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# The Effect of Changes in World Crude Oil Prices on U.S. Automobile Exports

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**ABSTRACT:** This study describes an export model where consumers differentiate between different types of automobiles by the distance they can travel on one dollar's worth of fuel. The model predicts that the overall demand for vehicles falls as crude oil prices rise, and that the demand for less fuel-efficient vehicles falls relatively more. In particular, we estimate that between 2007 and 2008, when the crude oil prices increased by 32 percent, the export demand for the SUVs manufactured in the United States declined by over $700 million. This implies that the relatively less fuel-efficient U.S.-model vehicles will tend to suffer a competitive disadvantage worldwide when crude oil prices are high. We discuss the potential role of the proposed CAFÉ standards in improving fuel-efficiency and growing exports of the U.S. vehicle fleet.

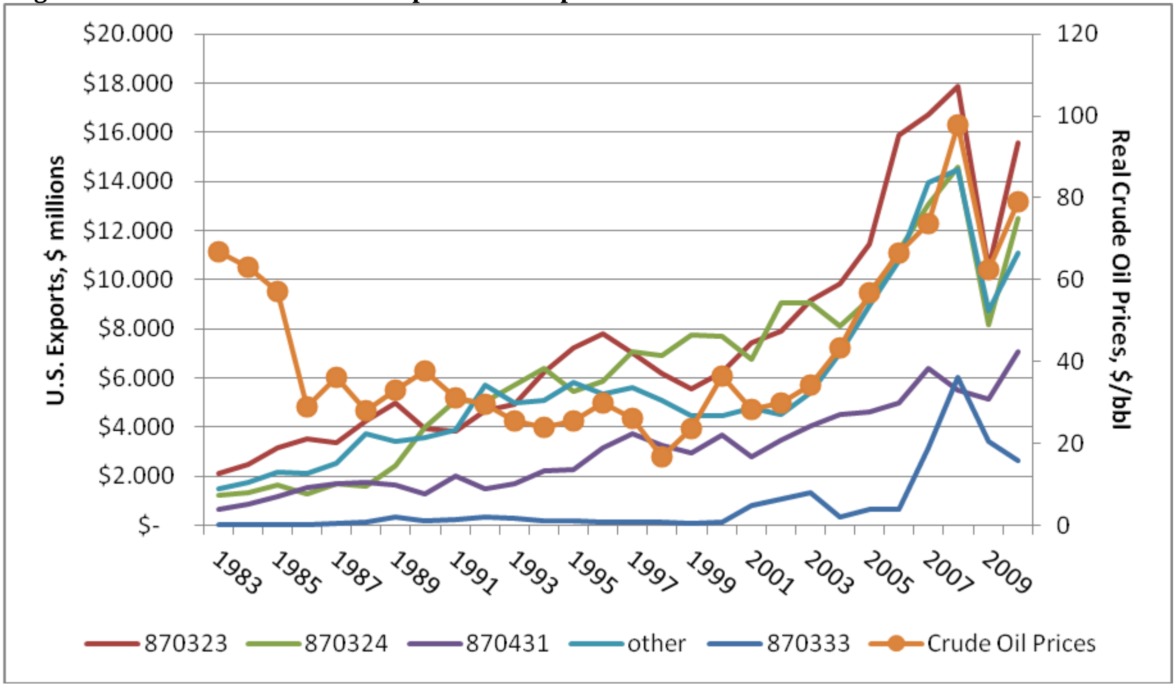
**Keywords**: Fuel efficiency; CAFÉ standards; International trade; Econometrics
**JEL Classifications**: C1; F1; Q4

## 1. Introduction

Sales of U.S. "sport utility vehicles" (SUVs) collapsed spectacularly in 2008, the same year that crude oil prices averaged $93/bbl and in some months exceeded $120/bbl, which some observers attributed to the SUV's relatively poor fuel efficiency. This was the same year, however, that the so-called "Great Recession" began, so it's not clear if the collapse in demand was due to high crude oil prices or a simple consequence of falling aggregate demand for all U.S. manufactured vehicles, a large proportion of which happen to be SUVs. While the main determinant of automobile demand is income, this article investigates whether consumers also respond to changes in fuel prices, represented by the world crude oil price.

We will focus on U.S. vehicle exports. There are enough U.S. vehicle export data to build an extensive panel data set. Furthermore, we know that U.S. vehicle exports are small enough in the world market that we can assume U.S. exporters are price takers, which simplifies the analysis. Despite being a net importer of cars, the U.S. exported $48.9 billion of automobiles and trucks in 2010, $35 billion of which was from three HS codes, 870323, 870324, and 870431 – medium and large size cars, and SUVs. Many of these exports are of European models that have manufacturing facilities in the United States. Figure 1 shows the trends in U.S. exports of these vehicles since 1983, and real crude oil prices.

