Fuel Consumption and Technological Progress in Chinese Automobile Sector

Yang Yu
Stanford University
(Working with Yang Shu and Yueming Lucy Qiu)

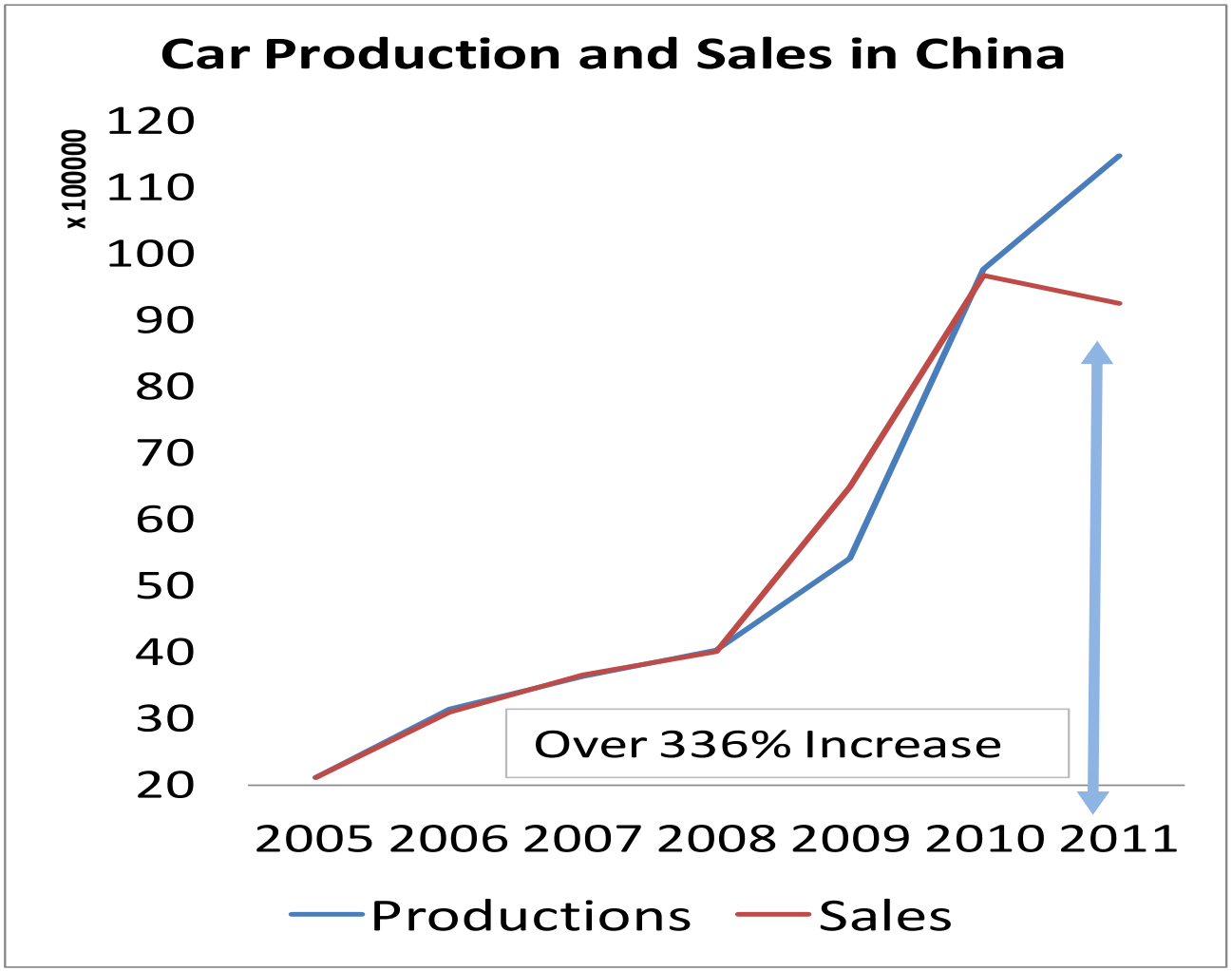
Outline

- Background
- China's Automobile Market and Fuel Consumption
- Technological Progress in Fuel Efficiency in China's Automobile Sector
- Conclusion

Background

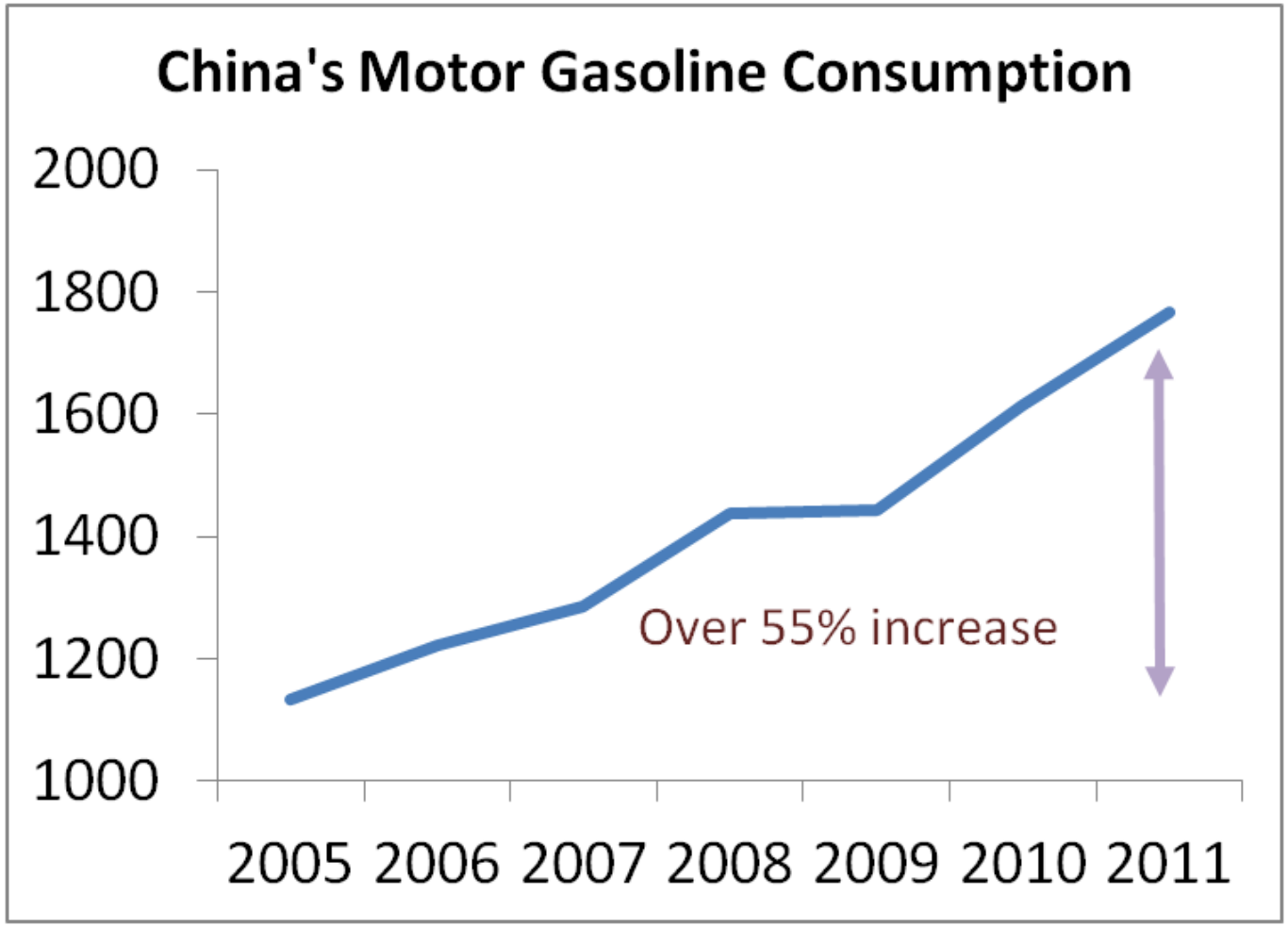
Does the blooming of China's Car Consumption Result in Dramatic Fuel Consumptions

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

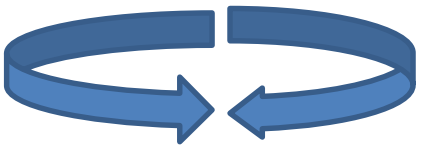
- **Why the increase rate of motor fuel consumption is far slower than that of car sales?**

