Global Fuel Economy Initiative
A fresh perspective

INTERNATIONAL TRANSPORT FORUM
LEIPZIG, 1 June 2017
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Introductions and update on GFEI
Sheila Watson, Deputy Director, FIA Foundation

Electric Vehicles, prospects and progress
Lew Fulton, Director STEPS, UC Davis

The Real Urban Emissions Initiative (TRUE)
Peter Mock, Europe Managing Director / EU Lead, ICCT

Discussion

Close
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Sheila Watson
FIA Foundation
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Lew Fulton
UC Davis
Modeling the future of electric vehicle adoption

Lew Fulton, Director
Alan Jenn, Postdoctoral Researcher
Gil Tal, Research Scientist
What will electric vehicle adoption look like in the future?

• The primary objective of this research is to investigate future international scenarios of electric vehicles (EVs) deep into the future. The broad set of questions we are interested in studying:
  – How many electric vehicles will be on the road in 2030? 2040? 2050?
  – When will we see 100 million EVs cumulatively in the world?
  – What sorts of vehicle pricing and attributes are required to boost adoption?
  – Which policies can be implemented in different countries to promote EVs in the most effective manner?

• Our work is unique for several reasons:
  – we leverage a massive dataset of EV sales across 39 markets
  – our focus is on international trends rather than a single country set of vehicle sales
  – We test three different forecast techniques
Our project leverages an extremely detailed dataset

- We are using a large dataset of new vehicle registrations from IHS Automotive.
- The data were cleaned and expanded in cooperation with the International Energy Agency.
- A quick summary of the dataset
  - Number of countries: 39
  - Unique vehicle models: 4,771
  - Unique vehicle manufacturers: 503
  - Total registrations: 509,194,651
  - Vehicle attributes: Axles, drive, engine size, # of cylinders, engine power, fuel type, transmission, turbo, price, segment, curb weight, footprint, fuel efficiency (NEDC/WLTP), and emissions (NEDC/WLTP)
INTERNATIONAL MARKETS
Norway is significantly off the charts at 1,900 EVs sold per 10,000 vehicles sold.
Deep forecasts of electric vehicle sales

- Forecasting is very uncertain, especially going deep into the future!
- In the literature, there is a huge range of future EV market shares in the future
- We aim to update these studies with more current data as well as examining a range of possible futures
Taking a three-pronged approach to forecasting

- Using the IHS registration data, we attempt to inform the construction of three separate models to forecast the sales of electric vehicles
  1. Discrete choice modeling approach
  2. Diffusion of innovation modeling approach
  3. Regression of trends approach
- This multi-model approach attempts to use strengths and assumptions of each model to understand different aspects of adoption
- Help to minimize errors and assumptions inherent in each respective model by capturing commonalities across all three
How do the different model projections compare?

- Discrete choice model yields the lowest adoption, this is sensible as the models reflect current consumer preferences.
- Shape of diffusion curve due to addition of demand due to exceeding vehicle lifetime.
- Different models vary in estimation across the same inputs by an order of 2 (from 60 million vehicles in 2040 up to 120 million vehicles).
Discrete choice model

- We simulate consumers’ decision making process about selecting a product among a set of discrete choices.
- An individual is more “attractive” based on its comparative value compared to other vehicles.
- Vehicle attributes inform “attractiveness”.

Vehicle Classes:
- Economy
- Compact
- Midsize
- Full Size
- Midsize SUV
- Minivan
- Cargo Van
- 12 Passenger Van

Vehicle Brands:
- GMC
- Mercedes-Benz
- Porsche
- INFINITI
- SUZUKI
- SUBARU
- Ford
- FIAT
- MITSUBISHI
- HYUNDAI
- TOYOTA

Vehicle Sales

Attributes:
- Engine Size, Power
- Fuel Efficiency
Basics of discrete choice modeling

- In discrete choice models, we attempt to simulate consumers’ decision making process about selecting a product among a set of discrete choices.
  1. A consumer chooses based on attributes of the product in comparison to other products (e.g. higher price all else equal is worse, higher efficiency is better)
  2. With a large enough sample of consumers and a diverse enough set of products, we are able to measure the “desirability” of each of the attributes
  3. Once the importance of each attribute is determined, we can freely introduce products with different levels of attributes to determine how the market will respond (assuming preferences don’t change and that the “desirability” was modeled correctly)
Structure of our choice model

• The utility for choices in our model is defined as:

\[ u_i = \beta_1 \text{price}_i + \beta_2 \text{em.rate}_i + \beta_3 \text{manufacturer}_i + \beta_4 \text{fuel.type}_i + \beta_5 \text{segment}_i + \varepsilon_i \]

• We run our model independently for each of the 39 countries, each of which has approximately several hundred models available each year in the market.

• While our regression is trained on a vehicle model level, our confidence on such small market shares is relatively small and therefore we choose to aggregate to less granular levels.

• Prices are standardized to euros for uniform comparison purposes, likewise the emission rates are based on the New European Driving Cycle (NEDC).
Cross-country comparison of price coefficients
Cross-country comparison of fuel economy (CO$_2$ emission) coefficients
Cross-country comparison of fuels (relative to gasoline)
Assumptions for forecasting

- We examine three basic scenarios for forecasting, each scenario assumes different prices and model availabilities for electric vehicles.
  - Price reductions are exogenous, their mechanisms are not explicitly stated but include learning-by-doing, competition, and policy incentives.
  - Model availability refers to the coverage of EVs in the market of vehicle models.
  - Range of EVs are increased over time to allay issues of range anxiety
Segment breakdown of electric vehicles

UC DAVIS
SUSTAINABLE TRANSPORTATION ENERGY PATHWAYS
Medium market (100,000-200,000) scenario predictions
Tiny market (<50,000) scenario predictions
• Vehicle sales continue to grow annually (left) but at drastically different rates depending on the scenario. By 2040, sales range between 1.2 million to 9 million annually across 38 countries.