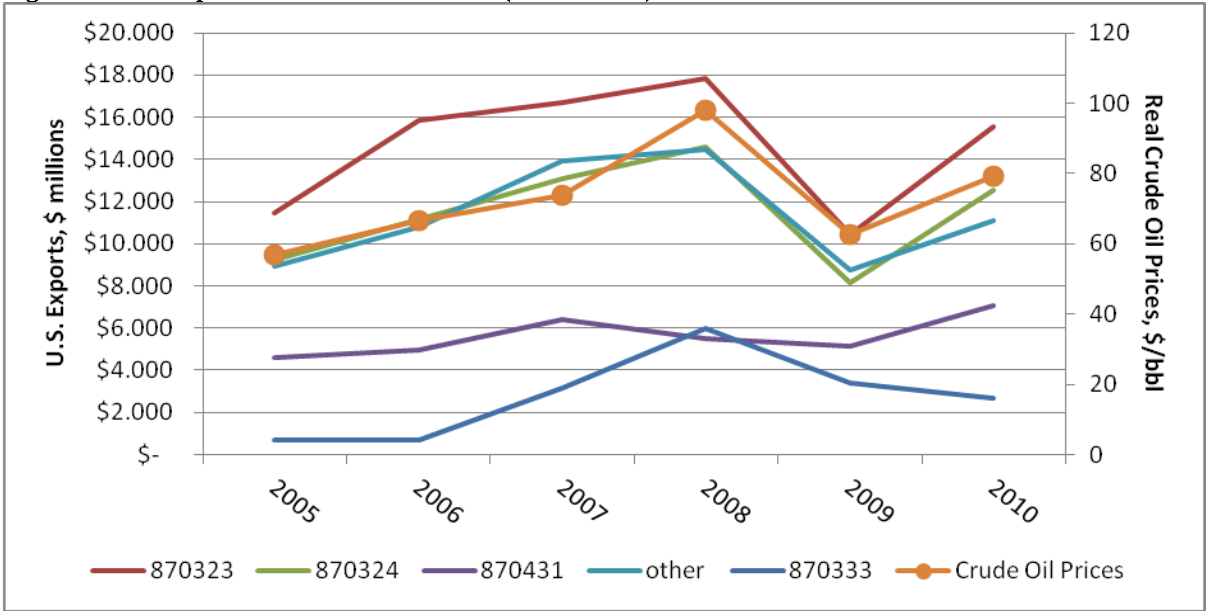
**Figure 1. Trends in U.S. Vehicle Exports and Imported Crude oil Prices**



Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division. TPIS Database: USHS EXPORTS, Revised Statistics for 1989-2010, and EIA Short-Term Energy Outlook, December 2011.

It is clear from Figure 1 that both crude oil prices and world automobile demand is highly correlated with world GDP. A more subtle effect can be seen in Figure 2, which shows the same information from 2005 to 2010.

**Figure 2. U.S. Exports and Crude oil Prices (2005 – 2010)**



Source: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division. TPIS Database: USHS EXPORTS, Revised Statistics for 1989-2010, and EIA Short-Term Energy Outlook, December 2011.

As crude oil prices continued to rise in 2007 and 2008, SUV exports (HS 870431) flattened in 2007 and fell in 2008, despite continued growth in car exports. Larger cars, like SUVs, tend to be relatively less fuel efficient. If it is true that demand for passenger vehicles falls as the cost of fuel rises, then the corollary is that demand for large, less fuel efficient cars would tend to fall relatively more.

The corollary has interesting implications for fuel-related policies, like fuel-efficiency standards. U.S.-model vehicles are relatively less fuel-efficient than European or Japanese models. A 2004 study by the Pew Center on Global Climate Change calculated that the average "mile per gallon" achieved by model year 2002 cars in the EU and Japan exceeded those in the United States by 54 and 94 percent, respectively[1]. When crude oil prices are high, the worldwide demand for U.S. model vehicles will fall relatively more than the competing European and Japanese models. This competitive disadvantage could be alleviated somewhat by, for example, making the joint corporate average fuel efficiency (CAFE) standards set by the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA) more stringent. To test the hypothesis that demand for vehicles falls as crude oil prices rise, and the corollary that demand for relatively less fuel-efficient vehicles falls relatively faster, we develop a theoretical trade model and test it using panel data on U.S. exports.

Traditionally, the demand for vehicles is modeled using a discrete choice framework introduced by Berry et al., (1995). In this framework an auto-buyer's utility of a chosen vehicle depends on the vehicle's price and attributes, as well as interactions between her personal preferences for a vehicle (e.g. number of cup-holders, leather interior) and vehicle characteristics. The latter allows nesting of vehicles that are close substitutes. The auto-buyer's preferences induce the substitution between vehicles within the nest. As shown by Hunt and Wozny (2010), aggregation over all auto-buyers of vehicles within each nest allows estimating a nested logit model where the market share of a vehicle is determined by its price, the discounted present value of future gasoline costs and vehicle-specific attributes.

While the discrete choice framework is a natural choice in the context of vehicle demand, estimating such a model requires detailed vehicle characteristics data for each model and make such as vehicle price, ownership history, weight, size, model configuration and others. Applying this framework to the context of this study requires detailed data on these characteristics for each importer of U.S. vehicles. These data are not available to us. Thus, we develop a trade model that incorporates interaction between auto-buyer's preferences and vehicle quality, but does not allow nesting of vehicles that are close substitutes.

Our trade model extends the standard Dixit-Stiglitz (1977) trade model with CES preferences and monopolistic competition, where the representative consumer's demand for vehicles with identical attributes is adjusted by the perceived fuel-efficiency that measures the cost of operating a vehicle. The perceived fuel-efficiency is a function of the quantity of gasoline that is required to drive a vehicle for one mile and the cost of oil. Our approach most closely follows the literature on quality and trade. Baldwin and Harrigan (2011) discuss the model of the demand for quality with preferences for what might be called box-size quality: the consumed varieties share the same characteristics but ones that are placed in a bigger box are perceived to have higher quality.[2] We specify a vehicle-quality function that is difference between the per-mile benefit of driving a vehicle (such as its size, number of cup-holders, interior design, etc) and the cost of driving that vehicle that is measured in dollars per mile-[3]When the crude oil price increases, the perceived vehicle quality drops, and auto-buyers substitute from low to high fuel-efficiency vehicle with nearly identical interior or exterior characteristics Thus, the auto-buyers make their purchasing decisions based on vehicle-quality adjusted price rather than observed vehicle sticker price.

