. Table 1 shows the regression results. The DID estimate suggests that the Japanese subsidy policy generated an international spillover benefit—an improvement in fuel economy by 8 to 11% in the US market.

**Method 2**: As described above, to obtain a subsidy in the Japanese subsidy program, firms had to improve their model's fuel economy up to each model's fuel economy target. Otherwise, a model could not be eligible for the subsidy. To examine why the intentional spillover could occur, it is helpful to consider a model of differentiated products with endogenous attribute choice.

Consider that firms decide whether they improve fuel economy to obtain the subsidy. Fuel economy improvement is a costly investment. It could also change their profit. A standard model of differentiated products assumes that firms endogenously change their product attributes by considering its implication to domestic demand and market outcomes only. I conjecture that multinational firms might change product attributes by thinking of global demand and market outcomes. That is, if they change fuel economy to obtain a subsidy in Japan, the subsidy has a direct effect on consumers in Japan, but the fuel economy improvement might spillover to countries outside Japan and affect outcomes in the global market.

I test this hypothesis with a binary choice model in Method 2 and a structural model of differentiated products in Method 3. Consider a binary choice model for each vehicle model $i$, where firms decide to obtain a subsidy ($S_i = 1$) by improving its fuel economy. To obtain the subsidy, a model had to have fuel economy ($e$) above the fuel economy target $\bar{e}(w)$ for its weight category—-we use $e$ for fuel economy and $w$ for vehicle weight. Because the fuel economy target ($\bar{e}(w)$) was a function of weight, firms could change either or both of the two product attributes: $e$ and $w$.

I hypothesize that if a model's fuel economy and weight in the pre-policy period $(e_0, w_0)$ were closer to the target, firms were more likely to respond to the policy incentive and obtain subsidy ($S_i = 1$). A standard theory also predicts that firms were more likely to obtain the subsidy if the model's sales in Japan is high because the upfront subsidy ($700 to $1,500) was applied to each consumer who bought the model. In addition, if firms consider not only the domestic demand but also its global demand, they might be more likely to obtain the subsidy if the model's global sales (or sales in the US, which is the largest auto market in the world) are high. I test these hypotheses by estimating the binary choice model:

$$Pr(S_i = 1) = \beta_1 \tilde{\Delta} e_i + \beta_2 \tilde{\Delta} w_i + \beta_3 Sales_{0i}^{JPN} + \beta_4 Sales_{0i}^{USA} + \beta_5 X_i + \epsilon_i, \quad (2)$$

where $S_i = 0$ if model $i$ obtained the subsidy, $\tilde{\Delta} e_i \equiv \bar{e_i} - e_{0i}$ is the difference between the fuel economy target ($\bar{e_i}$) and the model's fuel economy in the pre-policy period ($e_{0i}$)—that is, how much fuel economy improvement was required to obtain the subsidy. Similarly, $\tilde{\Delta} w_i \equiv \bar{w_i} - w_{0i}$ is the difference between the weight category cutoffs in the fuel economy target ($\bar{w_i}$) and the model's weight in the pre-policy period ($w_{0i}$). $Sales_{0i}^{JPN}$ and $Sales_{0i}^{USA}$ are the model's sales in Japan and USA in the pre-policy period.

I predict that $\beta_1 < 0$ and $\beta_2 < 0$ because firms may be more likely to respond to the policy and obtain the subsidy if a model's fuel economy and weight in the pre-policy period $(e_0, w_0)$ were closer to the target. I predict that $\beta_3 > 0$ and $\beta_4 > 0$ if firms obtained the subsidy for models that had higher sales in Japan ($\beta_3$) and the United States ($\beta_4$).

Table 2 shows the preliminary results. I find empirical results that are consistent with the theoretical predictions. In particular, the positive and statistically significant coefficient on $\beta_4$ implies that firms incorporate the international spillover implication when they changed their product characteristics in response to the Japanese subsidy.

**Method 3**: The two methods described above are useful to provide empirical evidence based on relatively less reliance on modeling assumptions. A limitation is that these methods do not provide the comprehensive welfare implications of the phenomena, especially because these results do not explicitly quantify implications to consumers and producers in each country.

To answer this question, I will build and estimate a structural model of differentiated products. Relative to the most commonly-used model developed by Berry, Levinsohn and Pakes (1995), I need to include two features in the model to answer my questions. First, I use an approach similar to Fan (2013) to incorporate that firms endogenously choose product attributes, which helps me to analyze how firms change their product attributes in response to the subsidy incentive. Second, a standard model of differentiated products with endogenous product attributes considers that firms choose product attributes by thinking of demand from a domestic market only. In my analysis, I will incorporate the possibility that firms might consider global demand. I empirically test if this model explains data better than the standard model.