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

Data

- 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

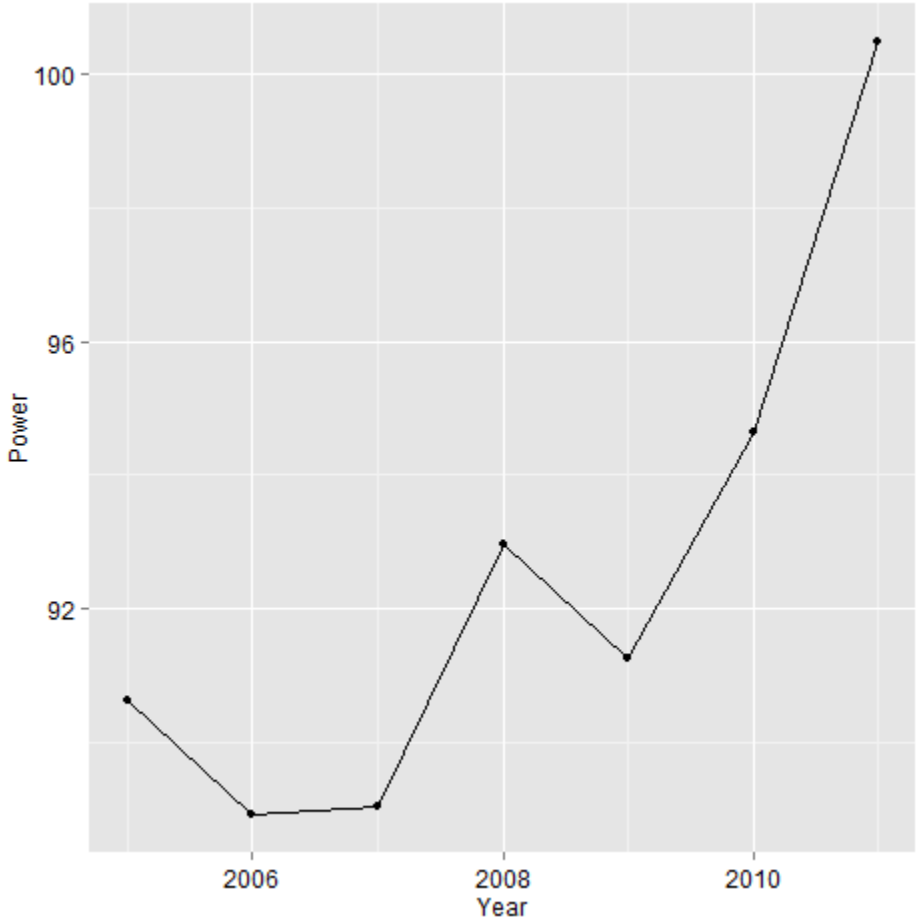
Data Availability

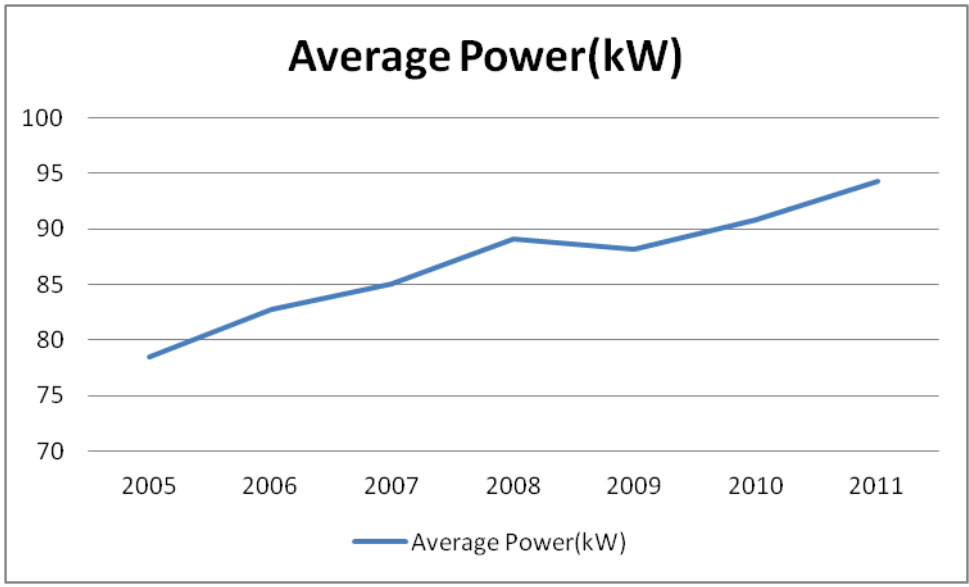
- Vehicle Mileage Travel
- Fuel Efficiency of Cars in China's Market
- Car Consumers' Preference

China's Automobile Market: Trend of Available Technologies and Consumers' Preference

Trend of Available Technology in the Market and Consumers' Preference

Average Horsepower(kW)

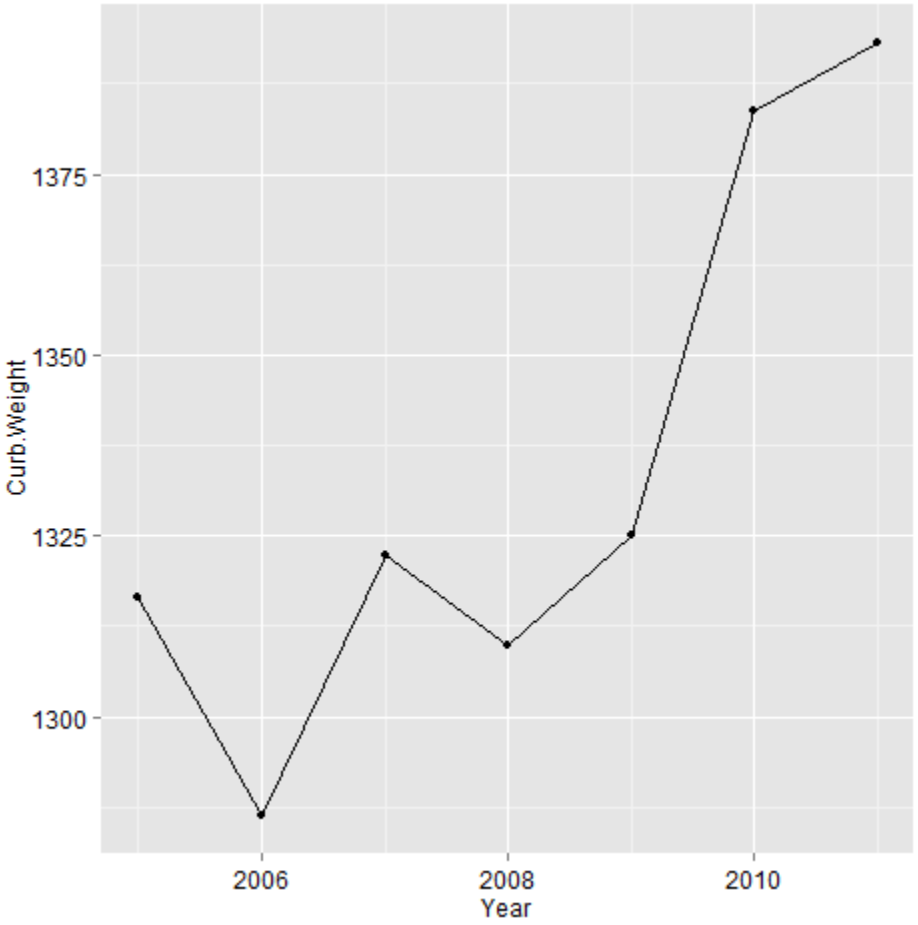


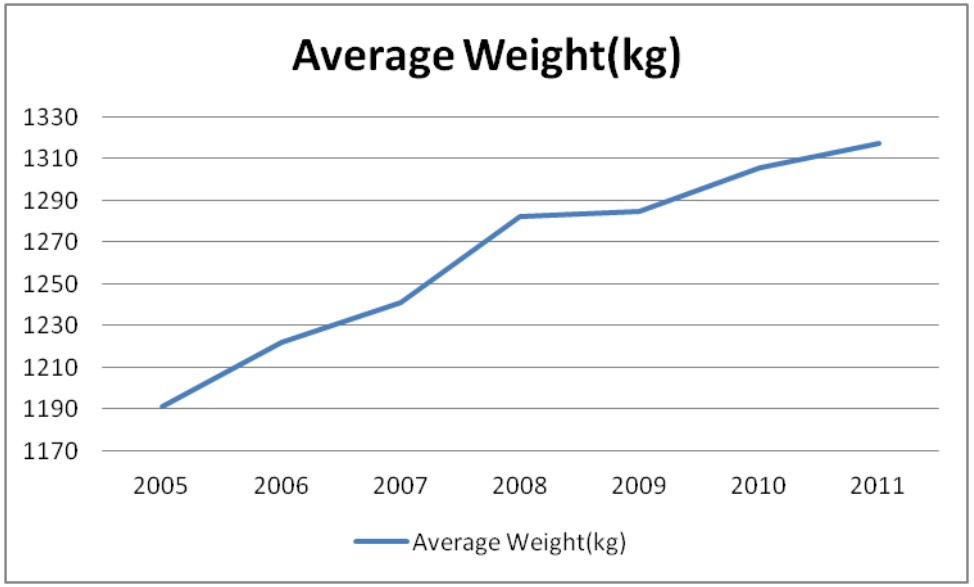


Sales weighted average is less than average

Data Source: MIIT Fuel Consumption Report of Light Vehicle

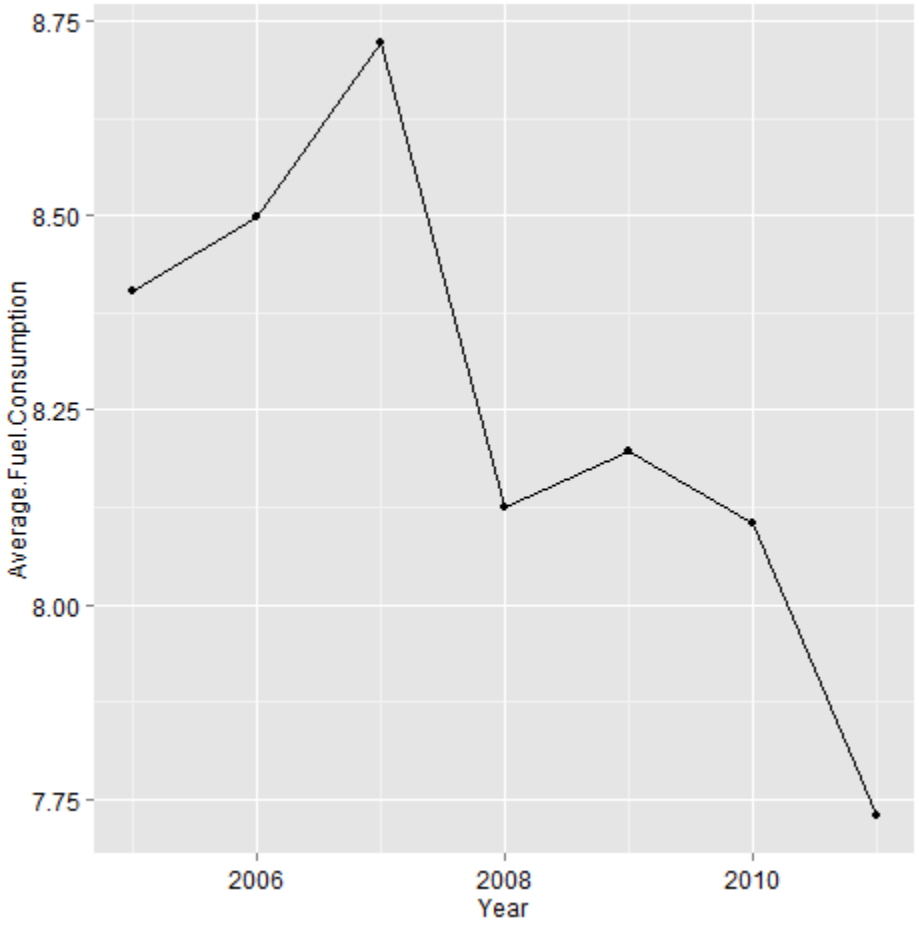
Average Curb Weight(kg)