Our analysis contributes to the literature on fuel energy economics. This literature examines the welfare impacts of addressing externalities in fuel consumption, comparing CAFE standards to pigouvian taxes on gasoline (e.g. Agras and Champan (1998); Gerard and Lave (2003); and Kleit, (2004)). A standard observation is that CAFE standards lower the marginal cost of driving, which tends to increase distance traveled somewhat. This is commonly referred to as the "rebound effect"

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[1] From the first column in Table 12 of "Comparison Of Passenger Vehicle Fuel Economy And Greenhouse Gas Emission Standards Around The World," Available at *http://www.c2es.org/docUploads/Fuel%20Economy%20and%20GHG%20Standards_010605_110719.pdf.*

[2] Similar modeling approach is used by Hummels and Klenow (2005), Hallak (2006), Hallak and Schott (2008), Maurice Kugler and Eric A. Verhoogen (2008)

[3] Gately (1990), Greene (1992), Mayo and Mathis (1988) and Blair, et al. (1984) also use cost per mile to measure fuel efficiency.

and is discussed in great length in the Regulatory Impact Analysis for CAFE standards (see, for example, page 364 of NHTSA's RIA for the 2012-2014 CAFE standards[4]). Pigouvian taxes on gasoline have no rebound effect and would therefore achieve the same regulatory goal (internalizing an externality associated with fuel consumption) at a lower cost. While we do not address the optimal regulation aspects of the CAFE standard, our results provide evidence of consumer response to changes in fuel prices. From this standpoint our analysis is pertinent to the economic literature that examines the so-called "energy paradox" and the optimal strategy to address externalities in fuel consumption[5]. The following section describes the model. Then we discuss the data and the results of econometric tests of the model.

## 2. Model of International Trade in Vehicles with Variable Fuel-Efficiency

Our empirical specification estimates the effect of a change in world crude oil prices on U.S. exports of HS codes, 870323, 870324, and 870431 – medium and large size cars, and SUVs. We derive this specification from a Dixit-Stiglitz monopolistic competition model of trade with fuel efficiency adjusted CES preferences.[6] We assume that foreign auto-buyers are sensitive to changes in the price of crude oil. When the price of crude oil rises, they substitute the consumption of large relatively fuel-inefficient vehicles with smaller high-gas mileage vehicles. U.S. automakers export cars that are differentiated by engine size and, therefore, by fuel-efficiency.[7]

The variable $a_i$ in utility function (1) represents the quantity of vehicles of type $i$ from the pool of vehicles $\Omega$ available for auto-buyers in country $j$ and year $t$. Since the foreign auto-buyer is assumed to choose a vehicle based on fuel efficiency, we adjust the variable $a_i$ in (1) by a vehicle quality function $q_{it}(B_i, F_i, P_{ot})$, that varies according to $B_i$, the benefits per mile of driving vehicles of type i; $F_i$, the quantity of fuel required to drive the vehicle one mile; and the expected homogeneous price of fuel per gallon, with a given information set $\Omega_t$ which is represented by the expected price for crude oil, $[E[P]]_{ot}]$. We assume that each auto buyer derives the demand for a vehicle of type $i$ from the same utility function in (1).

$$U_{jt} = \left( \int_{i\in\Omega_{jt}} (a_i q_{it})^{1-1/\sigma}\, di \right)^{\frac{1}{1-1/\sigma}} ; \sigma > 1 \qquad (1)$$

In the utility function (1) $\sigma$ is a constant elasticity of substitution between vehicles with the variable fuel-efficiency $e_{it}$.

We assume that $\partial q_{it}/\partial F_i < 0$ and $\partial q_{it}/\partial P_{ot} < 0$. The first partial derivative indicates that as the fuel requirement increases, the efficiency of type $i$ vehicles declines. The second partial derivate indicates that as the expected crude oil price increases, the expected cost of driving a vehicle of type $i$ increases and, therefore, the perceived vehicle quality declines.

Let $Y_{jt}$ be the income of country $j$ in year $t$, which equals its expenditure level on vehicles. Then country $j's$ fuel-efficiency adjusted demand for U.S. vehicles of type $i$ in year $t$ is given in (2).

$$a_{ijt}(i) = \frac{[(p]_{jt})^{-\sigma} q_{it}^{\sigma-1} Y_{jt}}{\Upsilon_{jt}^{1-\sigma}}; \quad \Upsilon_{jt}^{1-\sigma} \equiv \int_{i\in\Omega_{jt}} \left(\frac{p_{it}}{q_{it}}\right)^{1-\sigma} di \qquad (2)$$

To evaluate the response of export demand for vehicles of type $i$ to changes in the expected world price of crude oil $P_{ot}$, we calculate the coefficient of crude oil price elasticity $\epsilon_{a_i, p_{ot}}$. We define the metric that measures vehicle quality $q_{it}(B_i, F_i, P_{ot})$ in (3).

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[4] Available at *http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/CAFE_2012-2016_FRIA_04012010.pdf*

[5] See Greene (2010) and Li et.al (2011) for recent discussion of the "energy paradox"

[6] Krugman (1980) provides the first example of applying such a model to estimate international trade flows.

[7] For the purpose of this study we do not consider the domestic auto market.

$$q_{it}\left( [B_i,F]_i,\ [P]_{ot} \right) = B_i \sum_{s=t+1}^{t+k} \left[ [E[P_{os}]]^{(-1/[MPG]_i)} \right] \tag{3}$$

In the perceived vehicle quality function (3), $\ln[[E[P]_{os}]]^{\frac{-1}{MPG_i}} \cong \frac{[-E[P]_{os}]}{MPG_i}$ represents the decrease in quality resulting from an increase in the expected cost of driving vehicle i, as measured in dollars per mile and $k$ denotes life-time of a vehicle[8]. For a given expected price of crude oil $[E[P]_{os}]$, the demand for the U.S. vehicles of type $i$ increases with their benefit (i.e. size of the trunk, number of cup-holders etc) and with miles per gallon (MPG). For a given vehicle's $B_i$ and its associated fuel-efficiency (MPG), the demand falls when the expected price of crude oil rises.

