Strategies of Manufacturers in the Automobile Sector
By

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Doctor of Philosophy
University of California, Irvine, 1990

SUBMITTED TO THE MIT SLOAN SCHOOL OF MANAGEMENT
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF BUSINESS ADMINISTRATION
AT THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

JUNE 2014

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Submitted to the MIT Sloan School of Management on May 9, 2014 in partial fulfillment of the requirements for the degree of Master of Business Administration

ABSTRACT

An in-depth analysis of the automobile data from 1980 to 2006 is carried out with a goal of understanding strategies employed by various manufacturers in bringing their models to the market in a retrospective fashion. The data analysis tries to identify the differences in specific parameters of focus by US and Asian manufacturers which might have led to their strategies of market positioning over this period. The analysis itself is carried out both qualitatively by understanding the data in different ways, and qualitatively by running regressions. We show that fuel economy and acceleration were the two parameters of focus for Asian Manufacturers whereas US manufacturers might have focused more on horsepower and torque during this period.

Thesis Supervisor: Christopher R. Knittel
Title: William Barton Rogers Professor of Energy, Professor of Applied Economics, MIT Sloan School of Management

Acknowledgements

It turns out writing a thesis for Sloan Fellows Program is an option. I wasn't sure whether I should opt to write a thesis or take enough classes instead as I was starting with the program. Almost everyone I talked to gave me advice strongly one way or the other, some saying that the thesis is once in a lifetime opportunity, the others saying that taking classes in a variety of subjects rather than focusing on a single topic of thesis is the reason to be at MIT.

During summer, Professor Tom Stoker taught us Economics, and I thoroughly enjoyed his class, probably because I still remember having a lot of difficulty in my undergraduate Economics course in early 1980's. I liked his way of teaching using visual/graphical representation of tough mathematical concepts (even though I like mathematics) in a way of increasing understanding. I decided to take the Econometrics class during Fall which he was one of the three professors for. During this class, I approached him to advise me on a thesis. He was more than happy to help me and suggested that I work with Professor Chris Knittel on automotive data. I am grateful to Professor Tom Stoker for his inspiration and support throughout starting from the class in summer through this thesis work.

Professor Chris Knittel readily agreed to be my thesis advisor, even though I assume this was a distraction for him with his busy schedule. He shared the automotive data he has had, and the amazing paper he published. He advised me on how to look into the data to increase my understanding so that the analysis will eventually be meaningful. He didn't even hesitate to write code for me when I didn't know what I was doing. I couldn't thank him enough for all his support and encouragement he provided throughout this work.

The decision to write a thesis, in retrospect, is the correct one. It enabled me to learn things that I would not have learned in the classroom, and establish a relationship with two great professors over this period. I am grateful for the opportunity.

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Introduction

Automobiles have been a big part of American society since the beginning of the 20th century. After Ford's introduction of mass-produced car, the industry consolidated into three big manufacturers in US, and US automobile industry dominated the worldwide market for many decades. Japanese auto manufacturers started introducing their smaller cars in 1970's, and eventually took a substantial market share from the US manufacturers, even in the native US market. Today, Japanese manufacturers effectively compete (and, to some extent, dominate) both in economy and luxury models in the US market place compared to their US counterparts. In the last decade, US manufacturers struggled to be profitable, needed government bailout money to stay in business, while there are more manufacturers from Asia entering the US market.

"Automobiles on Steroids: Product Attribute Trade-Offs and Technological Progress in the Automobile Sector" by Christopher R. Knittel[1] is the inspiration for this thesis. In this paper, Knittel analyzes the data from the automobile sector and reaches many important conclusions, some of which are as follows:

- Average fuel economy of the passenger cars went up barely while the horsepower, curb weight, torque, and 0-60 acceleration went up dramatically.
- Number of light trucks sold in the market as a percentage of the whole market went up significantly as well.
- Technological progress made over the period of 1980 to 2006 has been significant, but resulted in minimal fuel economy improvements due to increase in horsepower, curb weight, and torque.
- Better fuel economy improvements could have been in place if the vehicle characteristics (such as horse power, curb weight, and torque) were kept constant.

The paper studies the automobile sector market in US as a whole. The automobile sector includes various groups of manufacturers from United States, Asia, and Europe, as well as individual manufacturers from US, Asia, and Europe. This thesis explores, in detail, the approaches the US manufacturers took compared to their counterparts from ASIA during the same period. In addition, we will also look at three US major manufacturers (GM, Ford, and Chrysler) and three Japanese major manufacturers (Toyota, Honda, and Nissan) to understand the strategies they employed over this period.