• The cumulative stock of EVs (right) also follows significantly different levels. By the end of the modeling period of 2040, adoption reaches just under 100 million EVs in 2040 (high scenario) down to around 20 million in 2040 (low scenario).
Discussion

• Despite consistency in model inputs, there are significant differences in outputs. The choice of model matters!
• 100 million vehicles by 2040 is an optimistic projection for choice and regression models but is achieved in the diffusion model.
• International factors are vital to consider and lead to stark differences in adoption potential across all three models.
Ongoing work

• Further calibration of models is needed:
  – Data cleaning
  – Investigating combinations of different variables
• Incorporating more variables and scenarios (e.g. charging infrastructure)
• Focusing on policy impacts and integrating existing policies
• Investigate uncertainty in each modeling scenario
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Peter Mock
ICCT
The problem
More than half of new cars in Europe have a diesel engine, unlike in most other major vehicle markets.
Emission limits for gasoline (G) and diesel (D) cars in the EU and US have converged in recent years.

Source: transportpolicy.net
In reality, nitrogen oxides emissions from diesel cars in Europe have not decreased as expected.

Source: http://eupocketbook.theicct.org
In fact, a modern heavy-duty truck emits less nitrogen oxides emissions than a small diesel car.

Source: http://eupocketbook.theicct.org
In Europe, more than 11,000 people die early because of excess diesel NO\textsubscript{x} emissions, every year.

Source: Deutsche Welle
The reason
A comparison of laboratory vs. on-road test results for 3 diesel cars in the US triggered “Dieselgate”

Source: http://www.theicct.org/use-emissions-testing-light-duty-diesel-vehicles-us

Source for photos: AVL / ERMES
Vehicles shown on photos are not related to test results shown
Government testing has confirmed earlier findings and points to numerous other defeat devices.

Source: http://theicct.org/blogs/staff/first-look-results-german-transport-ministries-post-vw-vehicle-testing
Using on-road vehicle testing (PEMS), it is possible to determine the worst offenders.

180 mg/km, for cars sold 2009-14 (Euro 5) | 80 mg/km, for cars sold 2014-current (Euro 6)

- Renault-Nissan
- Fiat Chrysler (incl. Alfa Romeo & Jeep)
- General Motors (Opel-Vauxhall)
- Hyundai
- Suzuki
- Ford
- Kia
- Volvo
- Daimler (Mercedes-Benz, Smart)
- PSA (Peugeot-Citroën)
- Honda
- Mazda
- Tata (Land Rover)
- Toyota
- Volkswagen
- BMW

Source: International Council on Clean Transportation

A popular type of defeat device is recognizing cold start conditions as type approval testing.
Nearly all manufacturers in the EU make use of the “thermo-window” defeat device.

Figure 9: Average NOx emissions of a Euro 5 diesel vehicle over the NEDC at various initial engine temperatures (Data source: Kühlwein, 2012)

The future
Remote sensing allows measuring the real-world emissions of thousands of vehicles – remotely!

Source: Kanton Zürich, Amt für Abfall, Wasser, Energie und Luft
Remote sensing indicated large-scale problems with recent diesel cars, long before Dieselgate.
TRUE will help to inform city administrations and citizens about real-world emissions of vehicles.

Paris and London mayors announce scheme to gauge car emissions

London Mayor Sadiq Khan (L) and Paris Mayor Anne Hidalgo attend a meeting on air pollution in Paris, France, March 29, 2017. REUTERS/Gonzalo Fuentes
The threat
Diesel cars are under more and more economic pressure, with electric vehicles becoming cheaper.

Without a trustworthy emissions testing and enforcement scheme, Diesel car sales will implode.
For more detail, please visit our ICCT website

The future of vehicle emissions testing and compliance

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Wei-Shiuen Ng
ITF
Low Carbon Global Road Freight

Wei-Shiuen Ng
GFEI Side Event, ITF Summit 2017
June 1, 2017
Global Freight Demand and CO₂ Emissions will Continue to Grow

Source: ITF Transport Outlook 2017
Surface freight tonne-kilometres by region
Baseline scenario, billion tonne-kilometres

Source: ITF Transport Outlook 2017
## New Study on Low Carbon Road Freight Scenarios

<table>
<thead>
<tr>
<th>Fuel Efficiency Scenarios (Emissions per vkm)</th>
<th>Vehicle Optimization Scenarios (Total vkm)</th>
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</thead>
<tbody>
<tr>
<td><strong>Scenario 1:</strong> Rapid expansion of existing fuel efficiency standards to five new markets (South Korea, Mexico, Brazil, India, and the EU)</td>
<td><strong>Scenario 3:</strong> Non-technological measures will be implemented, • vehicle optimization measures, changes in average load factor and number of empty runs • operational measures • modifications to regulations on the weight and dimensions of vehicles • asset sharing • route optimisation</td>
</tr>
<tr>
<td><strong>Scenario 2:</strong> Existing fuel efficiency standards in Canada, China, Japan, and the US will be improved at a regular interval till 2030 and 2050</td>
<td><strong>Scenario 4:</strong> Combines improvements in and expansion of fuel efficiency standards together with non-technological measures to capture the cumulative impact of these different policies on the reduction of global road freight CO₂ emissions</td>
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