Using (2) and (3), we calculate the crude oil price elasticity of demand for U.S. vehicles $\epsilon_{a_i, P_{ot}}$ in (4).[9]

$$\epsilon_{a_i, P_{ot}} = \frac{\partial a_i}{\partial P_{ot}} \frac{[E[P]_{os}]}{a_i} = -(\sigma - 1)\frac{[E[P]_{os}]}{MPG_i} < 0 \tag{4}$$

The negative sign of the crude oil price elasticity in (4) indicates that, as the expected world crude oil price increases, the export demand for U.S. vehicles declines. Moreover, the export demand for relatively fuel inefficient vehicles would fall more relative to more fuel-efficient vehicles. Since the MPD varies by vehicle type, we expect that

$$|\epsilon_{(medium,\ [P]_{ot})}| < |\epsilon_{(large,\ [P]_{ot})}| < |[\epsilon]_{(SUV,\ [P]_{ot})}|.$$

We assume that U.S. auto-manufactures are monopolistically competitive firms. They take foreign auto demand (2) and the available engine technology as given. The latter assumption implies that that all vehicles of type $i$ have the same MPG.[10] The delivered price of vehicles of type $i$ to country $j$ in year $t$ is equal to a constant mark-up over the marginal cost of the U.S. exporters (represented by $M_{it}$)

$$P_{ijt} = \frac{\sigma}{\sigma - 1} M_{it} \tag{5}$$

By substituting the pricing rule (5) and the efficiency function (3) into the demand function in (2), we obtain the following reduced-form expression for the total value for the U.S. exports of each type of vehicles to country $j$ in year $t$

$$X_{ijt} = \left[ B_i [[E[P]_{os}]]^{-\frac{1}{MPG_i}} \right]^{(\sigma-1)} \left( \frac{\sigma M_{it}}{(\sigma - 1)Y_{jt}} \right)^{1-\sigma} N_{it}\, Y_{jt} \tag{6}$$

The variable $N_t$ represents the number of U.S. producers. We assume that U.S. auto-manufactures produce differentiated vehicles of type $i$ but have identical costs of production.

To derive our empirical specification we begin by taking a log-linear approximation of (6) in (7), where lower-case variables indicate the natural logs of the variables. Furthermore, we assume that the expected price of oil next year is equal to this year's price: $E[P_{ot+1}] = P_{ot}$

$$x_{ijt} = (\sigma - 1)b_i - (\sigma - 1)\left[ \left[\frac{p_{ot}}{mpg}\right]_i \right] - \sigma(\sigma - 1)m_{it} + (\sigma - 1)(\sigma - 1)y_{jt} + n_{it} + y_{jt} \tag{7}$$

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[8] $DPM = {}^{P_{ot}}/_{Gallon} * {}^{Gallon}/_{Mile} = {}^{P_{ot}}/_{Mile}$

[9] We derive the oil price elasticity using the vehicle demand function (2) and the definition of perceived vehicle quality in (3). Substituting (3) into (2) yields the demand function (A1).

$$a_{ijt}(i) \frac{[(p]_{jt})^{-\sigma} B_i^{\sigma-1} [P_{ot}]^{-\frac{\sigma-1}{MPG_i}} Y_{jt}}{Y_{jt}^{1-\sigma}} \tag{A1}$$

The oil price elasticity is derived in (A2).

$[(p]_{jt})^{-\sigma} B_i^{\sigma-1})$

[10] This assumption can be relaxed by letting auto-manufactures produce vehicles with variable fuel-efficiency. However, empirically we do not observe substantially different fuel efficiency for vehicles of the same type.

With our assumption that the MPG for all vehicles of type $i$ is the same, we replace $\frac{1}{mpg_i}$ in (7) with an indicator variable for each vehicle type. Let $medium, large$ and $suv$ be indicator variables that are equal to one when the exported vehicles are indentified by HS: 870323, 870324, and 870431 respectively and zero otherwise. Then our final estimation equation is given in (8).

$$x_{jt} = \beta_0 + \beta_1\, p_{ot} + \beta_2 large_{jt} * p_{ot} + \beta_3 suv_{jt} * p_{ot} + \beta_4 GDP_{jt} + \beta_5 RER_{jt} + \zeta_t + \xi_j + \varepsilon_{jt} \qquad (8)$$

In the specification (8) the difference in price levels between the United States and the importer $j$ is measured with bilateral real exchange rates ($RER_{jt}$); income of the importer $j$ is measured with GDP of country $j$; $\zeta_t, \xi_j$ are the year and importer fixed effects respectively; is the error term of the model, and vehicles of medium size are the reference category.[11]

The estimate of the elasticity parameter $\beta_1$ can be interpreted as a percentage change in exports of medium size vehicles that results from a percent change in the world price of crude oil. The estimates of elasticity parameters $\beta_2$ and $\beta_3$ are measuring the effect of changes in the world price of crude oil on exports of large vehicles and SUVs relative to the exports of medium size vehicles. Our model predicts that $\hat{\beta}_1, \hat{\beta}_2, \hat{\beta}_3$ are all strictly less than zero and that $\hat{\beta}_3 < \hat{\beta}_2$.

## 3. Data

The final estimating equation (8) requires an indicator of demand and the world crude oil price. For the indicator of demand, we use panel data of U.S. exports of HS code 870323 (“medium-sized cars”), 870324 (“large-sized cars”), and 870431 (“SUVs”), which accounted for $35 billion of the total of $49 billion of U.S. vehicle exports in 2010. The panel data consists of 26 countries that jointly account for 90 percent of U.S. exports of the three HS codes. We list these countries in Table 1.

**Table 1. List of Importing Countries**

| | | | | |
|---|---|---|---|---|
| Australia | | India | | Qatar |
| Benin | | Japan | | Russia |
| Brazil | | Jordan | | Saudi Arabia |
| Canada | | Korea | | United Arab Emirates |
| Chile | | Kuwait | | United Kingdom |
| China | | Lebanon | | Vietnam |
| Dominican Republic | | Lithuania | | |
| Finland | | Mexico | | |
| Germany | | Netherlands | | |
| Hong Kong | | Nigeria | | |

We include data from 1983 to 2010. For fuel prices, we use the “annual average imported crude oil price” reported in the December 2011 Energy Information Administration’s “Short-Term Energy Outlook.”