The approaches and strategies we are specifically interested in, whether it is by a group of manufacturers or an individual manufacturer, are the following:

- Fuel Economy vs Horsepower
- Fuel Economy vs curb weight
- Fuel Economy vs torque

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[1] Knittel, Christopher R. "Automobiles on Steroids: Product Attribute Trade-offs and Technological Progress in the Automobile Sector." The American Economic Review, 101(7), 2011, pp. 3368-3399.

- Fuel Economy vs 0-60 Acceleration
- Technological Progress over this period

By understanding what has happened in these parameters from various manufacturers over 1980-2006, we can understand the strategies employed by Asian manufacturers to capture market share in United States. We also will understand the strategies used by US manufacturers during this time.

The data analysis is done in three different ways:

- Visual Analysis: In this case, we show graphically where the various manufacturers contrast with each other in a graphical fashion.
- Quartile Analysis: We group automobiles into four groups based on one or more attributes, and see if the manufacturers focused on which of the groups, if any.
- Yearly Analysis: We look at the data to see changes in trends from year to year through the range of the data.
- Regression Analysis: We run regressions on the data to gain quantitative understanding of strategies employed by various groups of manufacturers as well as individual manufacturers relative to each other and industry as a whole.

Most of the data analysis is done using STATA software (version 13), and where it makes sense, the STATA commands that produce the results are shown in this thesis.

In what follows, we present Visual, Quartile, Yearly, and Regression analyses, in that order, followed by our conclusion. Each of these analyses is done separately for passenger cars and light trucks.

Visual Analysis

The purpose of visual analysis is to understand the data qualitatively to see if there are any trends. Finding qualitative trends improves our understanding of the data enables us to do regression analysis in a more meaningful way.

The specific trends we are interested in are:

- Fuel Economy vs Curb Weight
- Fuel Economy vs Horsepower
- Fuel Economy vs Torque
- Fuel Economy vs 0-60 Acceleration.

For each of these trends, we look at where the automobile sector as a whole was as well as where US, Asian, and Other groups of manufacturers were in 1980 and 2006. Finally, we will also look at three US major manufacturers and three Japanese manufacturers.

Passenger Cars

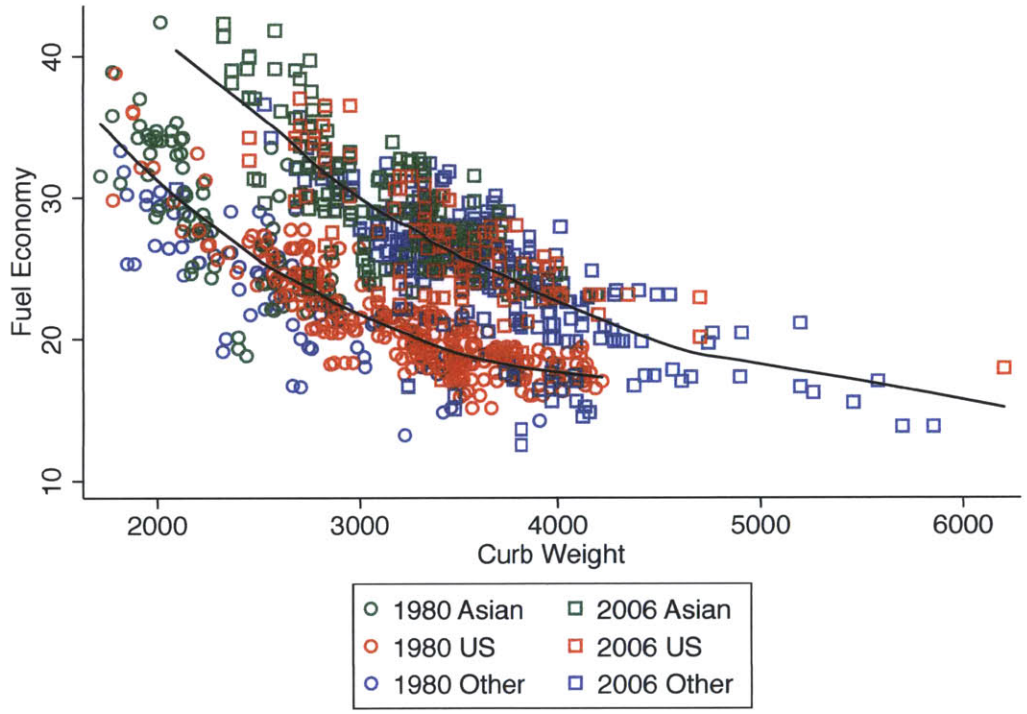
In this section, we analyze the passenger car models that were sold in US market.