Estimates from the structural model allows me to quantify the policy impacts for firms and consumers. In particular, I can quantify how the Japanese subsidy policy affected US consumers. The answer to this question is ambiguous. On one hand, it is possible that the US consumer surplus went up if the Japanese subsidy policy improved the fuel economy of cars in the US market. On the other hand, the US consumer surplus could go down if some of the fuel economy improvements came from significant increases in price.

Implications for firms are even more ambiguous. The policy impact depends on 1) how the policy changed each model's product attributes and marginal costs, 2) which automakers benefited from the Japanese subsidy policy in both the Japanese and US market, and 3) how the subsidy policy changed the markups in both markets. I will integrate these analyses to quantify the policy's welfare implications for consumers and producers in each country.

## 3. Research Team

The research team will consist of the project investigator of this project, Koichiro Ito, an associate professor at Harris School of Public Policy at University of Chicago, and research assistants.

## 4. Conflict of Interest

The PI, Koichiro Ito, does not have any conflict of interest for this project.

## 5. How the potential findings help to inform research or policy issues of interest to DOT

The automobile industry plays a key role in the design of transportation policies. Automakers are multinational firms, but as I mentioned in the introduction of this proposal, nearly all previous economics studies do not investigate a domestic transportation policy's potential impact on global markets. Findings from my project provides two board policy implications. First, a foreign country's transportation policy might affect consumers in the United States—a foreign policy might affect products sold by foreign firms that are also sold in the United States. Second, conversely, US transportation policies might affect consumers in other countries—a US policy may affect products sold by multinational firms that are also sold in other countries. These implications enhance the importance of US transportation policies especially because the United States has the largest automobile market in the world. Findings from this project could also shed light on the importance of international corporations in transportation policies because each country's policy might affect global markets simultaneously. After the completion of the project, I would be excited to deliver the summary of research findings to policymakers in the DOT and have policy-oriented discussions on this topic.

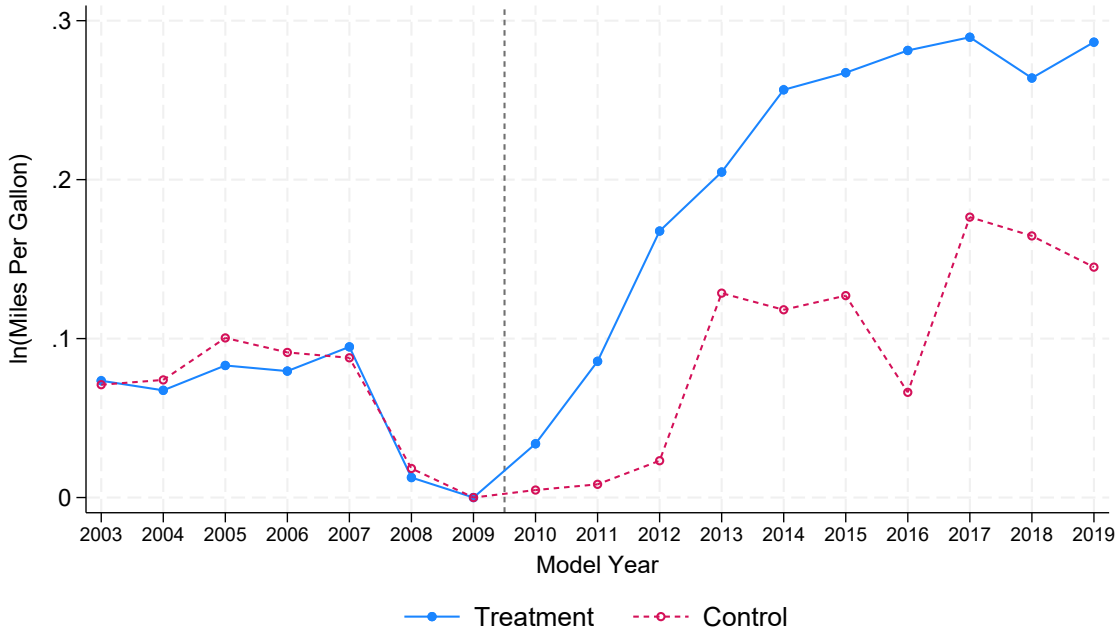
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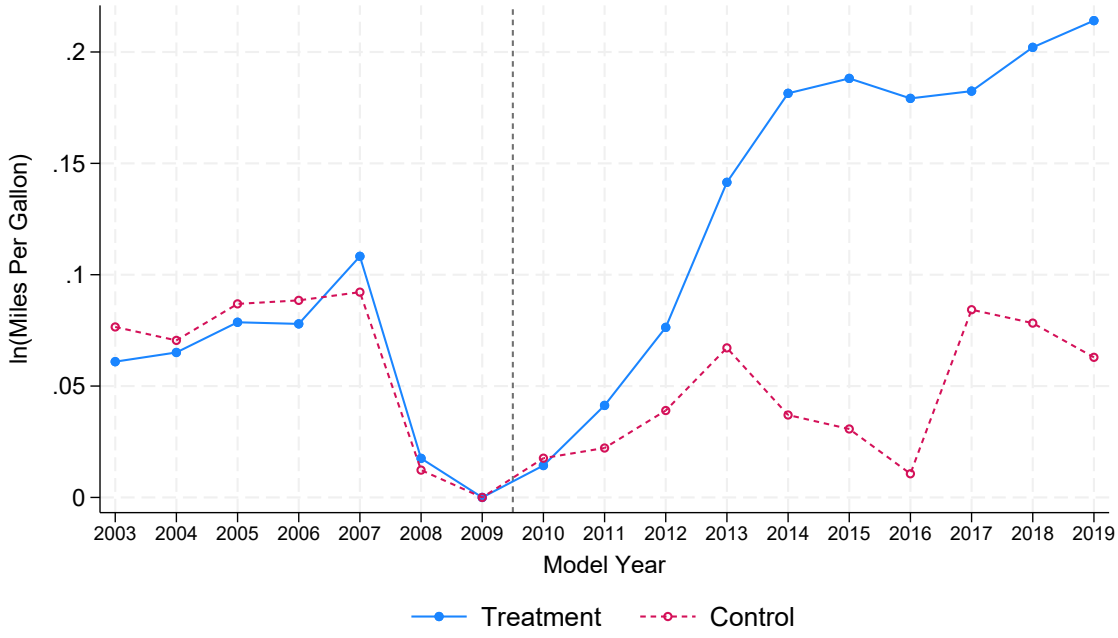
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Figure 1: Average Fuel Economy of Japanese Vehicles in the US market