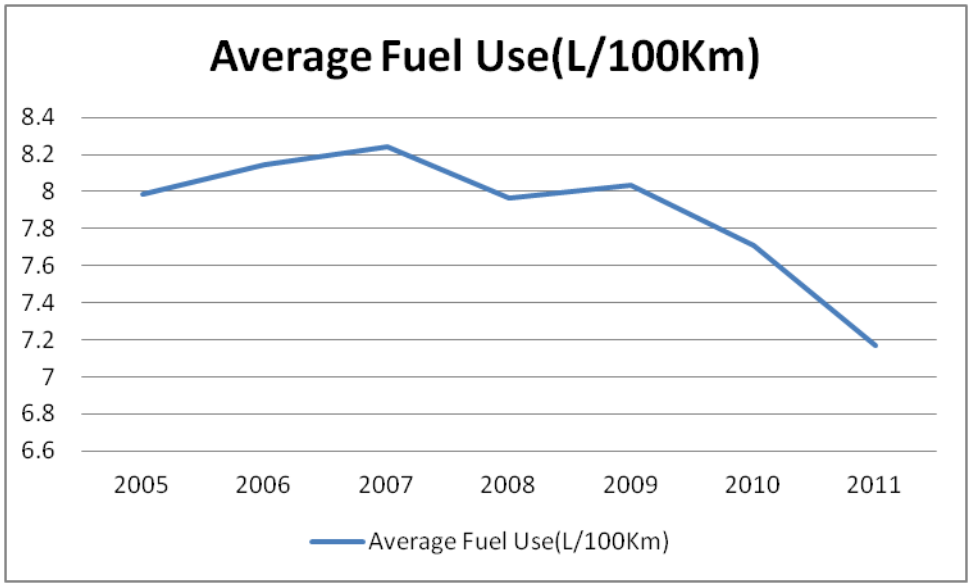




Trend of Available Technology in the Market
Fuel Efficiency and Displacement

Average Fuel Use (Liter/100Km)

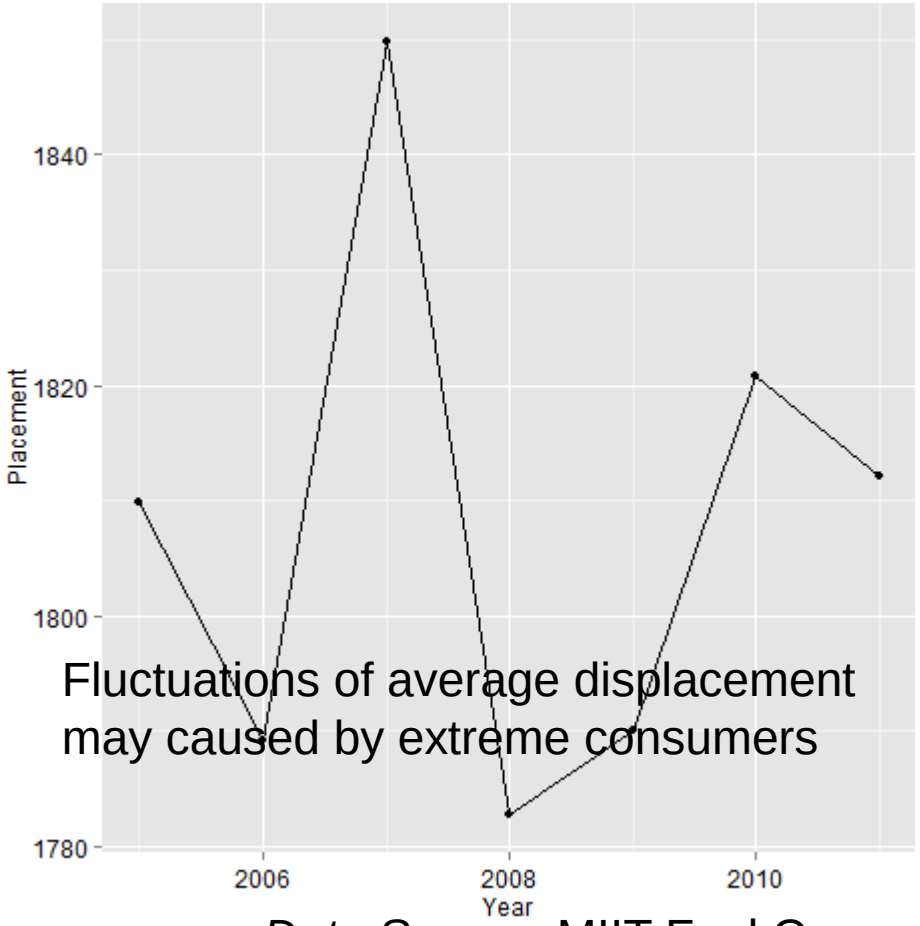


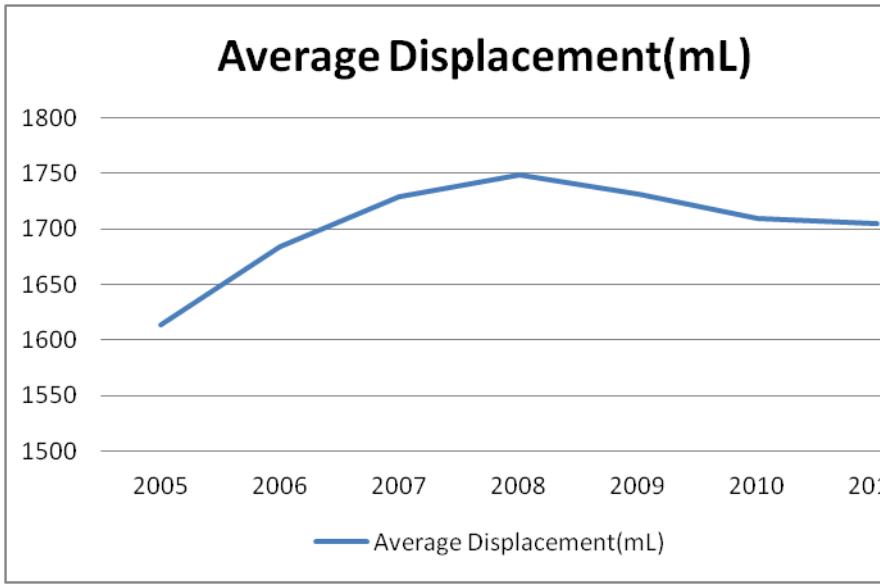


Data Source: MIIT Fuel Consumption Report of Light Vehicle

Trend of Available Technology in the Market
Fuel Efficiency and Displacement

Displacement(Liter)