As a robustness check addressing an econometric issue that is discussed in the next section, we estimate specification (8) with gasoline pump prices for selected countries. Figure 3 illustrates the relationship between gasoline pump prices (inclusive of taxes) and world crude oil prices.

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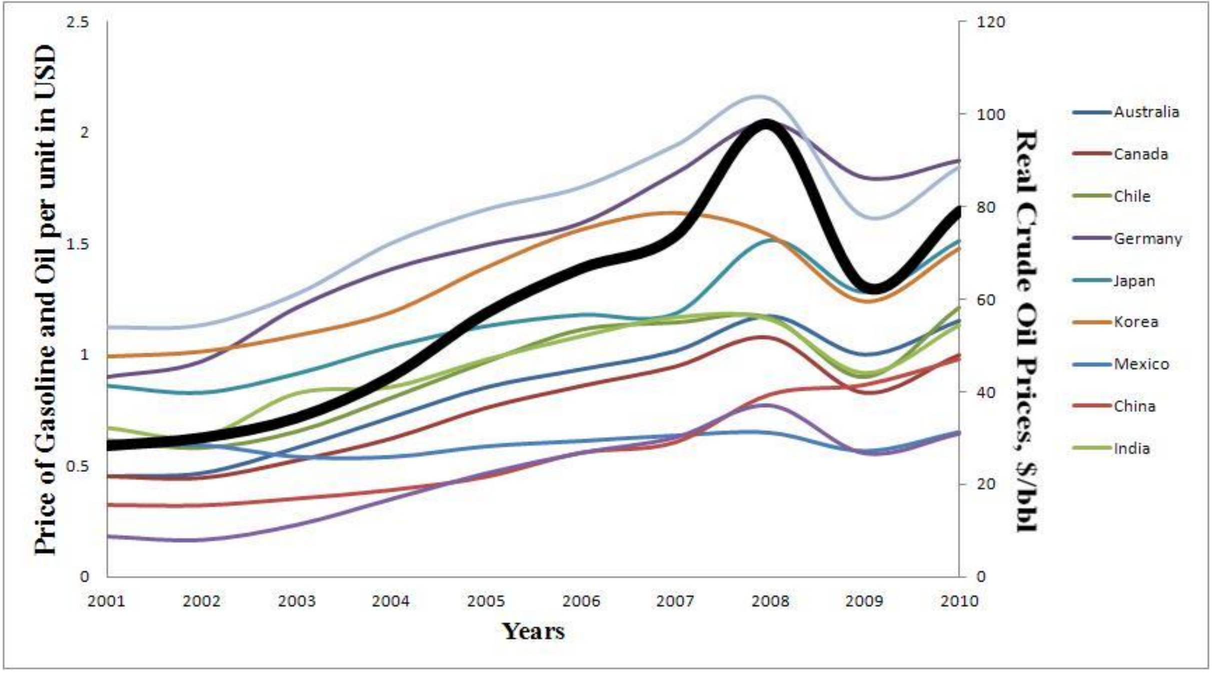
[11] The error term $\varepsilon_{jt}$ contains unobservable shocks that may both affect the world price of crude oil and the demand for U.S. vehicle exports, thereby raising concern about the endogeneity of crude oil prices. However, given that the share of crude oil consumption needed for driving vehicles that are exported from the United States is small relative to overall crude oil use, it is unlikely that a shock to the demand for the U.S. vehicles affects the crude oil price.

**Figure 3. Gasoline Pump and World Oil Prices by Year and Country**



Source: EIA Short-Term Energy Outlook, December 2011 and IEA database

Gasoline pump prices generally follow the crude oil price trend. The correlation between gasoline pump prices and crude oil prices exceeds 0.71 for all countries in our sample. However, there is considerable country-specific heterogeneity in year to year changes in gasoline pump prices. For example from 2006 to 2008, crude oil prices increased by 46%, while the gasoline pump prices fell in Korea by 1.6% and increased Germany by 28%.

Gasoline pump prices are available from the International Energy Agency (IEA). Unfortunately, IEA only has complete price series for 13 out of the 26 countries in our sample, and then only for the years 2001–2010. Importantly, IEA does not have gasoline pump prices for Middle East countries. These countries import U.S. manufactured luxury vehicles that we classify as "large-sized cars". We expect that the omission of these countries would distort the previously discussed order of oil price elasticities.

Equation (8) also requires indicators of GDP growth and real exchange rates. We take indicators of GDP growth from the Economist Intelligence Unit, and exchange rate indicators are taken from measures of real exchange rates compiled by the Economics Research Service of the U.S. Department of Agriculture. Both of these are standard practice for gravity models of trade.

## 4. Estimation Results

As mentioned in the "Data" section, we estimate the parameters in (8) using a panel of 26 top importers by value of U.S. manufactured medium and large vehicles and SUV's from1983 to 2010. To control for a variety of country characteristics, including barriers to commodity imports, we estimated (8) with country fixed effects. Since the United States is the source country for all of the trade flows in the dataset, the year fixed effects in the specification would control for the size of the U.S. production base and production costs. However, because the world oil prices we use in our estimate do not vary across countries in any given year, we are unable to estimate specification (8) with year fixed effects as the estimate of the oil price elasticity $(\beta)$ would not be identified. To estimate specification (8) with year fixed effects, we use gasoline pump prices that vary by country and year.

As indicated in our theoretical model, auto buyers form expectations about the price of fuel in order to alter their driving habits to maintain the desired level of car efficiency by either switching to a vehicle with better MPG, or by reducing the number of miles they drive. We estimate specification (8) with one, two and three year lags in the price of oil. We report the estimates of the parameters of specification (8) in Table 2.

