Economic and Environmental Impacts of Long-Term Scenarios of Low Emissions Mobility in Spain

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Content

• Motivation

• Model

• Case study and results

• Conclusion and future work
Motivation: EVs are needed

• ICE based road transport
  • Global: responsible for almost 25%*75% of CO₂ emissions
  • Local: responsible for air pollution (NOₓ & PMₓ) and noise

• Transition towards sustainable transportation
  • International regulation of emissions reduction: Paris Agreement, Directive (EU) 2019/1161
  • Although Technology neutral ➔ EV is a main tool towards sustainability
  • Countries and carmakers set mid and long term targets
  • But decision making is
    • On the consumer
    • On the municipalities
    • Requires detailed long term analysis including demand dynamics
Motivation: existing models

• Long term models to evaluate transport traction technology transition
  • **Energy based:**
    • Markal-TIMEs (opt. model, min cost)
    • MASTER.SO (opt. model, max welfare)
  • **Travel modelling & land use:**
    • AsTra
    • MARS

[Images: Cost and emissions balance, AsTra, MARS]
Model: introduction

• **Focus and improvements**
  
  • Focus on fleet-aging dynamics
  
  • Detailed historical data of existing fleet
  
  • Aging of fleet impact on characteristics and use
  
  • Flexible modelling to incorporate inputs from demand side and transport policies
  
  • Scalability and replicability
  
  • Open source model at [evobservatory.iit.comillas.edu](http://evobservatory.iit.comillas.edu)
Model: structure

Data Base
- Historic vehicle fleet
- Efficiency
- Emmissions
- Evolution hypothesis

Modeling algorithm of the vehicle fleet evolution

Primary results:
- Fleet evolution (by technology)

Secondary results:
- Energy consumption and efficiency

Parameters to modify scenarios
- % registrations in 2051
- Evolution parameters
Model: structure

**Economical and Legislative/Regulatory field:**
- Micro-economic studies
- Macro-economic studies
  - Taxation

**Social field:**
- Behavior analysis
- Modal shift?
- Urban development

**Tech-Energy field:**
- Energy demand
- Distribution grid
- Energy dependence
- Charging infrastructure

- Bicycles
- Passenger cars
- Car-sharing
- Public transport
- Freight delivery
- Railway

**WTW**

**WTT**

**TTW**
Model: mathematic formulation

- **HISTORICAL DATA BASE:**
  - Vehicle fleet
  - Consumption
  - Emissions

- **PARAMETERS DATA BASE:**
  - Hypothesis
  - Scenarios

| **MILEAGE** |
| **OBJECTIVE** |
| Kind of route |

| **FLEET EVOLUTION** |
| Traction technology |
| Age |
| Kind of route |

| **ENERGY** |
| **CONSUMPTION** |
| Traction technology |
| Age |
| Kind of route |

| **EMISSIONS** |
| Traction technology |
| Age |
| Kind of route |

**TTW Model**
Model: formulation

- Fleet evolution since 1990
  - Different types of traction technologies
- Energy consumption and emissions
  - Trends
- Use of car
  - Considering urban and road

### Vehicle fleet Consumption Emissions

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Fuel consumption [l/100km]</th>
<th>CO₂ emissions [g/km]</th>
<th>NOₓ emissions [mg/km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>5.93</td>
<td>155.93</td>
<td>341.41</td>
</tr>
<tr>
<td>Petrol</td>
<td>7.31</td>
<td>165.16</td>
<td>67.35</td>
</tr>
<tr>
<td>HEV</td>
<td>5.96</td>
<td>135.60</td>
<td>6.55</td>
</tr>
<tr>
<td>LPG</td>
<td>8.81</td>
<td>156.90</td>
<td>72.01</td>
</tr>
<tr>
<td>BEV</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>PHEV</td>
<td>2.09</td>
<td>48.14</td>
<td>41.44</td>
</tr>
<tr>
<td>CNG</td>
<td>5.00</td>
<td>130.10</td>
<td>52.51</td>
</tr>
</tbody>
</table>

### Power generation Scenario

<table>
<thead>
<tr>
<th>RES (%)</th>
<th>2020</th>
<th>2030</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>44</td>
<td>68</td>
<td>79</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average CO₂ emissions (tCO₂/MWh)</th>
<th>2020</th>
<th>2030</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.154</td>
<td>0.059</td>
<td>0.035</td>
<td></td>
</tr>
</tbody>
</table>
Model: formulation

- Annual driven distance depends on the age of the vehicle:
  \[ Mileage(m, r, a, t) = Mileage_{ref}(m, r, t) \cdot \beta_{dis}(m, r, t - a) \]