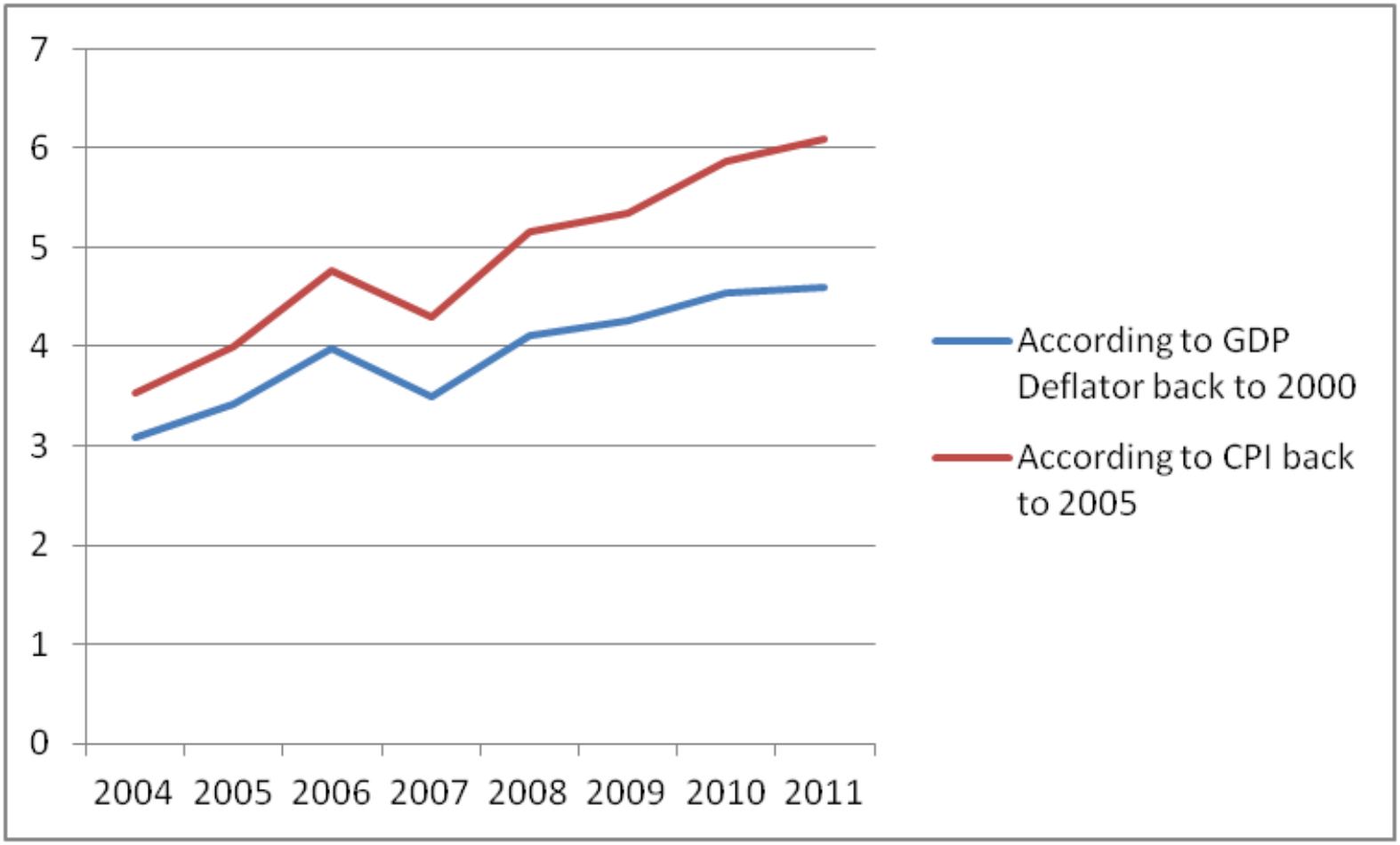


Fluctuations of average displacement may caused by extreme consumers

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



- During these years
  - Fuel Price increased
  - Congestions become more and more serious
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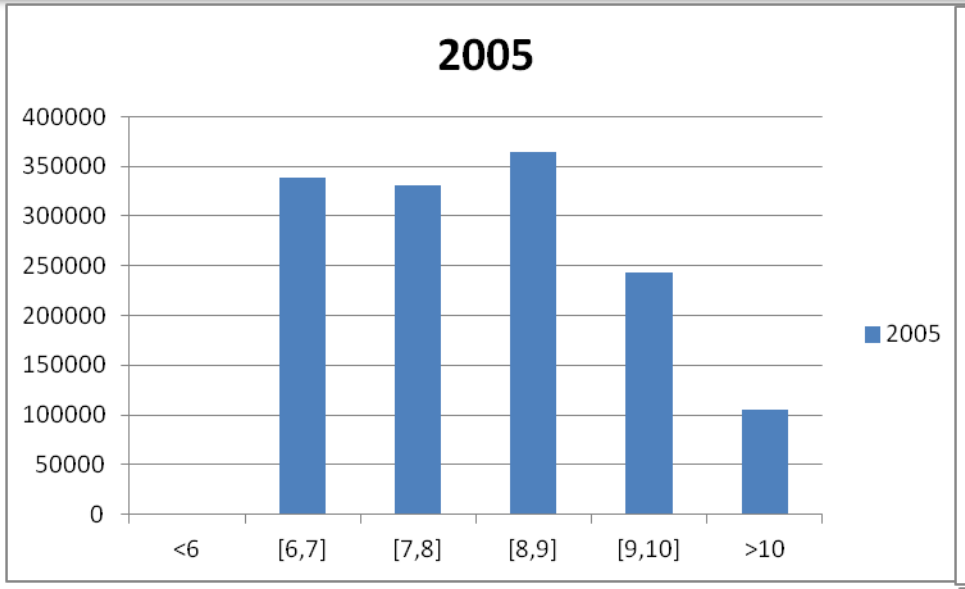
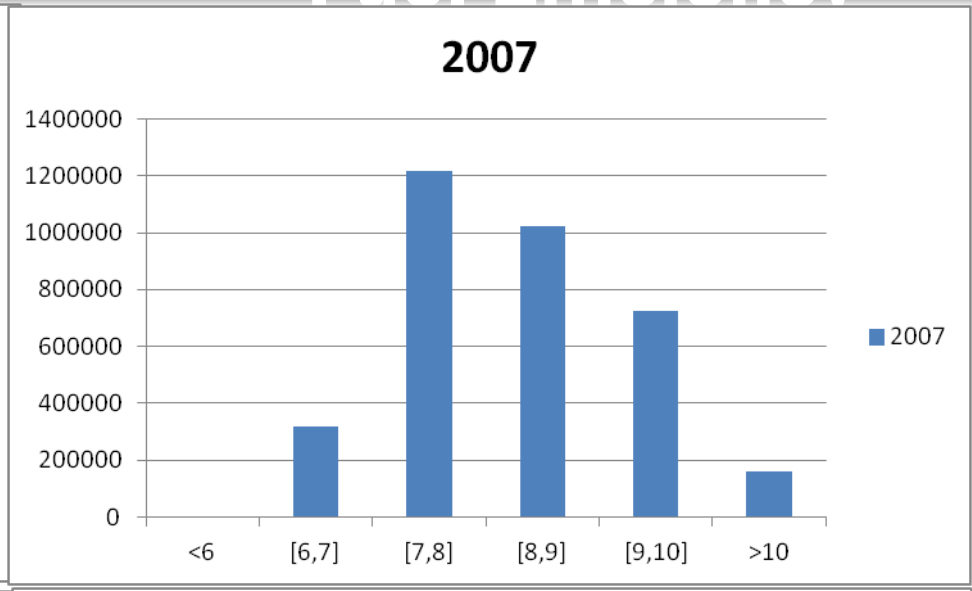
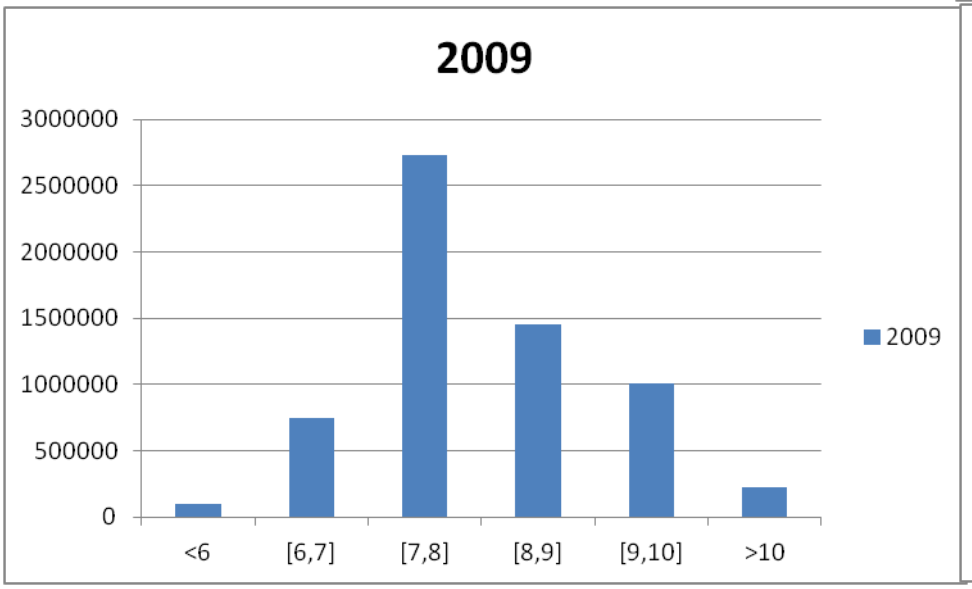
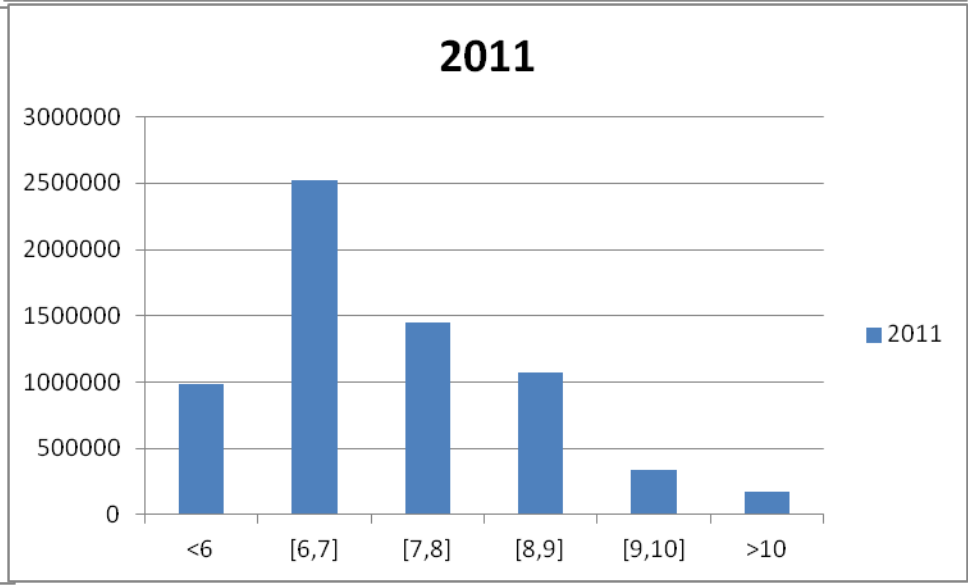
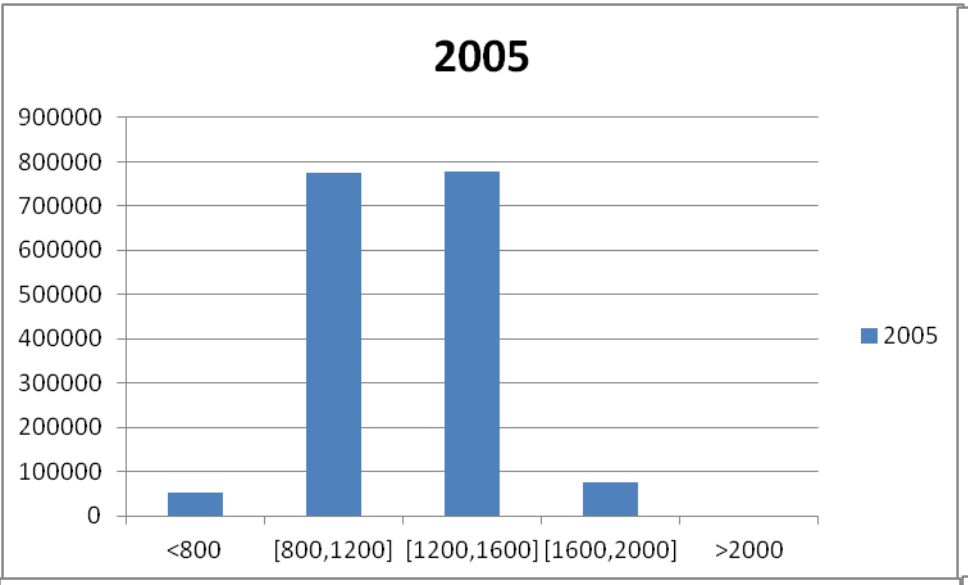
Consumers' Preference: Fuel Efficiency