**Table 2. The Effect of Change in the World Oil Price on the U.S. Vehicle Exports**

| | (1) | (2) | (3) |
|---|---|---|---|
| Variables | One Year Lag | Two Years Lag | Three Years Lag |
| Medium Size (< 3000 cc) | -0.317** | -0.340** | -0.235 |
| | (0.159) | (0.159) | (0.155) |
| | | | |
| Large Size (>3000 cc) | -0.423*** | -0.447*** | -0.342** |
| | (0.041) | (0.041) | (0.041) |
| | | | |
| SUV | -1.035*** | -1.059*** | -0.949*** |
| | (0.088) | (0.088) | (0.088) |
| | | | |
| Log of Real Exchange Rates | -1.349** | -1.345** | -1.317** |
| | (0.575) | (0.458) | (0.562) |
| | | | |
| Log of GDP | 3.178*** | 3.148*** | 3.059*** |
| | (0.389) | (0.380) | (0.368) |
| | | | |
| Country Fixed Effects | Yes | Yes | Yes |
| Year Fixed Effects | No | No | No |
| R-Squared (within) | 0.504 | 0.505 | 0.479 |
| Observations | 1965 | 1964 | 1963 |
| Notes: | | | |
| Dependant variables is Log of U.S. Exports of Vehicles | | | |
| Robust standard errors in parentheses clustered by 26 country groups | | | |
| *p<0.1**,p<0.05 ***, p<0.01* | | | |

The estimates of crude oil price elasticity of demand for each type of vehicle are negative and significant for the first two lags in the crude oil prices. An increase in the price of crude oil would reduce demand for all types of vehicles, but most strongly for SUVs. We estimate that the crude oil price elasticity of demand for Medium Size, Large Size vehicles and SUVs with one and two year lags is -0.3, -0.4 and -1 respectively. That is, a change in the crude oil price of one percent reduces the demand for U.S. manufactured “Medium Size”, “Large Size” vehicles and SUVs by about 0.3 percent, 0.4 percent and 1 percent respectively.

As a robustness check we report the results when specification (8) is estimated using gasoline pump prices in Table 3. The variation in gasoline prices across countries and years allows us to estimate specification (8) with year fixed effects. While the magnitude of the estimated gasoline price elasticity is similar to the estimated oil price elasticity for “Medium Size” vehicles, the gasoline price elasticity for SUVs is smaller than oil price elasticity for SUV’s. More importantly, none of the elasticity estimates are significant. These results reflect both a smaller number of observations and the omission of countries due to data limitations. However, although the results using gasoline prices are not significant, the estimated coefficients do not seem to indicate that estimating specification (8) with world crude oil prices substantially biases our oil price elasticity estimates. We use these estimates in calculating the contribution of change in oil prices to changes in the export demand of each vehicle type.

Our estimates confirm the relative order of magnitudes of the crude oil price elasticities of demand predicted by the theoretical model for each vehicle type. The increase in the crude oil price has the smallest negative effect on export demand for “medium size” vehicles and the largest negative effect on the export demand for SUVs.

Our model predicts yearly changes in export demand by changes in world oil prices, GDP and the real exchange rates. Using the elasticity estimates from the column 1 of Table 2, we calculate the predicted export value for each vehicle type in year $t$ based on sample export value in the year $t-1$ .

$$\widehat{X_{Medium\ Size,t}} \cong X_{Medium\ Size,t-1} * \left(\widehat{\beta}_1 * \%\Delta p_{oil,t-1} + \widehat{\beta}_4 * \%\Delta GDP + \widehat{\beta}_5 * \%\Delta RER\right) \quad (9,a)$$

$$\widehat{X_{Large\ Size,t}} \cong X_{Large\ Size,t-1} * \left([\%\Delta p_{oil,t-1} * \left[\widehat{\beta}]_1 + \widehat{\beta}_2\right] + \widehat{\beta}_4 * \%\Delta GDP + \widehat{\beta}_5 * \%\Delta RER\right) \quad (9,b)$$

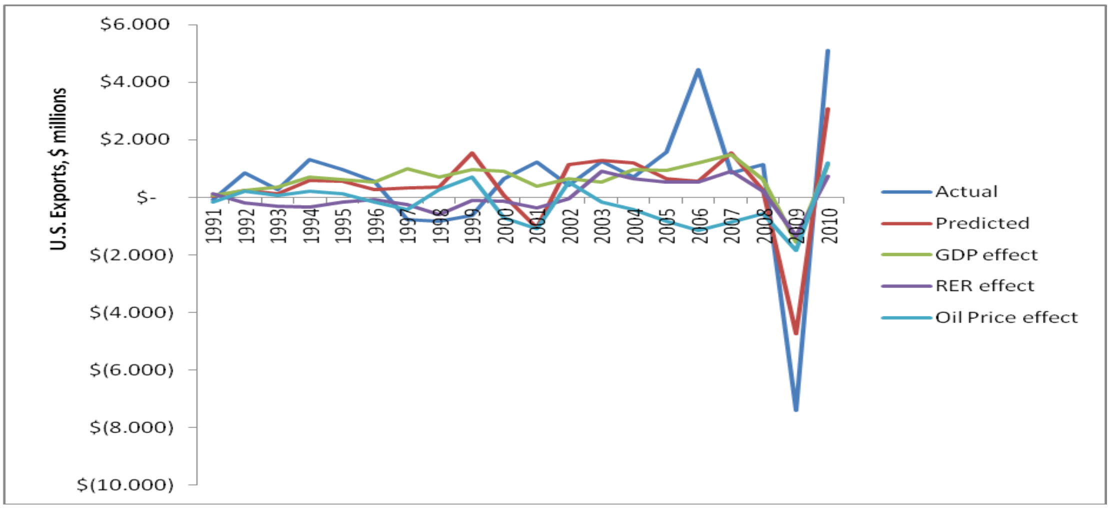
$$\widehat{X_{SUV,t}} \cong X_{SUV,t-1} * \left([\%\Delta p_{oil,t-1} * \left[\widehat{\beta}]_1 + \widehat{\beta}_3\right] + \widehat{\beta}_4 * \%\Delta GDP + \widehat{\beta}_5 * \%\Delta RER\right) \quad (9,c)$$