US vs Asian vs Other Manufacturers

First, we look at how US manufacturers as a group produced passenger vehicles in 1980 and in 2006 compared to Asian and the rest of the manufacturers as well as the industry as a whole. Each one of the four plots below show two curves, one for 1980 and one for 2006 for the industry average. Circles indicate specific models in 1980 and squares indicate models in 2006. Further, models from US, Asian, and other manufacturers are depicted using green, red, and blue markers.

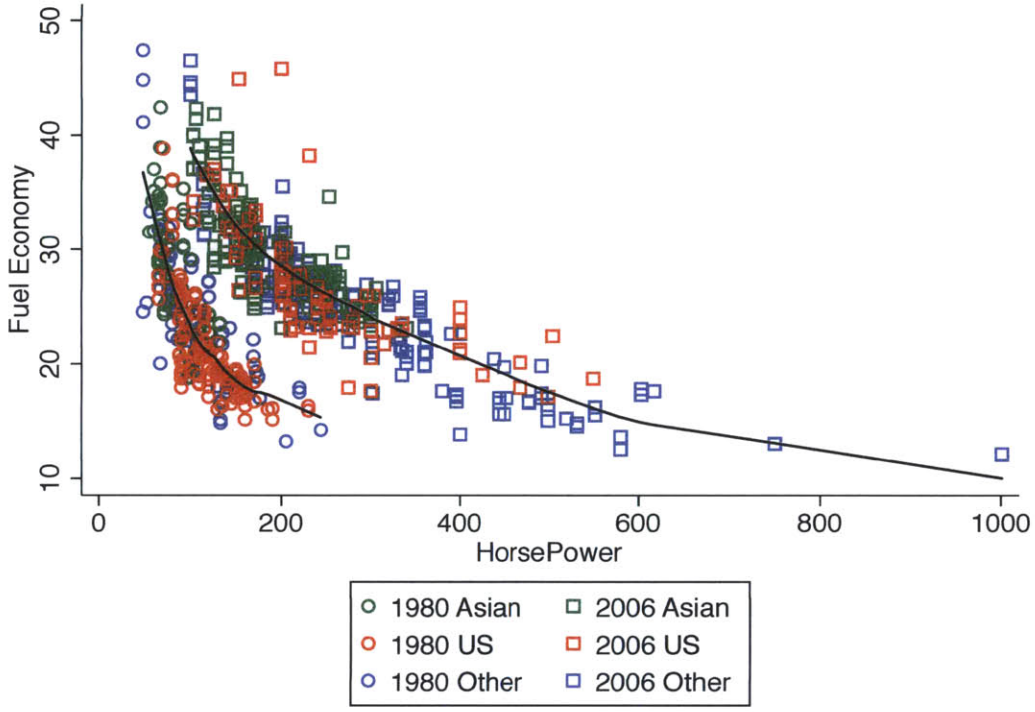
Fuel Economy vs Curb Weight

The following plot shows the fuel economy vs curb weight. As can be seen, the overall fuel economy went up from 1980 to 2006. Asian manufacturers tend to be higher fuel economy and lower curb weight, compared to US manufacturers.



