Fuel Consumption and Technological Progress in Chinese Automobile Sector

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Outline

• Background

• China’s Automobile Market and Fuel Consumption

• Technological Progress in Fuel Efficiency in China’s Automobile Sector

• Conclusion
Background
Does the blooming of China’s Car Consumption Result in Dramatic Fuel Consumptions
Dramatic Market Growing During Last Decades

Data Source: CAAM Statistical yearbook of China automobile industry
Increase of China’s Motor Gasoline Consumption

Data Source: EIA
Why the increase rate of motor fuel consumption is far slower than that of car sales?
Decompose the Fuel Consumption

Fuel Consumption = \sum VMT_i \times Fuel Efficiency \times Sales of Model i

- Progress of Available Technology
- Travel behavior
- Consumer Preference
• More than 3000 car models from 2005 to 2011

• Technological attributes: e.g. fuel use per 100 km (inverse of fuel economy), horsepower, curb weight

• Technology sources
Data Availability

- Vehicle Mileage Travel
- Fuel Efficiency of Cars in China’s Market
- Car Consumers’ Preference
China’s Automobile Market: Trend of Available Technologies and Consumers’ Preference
Trend of Available Technology in the Market: Bigger Cars with Larger Power

Average Horsepower (kW)  Average Curb Weight (kg)

Data Source: MIIT Fuel Consumption Report of Light Vehicle
Trend of Available Technology in the Market
Fuel Efficiency and Displacement

Average Fuel Use (Liter/100Km)  Displacement (Liter)

Data Source: MIIT Fuel Consumption Report of Light Vehicle
Consumers’ Preference:
Sales Weighted Average of Technologies

Average Weight (kg)

Average Power (kW)

Average Fuel Use (L/100Km)

Average Displacement (mL)
Consumers’ Preference: Fuel Efficiency

**2005**

- <6: 350,000
- [6,7]: 400,000
- [7,8]: 350,000
- [8,9]: 200,000
- [9,10]: 150,000
- >10: 100,000

**2007**

- <6: 150,000
- [6,7]: 200,000
- [7,8]: 300,000
- [8,9]: 250,000
- [9,10]: 200,000
- >10: 150,000

**2009**

- <6: 50,000
- [6,7]: 70,000
- [7,8]: 250,000
- [8,9]: 150,000
- [9,10]: 100,000
- >10: 50,000

**2011**

- <6: 70,000
- [6,7]: 100,000
- [7,8]: 150,000
- [8,9]: 100,000
- [9,10]: 50,000
- >10: 20,000
Data Availability

• Vehicle Mileage Travel

• Fuel Efficiency of Cars in China’s Market

• Car Consumers’ Preference
Technological Progress of China’s Automobile Sectors
Research Questions

• Did fuel efficiency of technologies in China’s market improve with the growth of the market?

• Did the fuel efficiency of each car model over the years depend on its technology source?

• Did the car models’ technological progress pattern differ by the policy pressures which they face to?
• Marginal cost for Car Model $i$ in Year $t$

$$c_{it} = C^1(fuel\ efficiency_{it}, X_{it}) + C^2(\Lambda_{it})$$

• Assume the direct investment on technologies related with energy efficiency for Car Model $i$ in Year $t$ is constant

• The company determines the fuel efficiency level and levels of other technology attributes by maximizing expected profit from this model. The selected levels of attributes must be available

$$\max_{\{fuel\ efficiency_{it}, X_{it}, \Lambda_{it}\} \in \Sigma_{it}} E[Profit(\Theta_{it}, c_{it}) | C^1 = \sigma]$$
Did Fuel Efficiency Tech Improve?

- The company will optimize above problem by trading-off among all technology attributes.
- The optimal fuel efficiency level comes from technology improvement and balancing with other related attributes

\[
fuel\ efficiency = T_t f(X|C^1 = \sigma)
\]

- Fixed Effects Panel Regression Model

\[
fuel\ efficiency = \beta_1 Year_t + (\ln X) \Gamma + \epsilon_{it}
\]

- Controlling all the related attributes, the coefficient of year dummy \(\beta_1\) is defined as the fuel efficiency technological change of Year \(t\) to Year 2005
Technological Progress in China’s Automobile Sector

Technological Progress in Fuel Efficiency Controlling on other Technological Attributes
<table>
<thead>
<tr>
<th>Dependent variable:</th>
<th>log(Average.Fuel.Consumption)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>log(Placement)</td>
<td>0.308*** (0.017)</td>
</tr>
<tr>
<td>log(Curb.Weight)</td>
<td>0.502*** (0.017)</td>
</tr>
<tr>
<td>log(Power)</td>
<td>-0.123*** (0.012)</td>
</tr>
<tr>
<td>mt</td>
<td>-0.033*** (0.004)</td>
</tr>
<tr>
<td>cvt</td>
<td>-0.061*** (0.009)</td>
</tr>
<tr>
<td>dct</td>
<td>-0.052*** (0.009)</td>
</tr>
<tr>
<td>alterf</td>
<td>-0.081*** (0.007)</td>
</tr>
<tr>
<td>hybrid</td>
<td>-0.362*** (0.024)</td>
</tr>
<tr>
<td>drive</td>
<td>0.009 (0.010)</td>
</tr>
<tr>
<td></td>
<td>(2)</td>
</tr>
<tr>
<td>log(Placement)</td>
<td>0.317*** (0.017)</td>
</tr>
<tr>
<td>log(Curb.Weight)</td>
<td>0.448*** (0.019)</td>
</tr>
<tr>
<td>log(Power)</td>
<td>-0.081*** (0.012)</td>
</tr>
<tr>
<td>mt</td>
<td>-0.046*** (0.004)</td>
</tr>
<tr>
<td>cvt</td>
<td>-0.064*** (0.009)</td>
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<tr>
<td>dct</td>
<td>-0.047*** (0.009)</td>
</tr>
<tr>
<td>alterf</td>
<td>-0.075*** (0.007)</td>
</tr>
<tr>
<td>hybrid</td>
<td>-0.357*** (0.024)</td>
</tr>
<tr>
<td>drive</td>
<td>0.011 (0.010)</td>
</tr>
</tbody>
</table>
China’s Automobile Market: Factors Impact the Trend of Technologies and Consumers’ Preference
Model China’s Car Market