**Table 3. The Effect of Change in the Gasoline Prices on the U.S. Vehicle Exports**

| | (1) | (2) |
|---|---|---|
| Variables | One Year Lag | Two Years Lag |
| Medium Size (< 3000 cc) | -0.351 | -0.571 |
| | (0.538) | (0.616) |
| | | |
| Large Size (>3000 cc) | -0.803 | -1.059 |
| | (0.403) | (0.088) |
| | | |
| SUV | -0.563 | -0.729 |
| | (2.294) | (2.311) |
| | | |
| Log of Real Exchange Rates | -0.742 | -1.140 |
| | (0.575) | (1.027) |
| | | |
| Log of GDP | 5.262*** | 4.849*** |
| | (1.500) | (1.550) |
| | | |
| Country Fixed Effects | Yes | Yes |
| Year Fixed Effects | Yes | Yes |
| R-Squared (within) | 0.07 | 0.08 |
| Observations | 374 | 373 |
| Notes: | | |
| Dependant variable is Log of U.S. Exports of Vehicles | | |
| Robust standard errors in parentheses clustered by 13 country groups:<br>Australia, Canada, Chile, Germany, Japan, Korea, Mexico, China, India, Russia, Finland, Netherlands and UK. | | |
| *p<0.1**,p<0.05 ***, p<0.01* | | |

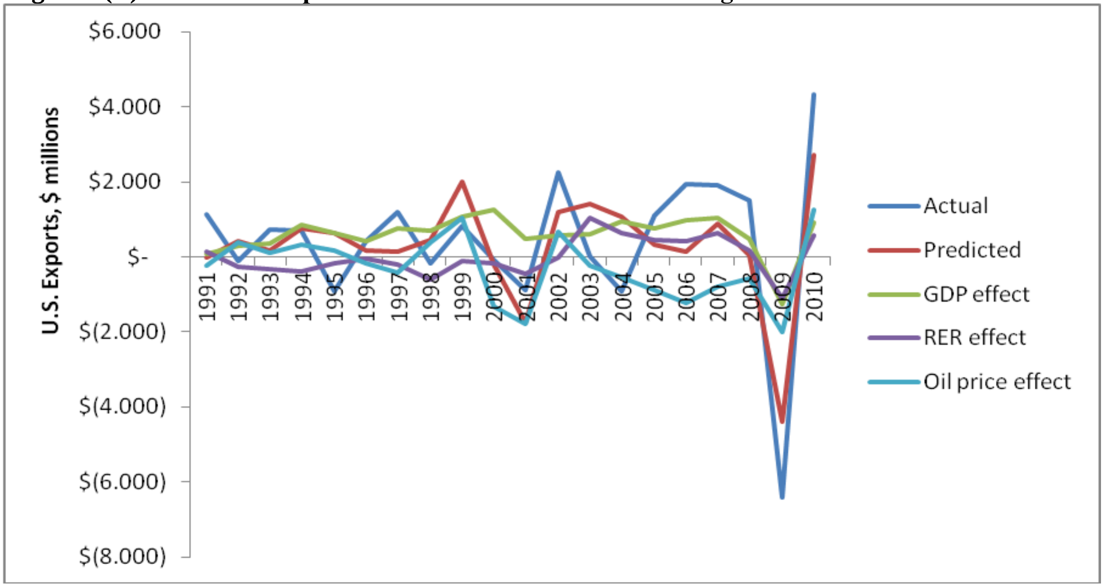
Based on calculations using expression (9), we plot sample and predicted values of the export demand for “Medium Size”, “Large Size” vehicles and SUVs respectively in Figure 4 (A – C).

**Figure 4(A). The Fit of Export Demand Determinants for “Medium Size” Vehicles**



Source: Author's Calculations

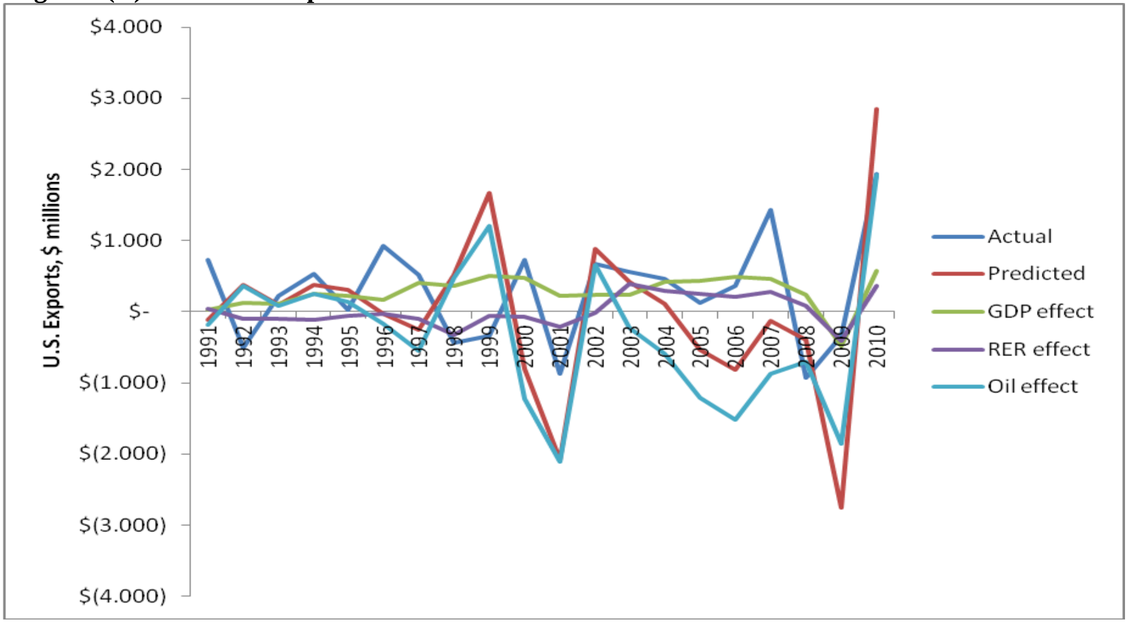
**Figure 4(B). The Fit of Export Demand Determinants for "Large Size" Vehicles**



