Strategies for Introducing Alternative Fuel Vehicles in India

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Outline

• Introduction to Automotive Sector in India
• High level description of Alternative Fuel Vehicle (AFV) Introduction Model
• AFV Management Flight Simulator demo
• Model deep dive
  ▪ Modeling consumer choice
  ▪ Modeling market expansion
  ▪ Modeling Infrastructure Co evolution
• Results & Conclusions
Why Introduce Alternative Fuel Vehicle in India?

Health: 620,000 premature deaths attributed to air pollution

Energy Security: 80% of crude oil is imported

Government of India launched National Electric Mobility Mission Plan in 2013

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Vehicular Penetration: Plenty of Head Room!

<table>
<thead>
<tr>
<th>Country</th>
<th>GNI per capita 2009 (US$)</th>
<th>Per 1000 person</th>
<th>Total Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.A</td>
<td>46,360</td>
<td>439</td>
<td>828</td>
</tr>
<tr>
<td>U.K</td>
<td>41,370</td>
<td>460</td>
<td>544</td>
</tr>
<tr>
<td>Japan</td>
<td>38,080</td>
<td>617</td>
<td>617</td>
</tr>
<tr>
<td>Brazil</td>
<td>8,070</td>
<td>165</td>
<td>275</td>
</tr>
<tr>
<td>China</td>
<td>3,650</td>
<td>34</td>
<td>119</td>
</tr>
<tr>
<td>India</td>
<td>1,220</td>
<td>13</td>
<td>117</td>
</tr>
</tbody>
</table>

Sources: 1. World Road Statistics, 2011, International Road Federation, Geneva. 2. Calculated on the basis of data received from Offices of State Transport Commissioners/UT Admins.

Total Number of Registered Cars and GDP Per Capita PPP (Ministry of Road Transport and Highways, 2009-2010 & 2010-2011)

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AFV Management Flight Simulator Demo
Modeling Market Expansion

S- Shaped Logistic Function

Sensitivity Analysis of Historical and Simulated Growth in Total Installed base of Vehicles from 2000-2010 Source: (Ministry of Road Transport and Highways, 2009-2010 & 2010-2011)

\[ V_t^* \text{ is the total desired Installed base in year } t \]

\[ V_t^* = \frac{\gamma \times V_{init} \times e^{(\alpha \frac{GDP}{TCO} - \beta)}}{\gamma + V_{init} \times e^{(\alpha \frac{GDP}{TCO} - \beta)}} \]
$U_j = \frac{Purchase\ Price_j}{\ln(GDP\ Per\ Capita)} + C_2 \times Operating\ Cost_j + C_3 \times Acceleration_j + C_4 \times Top\ Speed_j +$

$C_5 \times Emissions_j + C_6 \times Scope_j + C_7 \times Refueling\ Cost_j$
Consumer Choice Model: Nested Multinomial Logit Functions

Affinity of Platform i to Platform j

\[ A_{ij} = U_{ij} \times F_{ij} \quad \forall i, j \in \{GAS, DES, HEV, BIO, CNG, H2, BEV, PHEV\} \]

Nested Multinomial Logit Function

\[ \text{Share}_{ij} = \frac{e^{A_{ij}}}{e^{\lambda \times ln ICE} + e^{\lambda \times ln PLUG} + e^{A_{i,CNG}} + e^{A_{i,BIO}} + e^{A_{i,H2}} + e^{A_{i,HEV}}} \]

Modeling Takeaway: Use Nested Multinomial Logit if you want to model any form of consumer choice
Refueling Station Coevolution

Modeling Takeaway: Remember to consider the Work In Progress (WIP)
Refueling Station Co-evolution

Mapping of Power Train Technologies to Fuel Type and Station Type
Infrastructure Co - Evolution – Detailed Causal Loop Structure
Scenario Analysis: Base Case

Non Electric AFV Sales (vehicles)

Annual Vehicle Sales HEV vs PHEV (vehicles)

ICE Vehicle Sales (vehicles)
Scenario Analysis : NEMMP 2020

<table>
<thead>
<tr>
<th></th>
<th>Incentive per Vehicle ($/Vehicle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEV</td>
<td>$1000</td>
</tr>
<tr>
<td>PHEV</td>
<td>$1500</td>
</tr>
<tr>
<td>BEV</td>
<td>$3000</td>
</tr>
</tbody>
</table>

xEV Vehicle Sales (vehicles)

Available Refueling Pumps (pump)
Limitations and Future Directions

All Models are Wrong!

- Assumption of homogenous customer
- Assumption about even spatial distribution of Fueling stations
- No constraint on fuel supply upstream of fueling station
- Fuel price is exogenously provided – dynamics of fuel price on fuel demand might provide better insights
Conclusion

• AFV introduction takes a long time to bear fruit!

• Strategies for introduction must be carefully studied before investing huge amounts

• PHEV is the Alternative fuel platform with greatest promise for India
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system design and management

Thank You