- Objective function to fit the objective driving distance for every year:
  \[ \min \left\{ \sum_{t, r} \left( \sum_{m} Mileage_{TOT}(m, r, t) - Mileage_{OBJ}(r, t) \right)^2 \right\} \]

- The number of new cars in the year \( a \), \( \tau_{rep}(a) \) is the result of the optimization algorithm
Model: formulation

- Fleet classified depending on registration year, $a$, and motorization, $m$:
  \[ Fleet_{TOT}(m, t) = \sum_{t} Fleet(m, a, t) \]

- Probability of being decommissioned, $i_{dec}$, depending on age and motorization:
  \[ Fleet(m, a, t) = Fleet(m, a, t - 1) \cdot i_{dec}(m, t - a, t) \]

- New cars technology depending on technology maturity:
  \[ Fleet_{new}(m, a) = Fleet_{new}(a) \cdot \alpha_{sales}(m, a) \]
  \[ Fleet_{new}(a) = \sum_{m} Fleet(m, a - 1) \cdot \tau_{rep}(a) \]

<table>
<thead>
<tr>
<th>FLEET EVOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traction tecnology</td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td>Kind of route</td>
</tr>
</tbody>
</table>

| Previous year fleet | Survival fleet | New cars |

BEV sales share

<table>
<thead>
<tr>
<th>Year</th>
<th>Previous year fleet</th>
<th>Survival fleet</th>
<th>New cars</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2025</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2032</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2039</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2046</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Model: formulation

- Energy consumption is a function of ran distance, type of driving (road, urban), motorization and age of the vehicles.

- Engine efficiency depends on age, type of route and fuel.

- Emissions are a function of consumed energy:

  - Emissions rate depends on age, type of route, fuel and pollutant.

RESULTS can be obtained per:

- Motor technology
- Year
- Fleet age
- Fuel
- Pollutant (CO₂, NOₓ, particulates)
Model: formulation

\[ [Energy_{pri}^{TTW}(z, m, t, p)] = [Matrix_{fin}^{pri}(z, m, t, p, f)] \cdot [Energy_{fin}^{TTW}(m, t, f)] \]

WTW Model
Model: formulation

- Emissions and energy consumption in raw material transformation processes are computed.
- There are matrix relationships between the primary and final energies
  - **Primary energy**: COAL, OIL, NATURAL GAS, NUCLEAR, RENEWABLES.
  - **Final energy**: Gasoline, fuel oil, compressed natural gas, electricity, biofuel.
- Total **energy consumption**: addition of consumption in transformation processes plus TTW.
- There are considered two sources of emissions:
  - Those due to extraction and shipping of raw material
  - Those due to transformation processes (power generation and refining)

**RESULTS** can be obtained per:
- Motor technology
- Year
- Fleet age
- Fuel
- Pollutant (CO$_2$, NO$_x$, particulates)
- Area (domestic, imports)
Case study

- **Objectives:**
  - Scalability
  - Replicability
  - Long term dynamic performance

- **Framework:**
  - **European Green Deal** Targets:
    - 55% emissions reduction from 1990 to 2030
    - transition towards zero emission transportation
  - Spain’s **PNIEC**:
    - 74% of RES in electricity generation for 2030
    - 5 million EV in 2030 (3 million cars)

- **Main hypothesis:**
  - Single intermediate scenario
  - Sales EV:
    - 40% in 2030
    - 80% in 2050
  - 70% of RES in electricity generation for 2030
  - Steady demand on road and urban routes
Case study results: passenger fleet

- changes in the fleet will need almost 15 years to be representative
- a full transformation of the passenger car fleet will require more than 30 years
- sales of vehicles between 1.3 and 1.5 million per year
- depending on purchasing power and needs of consumers in Spain
Case study results: energy consumption
Case study results: energy consumption
Case study results: Emissions

**CO2 emissions from passenger cars in Spain**

- Petrol
- Diesel
- LNG
- CNG
- BEV
- PHEV
- HEV

**NOx emissions from passenger cars in urban areas in Spain**

- Petrol
- Diesel
- LNG
- CNG
- BEV
- PHEV
- HEV
Conclusions and future work

- **Proposed model:**
  - Allows to study **long term** economic and environmental **effects**.
  - **Power generation** is considered.
  - **Updated** technical **data**
    - fleet and technological trends
    - obtained from other studies or specialized models

- **Impact and effects of the electric vehicle:**
  - Transition to a sustainable transport **takes time**
  - EV **reduces dependence** on energy imports.
  - **Environmental benefits**.
  - Help to achieve strategic **European** and Spanish **targets**

- **Future studies and developments:**
  - **Integration of other transport alternatives:**
    - Heavy trucks and busses, light commercial vehicles, motorbikes, flights, maritime and railway
  - **Coordination with other models** (economic, social)
Thank you very much!