\[
\max_{\{\text{fuel efficiency}_{it}, X_{it}, \Lambda_{it}\} \in \Sigma_{it}} E[\text{Profit}(\Theta_{it}, c_{it}) | C^1 = \sigma]
\]

- Which particular Characteristics of China’s market can affect \(\Theta_{it}\) and the shape of \(C_{it}\)?
Technological Progresses of Different Technological Sources
China’s Car Market Are Dominated by Foreign Technologies

**Data Source:** CAAM Statistical yearbook of China automobile industry
We define technology source as the original country where the model is designed.
• The technology source of Corolla is Japan

These foreign technologies manufactured in China can easily switch their current model to a new technology versus domestic technologies are slower.

Technologies from different foreign sources have different combination of technological attributes.
Research Questions

• Did fuel efficiency of technologies in China’s market improve with the growth of the market?

• Did the fuel efficiency of each car model over the years depend on its technology source?

• Did the car models’ technological progress pattern differ by the policy pressures which they face to?
Impacts of Technology Sources

\[
\max_{\{\text{fuel efficiency}_{it}, X_{it}, \Lambda_{it}\} \in \Sigma_{it}} E[\text{Profit}(\Theta_{it}(\text{Technology Source}), c_{it}(\text{Technology Source})) | C^1 = \sigma]
\]

- Every year, the optimal strategy of trading off among related technologies vary across technology sources.
- The optimal fuel efficiency level and its improvement in each year is a function of technology sources.

\[
\text{fuel efficiency} = \beta_1 T_i + \beta_2 \text{Technology Source} + \beta_3 T_i \times \text{Technology Source} + (\ln X) \Gamma + \varepsilon_{it}
\]
Domestic Technology versus Foreign Technologies

Technological Progresses by Different Sources

- China
- France
- Germany
- Japan
- Korea
- US
Technological Progress of Car Models Under Different Policy Pressures
China’s Fuel Efficiency Standard

- Announced in 2004
- Phase I is implemented in 2005 and 2006
- Phase II is implemented in 2008 and 2009 (Wagner et al. 2009)

Fig. 7. Chinese passenger car fuel consumption limits.

Figure from Wagner et al. 2009
• Three types of models:
  • nearly 50% models had already satisfied the Phase II standard in 2005 (group A);
  • Some satisfied the standard in 2006 (group B)
  • Some satisfied the standard in 2007 (group C)

• The classification can be represent by vector:

$$\Phi = (\phi_{2005}, \phi_{2006}, \phi_{2006})$$

$$\phi_t = \begin{cases} 
1, & \text{if model i satisfied Phase 2 standard in year } t \\
0, & x \geq 0
\end{cases}$$
Research Questions

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Who Meet the Standard First?

- Group A: meeting Phase II standard by 2005
- Group B: meeting Phase II standard by 2006
- Group C: meeting Phase II standard by 2007

Heaviest car meet the standard first

Progress of meeting standard include increase weight and decrease fuel consumption
Model the Constraints of China’s Fuel Economy Standards

\[
\max \{\text{fuel efficiency}_{it}, x_{it}, \Lambda_{it}\} \in \Sigma_{it} \quad E[\text{Profit}(\Theta_{it}, c_{it}) | C^1 = \sigma]
\]

Subject to: \(\text{fuel efficiency}_{i,2008} \in \Psi_{i,2008} \mid 1(\text{fuel efficiency}_{it} \in \Psi_{i,2008})\)

- The optimal fuel efficiency level and technology improvement is a function of:

  \[
  1(\text{fuel efficiency}_{it} \in \Psi_{i,2008})
  \]

- Which is a function of:

  \[
  \Phi = (\phi_{2005}, \phi_{2006}, \phi_{2006})
  \]

- Therefore, \(\Phi\) can affect the fuel efficiency and technology improvement in each year

  \[
  \text{fuel efficiency} = \beta_1 T_i + \beta_4 \Phi + (\beta_{\phi_{2005}} T_i, \beta_{\phi_{2006}} T_i, \beta_{\phi_{2007}} T_i) \times \Phi + (\ln X) \Gamma + \varepsilon_{it}
  \]
Technological Progresses of Two Model Groups

Technological Progress of Car Models Satisfying Phase II in Different Years

- Satisfied Phase II in 2005
- Satisfied Phase II in 2006
- Satisfied Phase II in 2007
Before 2007, average fuel efficiency in China was degrading; after 2007, we see improvement in fuel efficiency.

Chinese domestic technologies and foreign technologies differ in their fuel efficiency trends.

For the models that met the second phase standards in advance in 2005, their fuel economy improvement was slower than those that did not.
• Dr. Lee Schipper and Dr. Vance Wagner for pointing out the fuel efficiency data source
Thank You!

Questions?

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Back up slide: Fuel Price

Graph showing the fuel price over time, with lines indicating 'According to GDP Deflator back to 2000' and 'According to CPI back to 2005'.