Panel A: Unweighted




Panel B: Sales-Iighted




*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.

Table 1: International Spillover Effects of on the US Automobile Market

| Dependent variable: Log of fuel economy (miles per gallon) | | | | |
|---|---|---|---|---|
| | (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 |

*Note*: This table shows the OLS regression results of equation (1). Standard errors are clustered at the model level.

Table 2: Binary Choice Model of Subsidy Take-up

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| $\tilde{\Delta}$ Fuel Economy (km/liter) | -0.127 | -0.095 | -0.107 | -0.094 |
| | (0.019) | (0.025) | (0.019) | (0.024) |
| $\tilde{\Delta}$ Weight (1000kg) | -5.247 | -5.143 | -0.592 | -0.388 |
| | (0.771) | (0.793) | (1.041) | (1.037) |
| Sales in Japan (millions) | 11.788 | 9.077 | 9.428 | 8.508 |
| | (3.209) | (3.490) | (3.213) | (3.383) |
| Sales in USA (millions) | 3.972 | 3.467 | 5.780 | 5.207 |
| | (1.520) | (1.542) | (1.484) | (1.501) |
| $\tilde{\Delta}$ Fuel Economy * Sales in Japan | | -2.769 | | 0.872 |
| | | (1.980) | | (1.987) |
| $\tilde{\Delta}$ Fuel Economy * Sales in USA | | -1.972 | | -3.621 |
| | | (1.310) | | (1.313) |
| $\tilde{\Delta}$ Weight * Sales in Japan | | | -512.971 | -548.809 |
| | | | (80.557) | (84.461) |
| $\tilde{\Delta}$ Weight * Sales in USA | | | -37.059 | -79.496 |
| | | | (56.909) | (59.078) |
| Number of observations | 466 | 466 | 466 | 466 |
| $R^2$ | 0.28 | 0.28 | 0.34 | 0.35 |
| Make fixed effects | Yes | Yes | Yes | Yes |

*Note*: This table shows the OLS regression results of equation (2). $\tilde{\Delta}$ Fuel Economy is each model's fuel economy target in the policy period minus the model's fuel economy in the pre-policy period. $\tilde{\Delta}$ Weight is each model's weight cutoff in the fuel economy target in the policy period minus the model's weight in the pre-policy period.