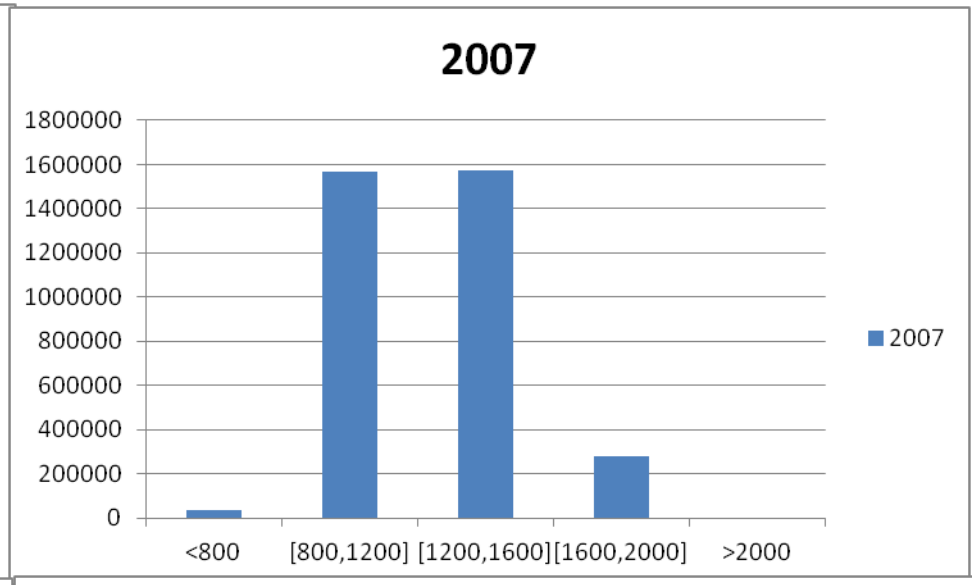









2005
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
<800
[800,1200]
[1200,1600]
[1600,2000]
>2000
2005


2007
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
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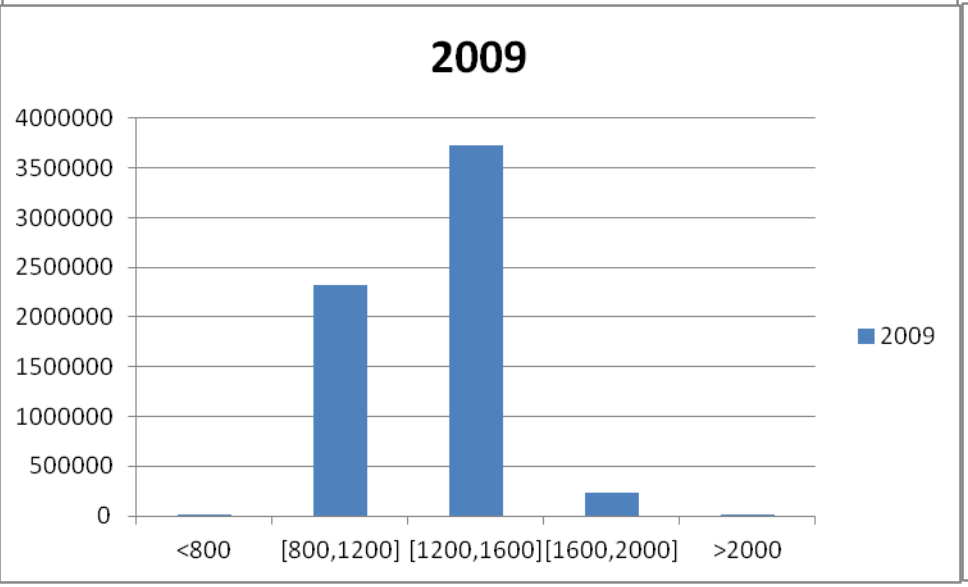
[1200,1600]
[1600,2000]
>2000
2007


2009
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3000000
2500000
2000000
1500000
1000000
500000
0
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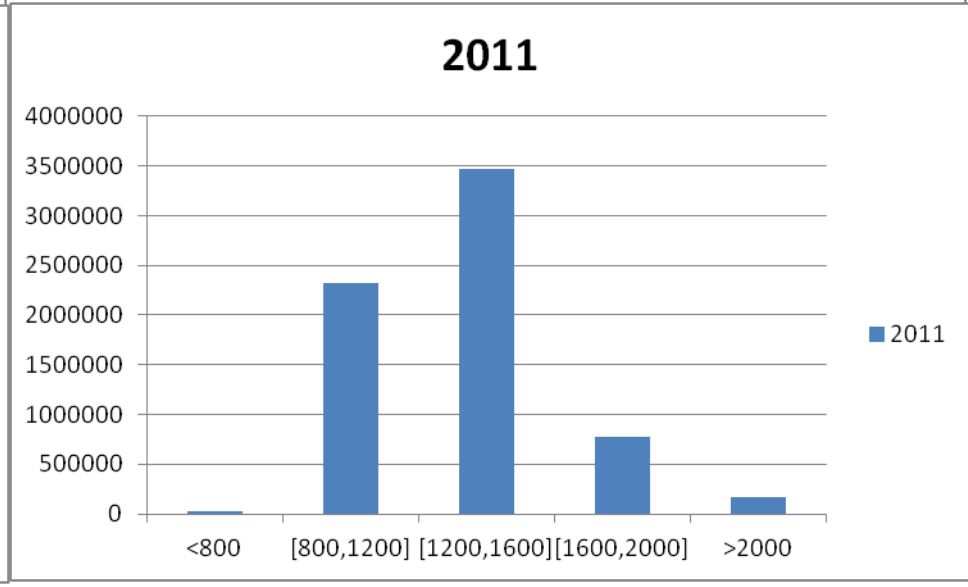
[1200,1600]
[1600,2000]
>2000
2009


2011
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
<800
[800,1200]
[1200,1600]
[1600,2000]
>2000
2011

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?

Theoretic Model(Knittel 2011)

- Marginal cost for Car Model i in Year t

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

- 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

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

Did Fuel Efficiency Tech Improve?

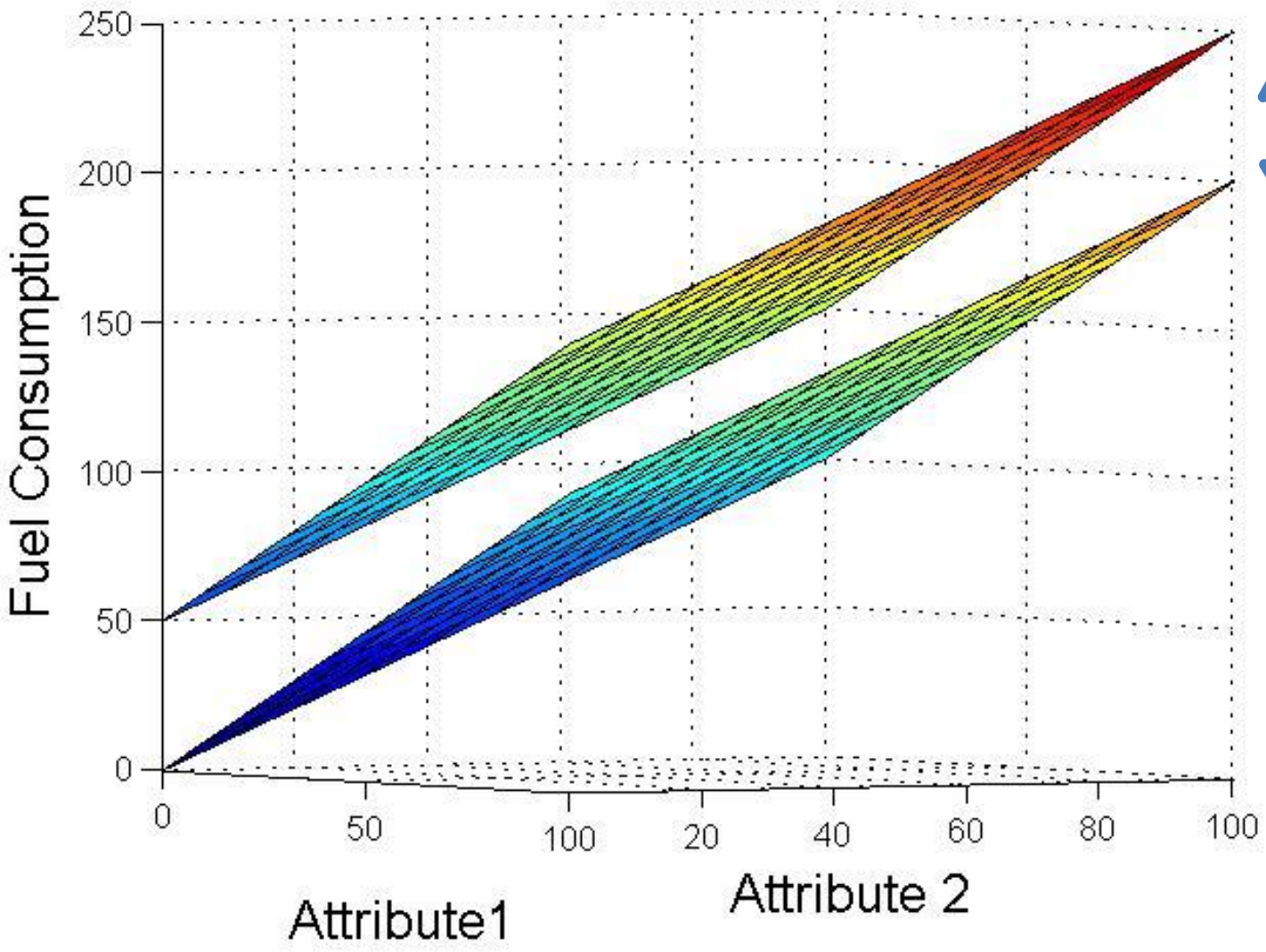
- The company will optimize above problem by trading-off among all technology attributes.
- The optimal fuel efficiency level comes from technology improvement and balancing with other related attributes