Source: Author's Calculations

Our model predicts the change in export demand for each vehicle type fairly well, particularly between 2007 and 2010. The oil price effect tends to reduce the demand for each vehicle type, but more so for SUV's. The negative oil price effect is generally offset by the positive increase in the importers' GDP. The GDP effect dominates the oil price effect in determining the demand for vehicle exports. This is mostly evident in the export volume decline for each vehicle type between 2008 and 2009 when the GDP of importers in our sample fell by nearly 3 percent despite the fall in the crude oil prices by 36 percent.

**Figure 4(C). The Fit of Export Demand Determinants for SUVs**



Source: Author's Calculations

In Table 4 we report the dollar value contribution of the change in oil prices to changes in U.S. exports of each vehicle type. We apply expression (9) to exports of vehicles between 2007 and 2008, when the real world price of crude oil increased by 32 percent. We find that during this period export volume of "Medium Size" and "Large Size" vehicles increased, while the exports of SUVs declined. The oil price effect was negative for all vehicle types. In particular, the negative oil price effect on SUVs was $705 million. This effect was only partially offset by the positive effects of GDP and RER on SUV exports.

**Table 4. Modeled Crude Oil Price, GDP and RER Effects on the Exports of U.S. Manufactured Vehicles**

| HS Code | Code Description | 2007-2008 | | | |
|---|---|---|---|---|---|
| | | Change in Exports | Oil Effect | GDP Effect | RER Effect |
| | | | | | |
| 870323 | Medium Size | $656,792,280 | -$562,486,282 | $609,639,281 | $609,639,281 |
| 870324 | Large Size | $49,435,097 | -$587,538,777 | $477,518,666 | $159,455,208 |
| 870431 | SUV | -$392,815,728 | -$705,177,251 | $234,167,309 | $78,194,214 |

## 5. Policy Implications

The estimated coefficients describing the relationship between vehicle exports and crude oil prices show that the effect on SUVs is about 3 times larger than the effect on medium sized vehicles. According to EPA data, the combined highway and city fuel economy of SUVs was 20.2 MPG in 2010 and 25.8 for cars (26.1 for mid-sized cars and 22.7 for large cars)[12]. Apparently increasing the fuel efficiency of vehicles by 28 percent drastically reduces the competitiveness impacts that U.S. automobile manufacturers suffer when crude oil prices rise.

The 2012-2016 CAFE standards call for an increase in fuel efficiency for cars from 27.5 MPG in 2010 to 37.8 by 2016. Expressed in gallons required to drive 100 miles, this is a 27 percent increase in fuel efficiency. For light trucks, the standards will increase from 23.5 MPG in 2010 to 28.8 in 2016, an 18 percent increase in fuel efficiency that will make the fuel efficiency of SUVs in 2016 equivalent to passenger cars in 2010.

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[12] Using a different methodology from EPA's, the National Highway Traffic Safety Administration calculates the fuel efficiency of domestic cars to be 32.5 MPG in 2010, and light trucks as 24.5 MPG, a 33 percent difference. EPA Data is available at *http://www.epa.gov/otaq/fetrends.htm.*

According to the early release of the Energy Information Administration's Annual Energy Outlook for 2012, real crude oil prices are projected to rise by 26 percent between 2012 and 2016.[13] According to our estimates, a 26 percent increase in crude oil prices (ceteris paribus) would lead to an 8 percent decline in medium size car exports, a ten percent decline in exports of large cars, and a 26 percent decline in SUV exports. U.S. exports of medium cars, large cars, and SUVs to the countries in our sample in 2010 was (in billions) $15.6, $12.5, and $7.1, so the isolated effect of the increase in crude oil price can be expected to cause exports to decline by $1.2, $1.3, and $1.8 billion, respectively. Achieving the CAFE standards may mute this effect, however. If the crude oil price coefficient on SUVs was 0.3 instead of 1, the losses from the projected increase in crude oil price would only be $0.6 billion, representing a $1.2 billion "improvement" in U.S. SUV exports in 2016.

## 6. Conclusion

This study describes an export model where consumers differentiate between different types of automobiles by the distance they can travel on one dollar's worth of fuel. We use a theoretical trade model that allows for differentiation between vehicle types that are distinguished by their relative fuel efficiency. The model predicts that rising fuel prices (as reflected in the basic input to vehicle fuel, crude oil) results in a decline in demand for exported vehicles, with demand falling more for the less fuel efficient vehicle types.

We tested the theoretical model with panel data from 26 major importers of exported U.S. vehicles for the years 1983-2010. Because one of our independent variables, crude oil prices, does not vary across countries in any given year, we were not able to use fixed year effects to account for changes in the U.S. production base and costs. However, testing the model with gasoline prices from a subset of the 26 countries for the years 2001-2010 did not result in estimated coefficients that indicated the results from the crude oil specification are significantly biased, although none of the coefficients in the gasoline price specification were significant.`The crude oil price specification indicates that a 1 percent increase in crude oil prices causes demand for exports of U.S. vehicles to fall 0.3 percent for medium size cars, 0.4 percent for large cars, and 1 percent for SUVs. This indicates a significant response to crude oil prices, since crude oil prices increased by 39 percent from 2005 to 2010.

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[13] This report is available at *http://www.eia.gov/forecasts/aeo/er/.*

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