Fuel Consumption and Technological Progress in Chinese Automobile Sector

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(Working with Yang Shu and Yueming Lucy Qiu)
• 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

China's Motor Gasoline Consumption

Data Source: EIA

Over 55% increase
• 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
• Consumer Preference
• Travel behavior
• 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 and Consumers’ Preference

Average Horsepower(kW)

Sales weighted average is less than average

Data Source: MIIT Fuel Consumption Report of Light Vehicle
Average Curb Weight (kg)
Trend of Available Technology in the Market
Fuel Efficiency and Displacement

Average Fuel Use (Liter/100Km)

Data Source: MIIT Fuel Consumption Report of Light Vehicle
Fluctuations of average displacement may caused by extreme consumers

Data Source: MIIT Fuel Consumption Report of Light Vehicle
• During these years
  • Fuel Price increased
  • Congestions become more and more serious
  • It is harder and harder to find a parking lot
  • More and more people can afford a car (later consumers may have lower income or willingness to pay than earlier consumers)

• Will consumers trend to buy
  • More fuel efficient cars?
  • Smaller cars?
Back up slide: Fuel Price

Graph showing fuel price with two lines:
- Blue line: According to GDP Deflator back to 2000
- Red line: According to CPI back to 2005

The graph tracks fuel price from 2004 to 2011.
• During these years
  • Fuel Price increased
  • Congestions become more and more serious
  • It is harder and harder to find a parking lot
  • More and more people can afford a car (later consumers may have lower income or willingness to pay than earlier consumers)

• Will consumers trend to buy
  • More fuel efficient cars?
  • Smaller cars?
Consumers’ Preference: Fuel Efficiency

**2005**

- <6: 100000
- [6,7]: 250000
- [7,8]: 300000
- [8,9]: 220000
- [9,10]: 150000
- >10: 40000

**2007**

- <6: 100000
- [6,7]: 200000
- [7,8]: 1400000
- [8,9]: 1000000
- [9,10]: 900000
- >10: 40000

**2009**

- <6: 20000
- [6,7]: 50000
- [7,8]: 300000
- [8,9]: 150000
- [9,10]: 100000
- >10: 30000

**2011**

- <6: 20000
- [6,7]: 40000
- [7,8]: 250000
- [8,9]: 150000
- [9,10]: 100000
- >10: 20000
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 $t$

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

• 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

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

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

- Fixed Effects Panel Regression Model

\[ fuel \text{ efficiency } = \beta_1 \text{Year}_t + (\ln X) \Gamma + \varepsilon_{it} \]

- 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

2005 2006 2007 2008 2009 2010 2011

-12% -10% -8% -6% -4% -2% 0% 2% 4%
<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
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<tr>
<td>log(Placement)</td>
<td>0.308***</td>
<td>0.317***</td>
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<tr>
<td></td>
<td>(0.017)</td>
<td>(0.017)</td>
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<tr>
<td>log(Curb.Weight)</td>
<td>0.502***</td>
<td>0.448***</td>
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<td></td>
<td>(0.017)</td>
<td>(0.019)</td>
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<tr>
<td>log(Power)</td>
<td>-0.123***</td>
<td>-0.081***</td>
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<tr>
<td></td>
<td>(0.012)</td>
<td>(0.012)</td>
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<td>cvt</td>
<td>-0.061***</td>
<td>-0.064***</td>
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<td>-0.052***</td>
<td>-0.047***</td>
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<td>alterf</td>
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<td>(0.007)</td>
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<tr>
<td>hybrid</td>
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<td>-0.357***</td>
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<td>(0.024)</td>
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<td>drive</td>
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<td>0.011</td>
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<td>(0.010)</td>
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Larger (larger power) cars improve slower

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<th>log(Curb.Weight):d2006</th>
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<td>(0.046)</td>
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<th>log(Curb.Weight):d2007</th>
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<td>(0.041)</td>
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<td>(0.038)</td>
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<th>log(Curb.Weight):d2011</th>
<th>0.115***</th>
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<td>(0.026)</td>
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<th>log(Power):d2007</th>
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<td>(0.023)</td>
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<tr>
<th>log(Power):d2008</th>
<th>0.041*</th>
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<td>(0.023)</td>
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<th>log(Power):d2009</th>
<th>0.047**</th>
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<tr>
<th>log(Power):d2010</th>
<th>0.066***</th>
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<tr>
<th>log(Power):d2011</th>
<th>0.070***</th>
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<tr>
<td></td>
<td>(0.023)</td>
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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
Foreign Technologies

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

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Japanese Car Model

Korean Car Model
Impacts of Technology Sources

\[
\max_{[\text{fuel efficiency}, X, \lambda] \in \Sigma} E[\text{Profit}(\Theta_{it}(\text{Technology Source}), c_{it}(\text{Technology Source}))] | C^1 = \sigma
\]

• 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

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
Observation

• Three types of models:
  • More than 40% 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:

\[
\Phi = (\phi_{2005}, \phi_{2006}, \phi_{2007})
\]

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

\[\text{Group Average Curb Weight}\]

\[\text{Group Average Fuel Consumption per 100Km}\]

- 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

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

Subject to: fuel efficiency \(i,2008 \in \Psi_{2008} | 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
Summery of Current Results

- 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.
Thank You!

Questions?

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