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

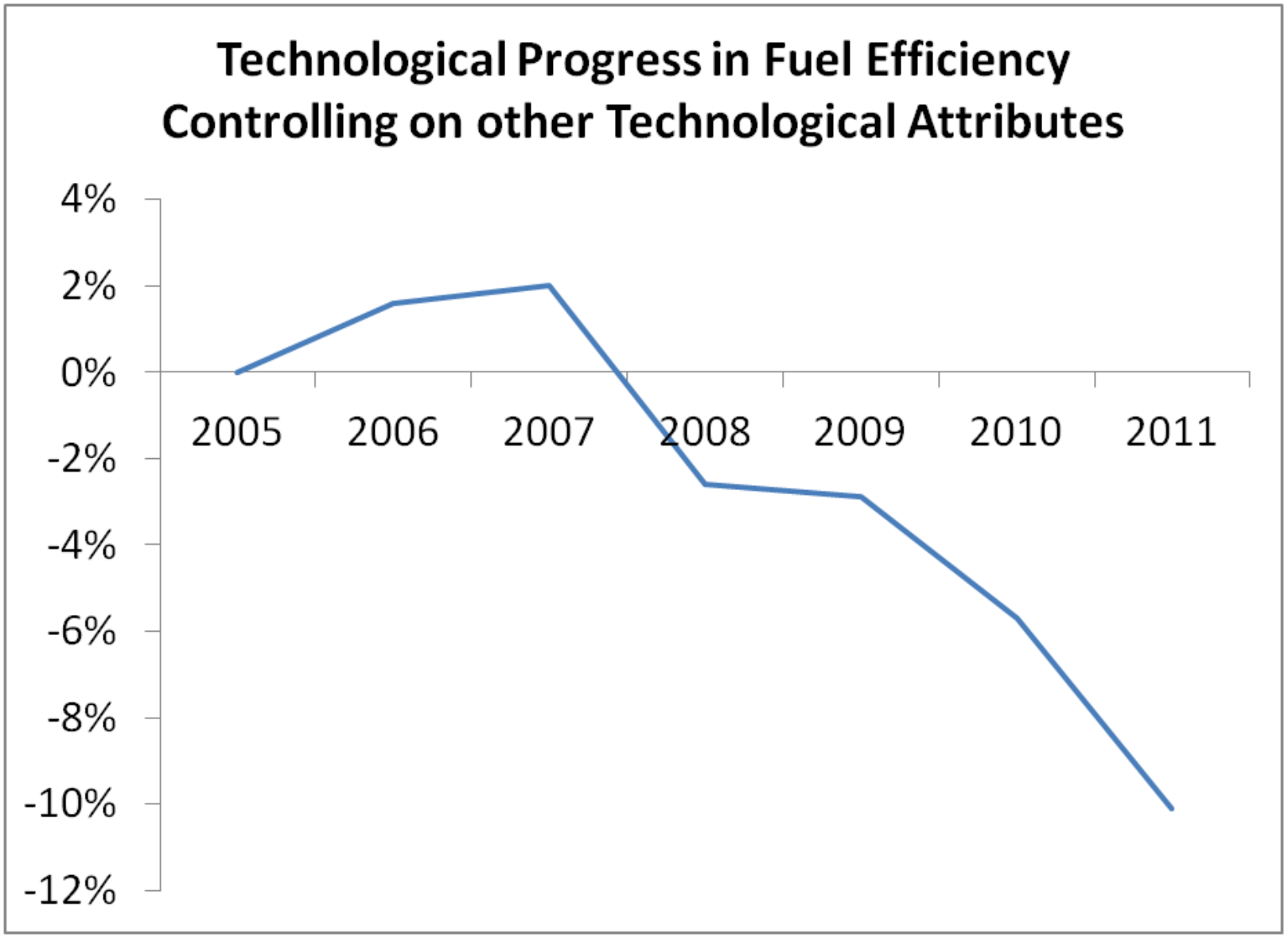
- Fixed Effects Panel Regression Model

$$fuel\ efficiency = \beta_1 Year_t + (\ln X)\,\Gamma + \varepsilon_{it}$$

- Controlling all the related attributes, the coefficient of year dummy β_1 is defined as the fuel efficiency technological change of Year t to Year 2005


Fuel Consumption
250
200
150
100
50
0
0
50
100
20
40
60
80
100
Attribute1
Attribute 2
Technological
Progress

Technological Progress in China's Automobile Sector



	Dependent variable:	
	log(Average.Fuel.Consumption)	
	(1)	(2)
log(Placement)	0.308***	0.317***
	(0.017)	(0.017)
log(Curb.Weight)	0.502***	0.448***
	(0.017)	(0.019)
log(Power)	−0.123***	−0.081***
	(0.012)	(0.012)
mt	−0.033***	−0.046***
	(0.004)	(0.004)
cvt	−0.061***	−0.064***
	(0.009)	(0.009)
dct	−0.052***	−0.047***
	(0.009)	(0.009)
alterf	−0.081***	−0.075***
	(0.007)	(0.007)
hybrid	−0.362***	−0.357***
	(0.024)	(0.024)
drive	0.009	0.011
	(0.010)	(0.010)

Larger (larger power) cars improve slower

log(Curb.Weight):d2006	0.167***
	(0.046)
log(Curb.Weight):d2007	0.089**
	(0.039)
log(Curb.Weight):d2008	0.018
	(0.041)
log(Curb.Weight):d2009	0.020
	(0.038)
log(Curb.Weight):d2010	0.074**
	(0.037)
log(Curb.Weight):d2011	0.115***
	(0.039)

log(Power):d2006	0.077***
	(0.026)
log(Power):d2007	0.036
	(0.023)
log(Power):d2008	0.041*
	(0.023)
log(Power):d2009	0.047**
	(0.022)
log(Power):d2010	0.066***
	(0.022)
log(Power):d2011	0.070***
	(0.023)

China's Automobile Market: Factors Impact the Trend of Technologies and Consumers' Preference

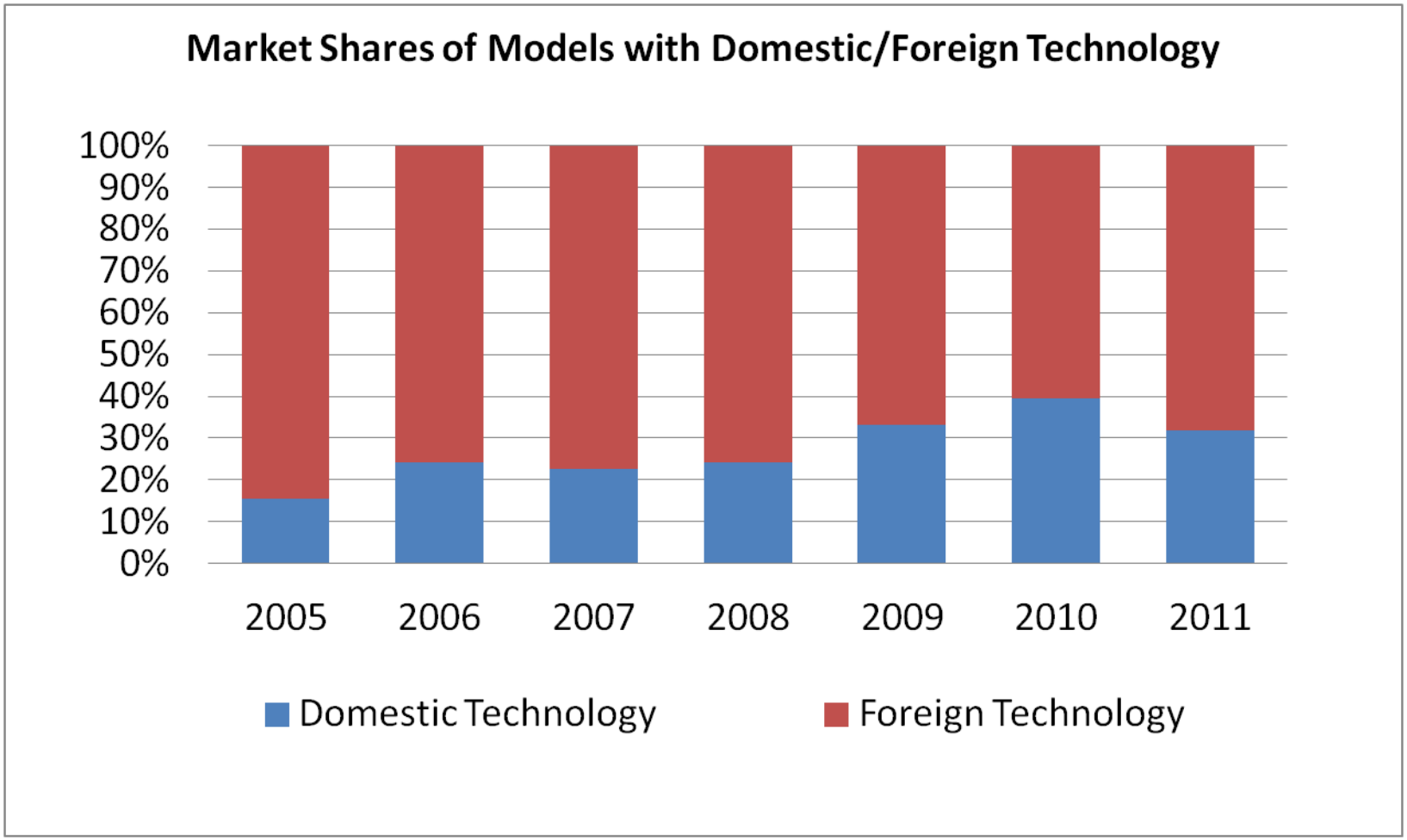
Model China's Car Market

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

- Which particular Characteristics of China's market can affect Θ_{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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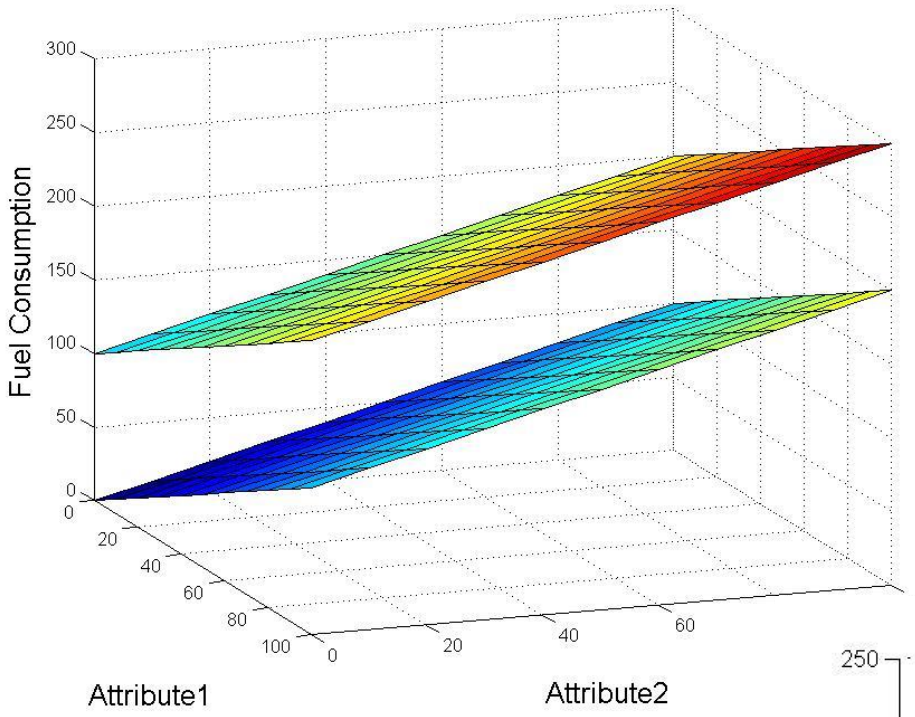
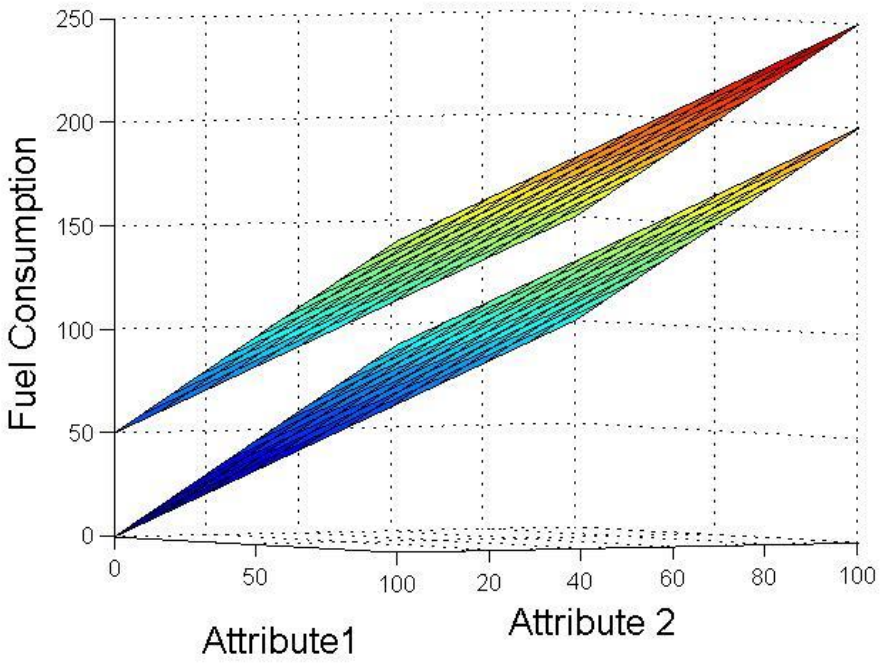


Japanese Car Model



Korean Car Model

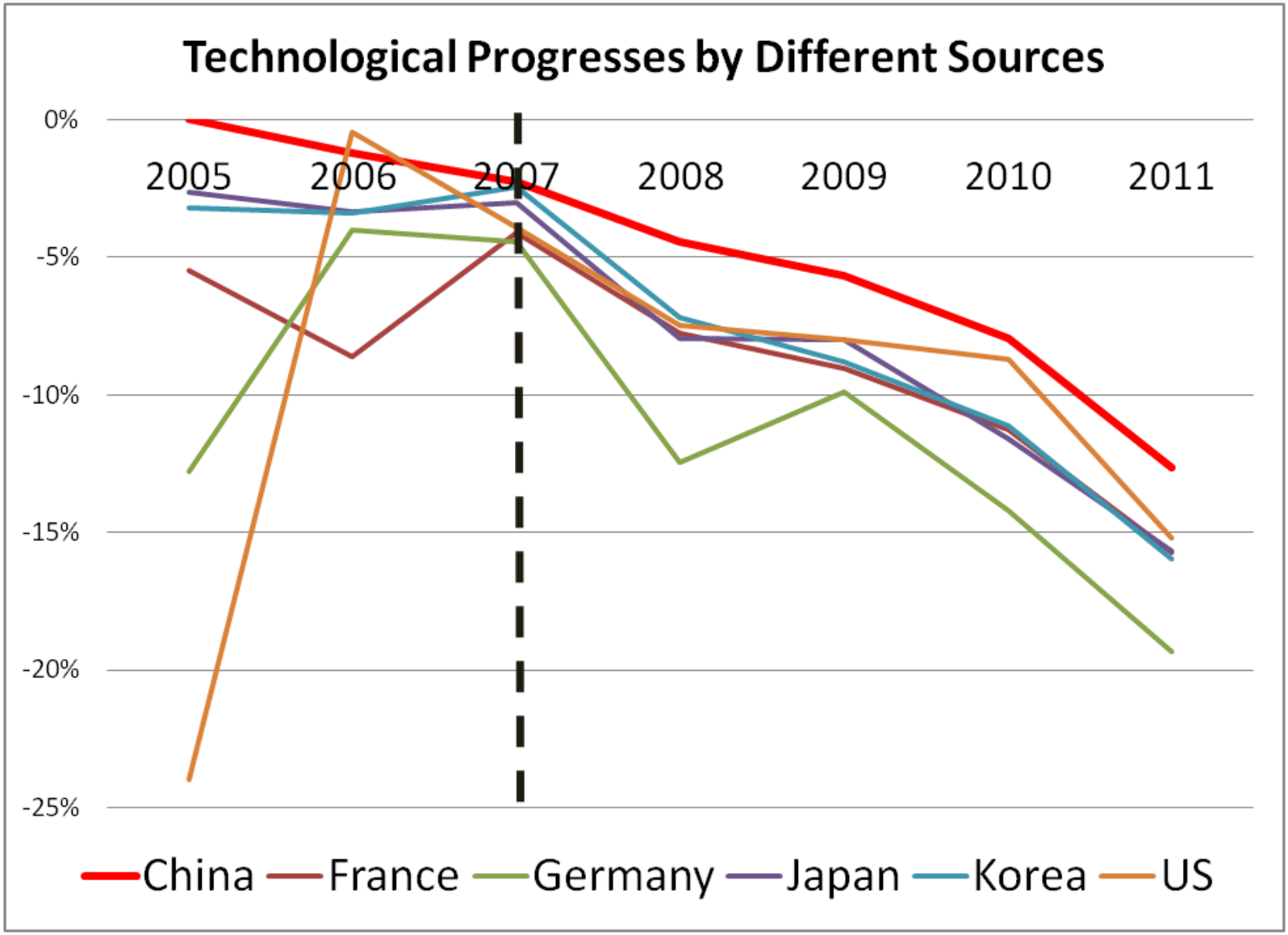
Impacts of Technology Sources

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

- 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 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)

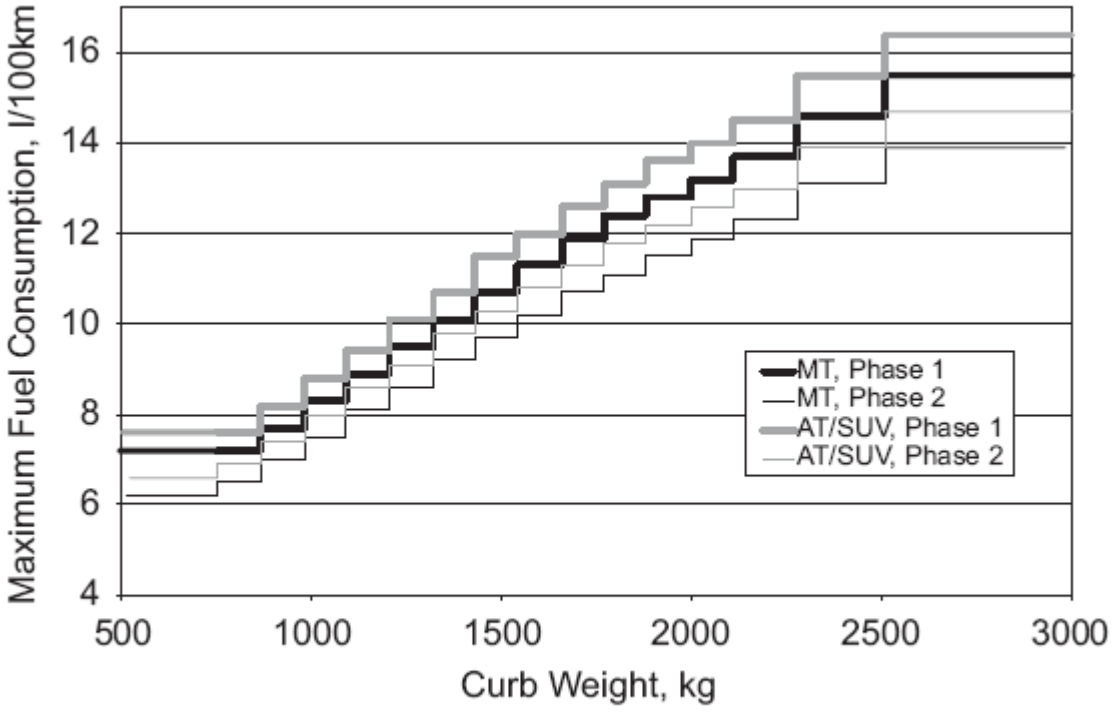


Fig. 7. Chinese passenger car fuel consumption limits.

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:

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

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

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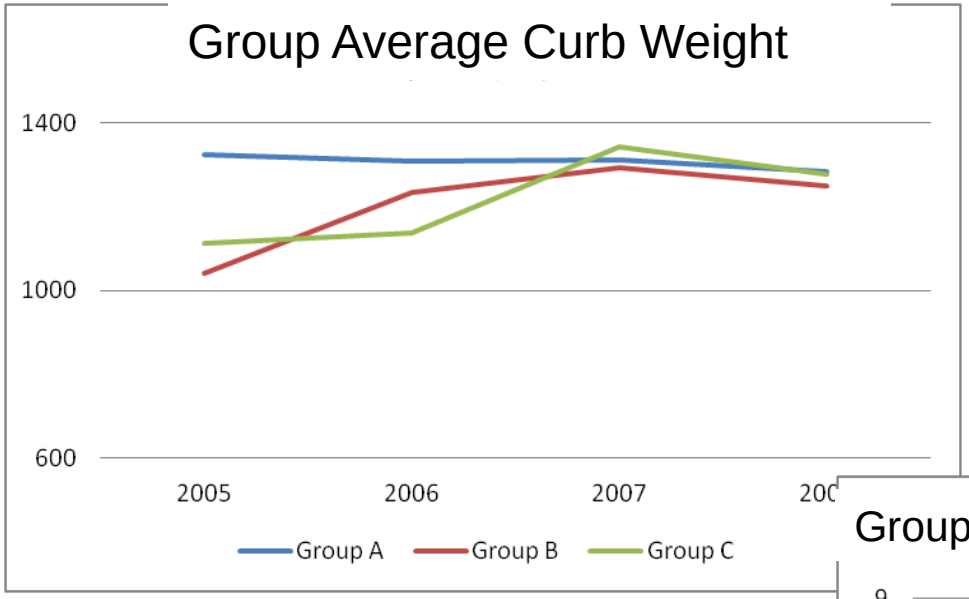
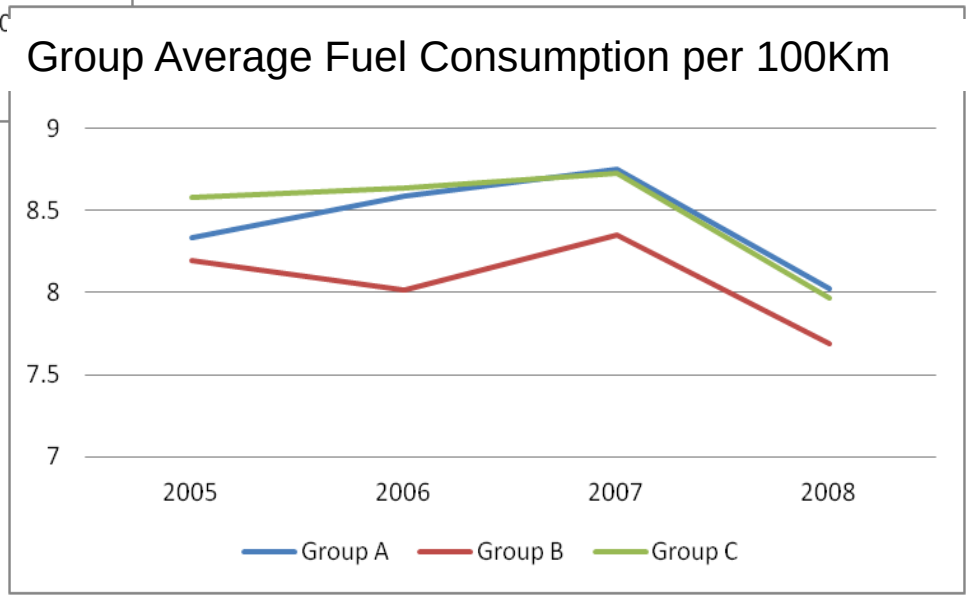
Who Meet the Standard First?



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



- 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

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

$$Subject\ to: fuel\ effeicienty_{i,2008} \in \Psi_{i,2008} | 1(fuel\ effeicienty_{it} \in \Psi_{i,2008})$$

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

$$1(fuel\ effeicienty_{it} \in \Psi_{i,2008})$$

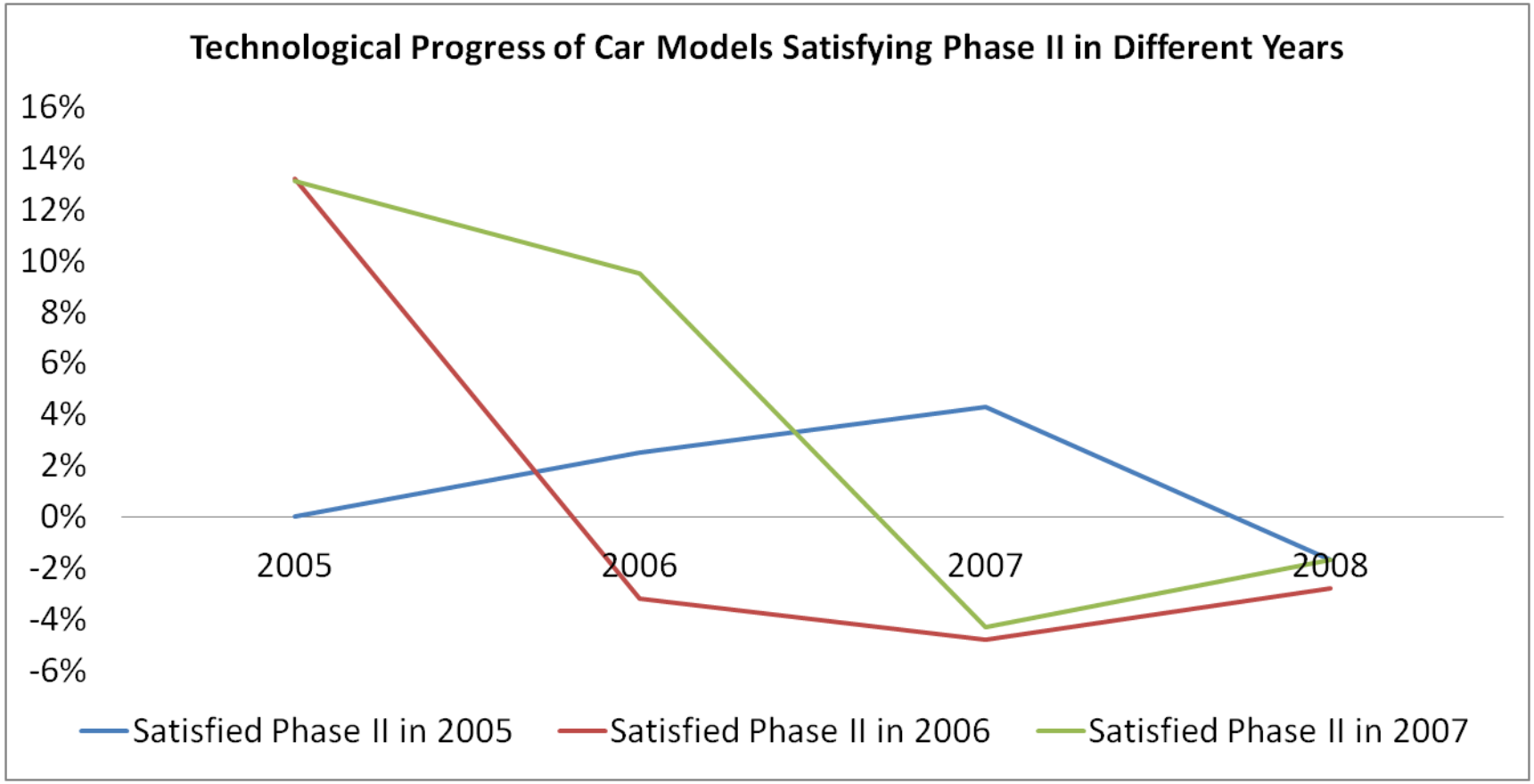
- Which is a function of:

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

- Therefore, Φ 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



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?

yangyu1@stanford.edu