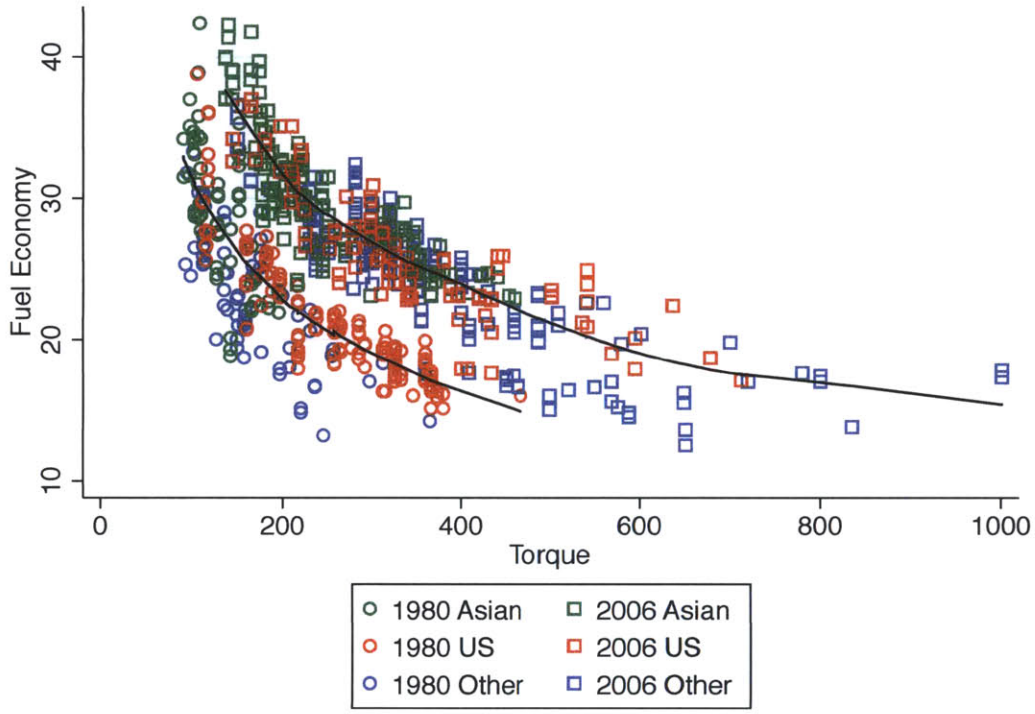
Fuel Economy vs Horsepower

The following plot depicts the passenger car models using their horsepower and fuel economy characteristics. For a given horse power, fuel economy improved from 1980 to 2006, which demonstrates technological progress. Asian manufacturers seemed to have focused on higher fuel economy and lower horse powered cars compared to US manufacturers. It is interesting that the rest of the industry produced models with very high horsepower and low fuel economy models as well as low horsepower and high fuel economy models. These obviously are from European manufacturers that produced high performance cars as well as highly efficient cars for city driving.



Fuel Economy vs Torque

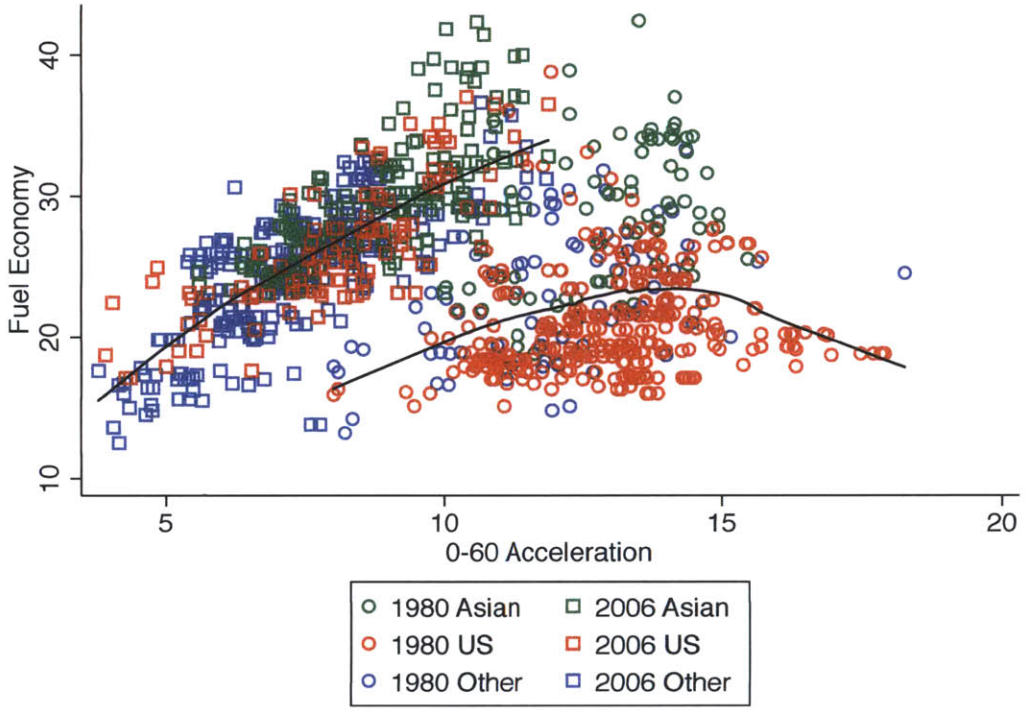
The following plot shows the passenger car models based on their fuel economy – torque characteristics. Again, fuel economy improved from 1980 to 2006. Asian manufacturers produced models with higher fuel economy and lower torque compared to their counterparts from US. European manufacturers produced higher torque models as well.



Fuel Economy vs Acceleration

In this plot, we show the models based on fuel economy and 0-60 Acceleration times. Please note that, since we use Acceleration times for the car to accelerate from 0 to 60 mph, the higher numbers indicate lower accelerations.

As before, fuel economy for a given acceleration improved from 1980 to 2006. Japanese manufacturers produced higher fuel economy and higher 0-60 acceleration times compared to US manufacturers. Europeans produced lowest times for 0-60 acceleration.

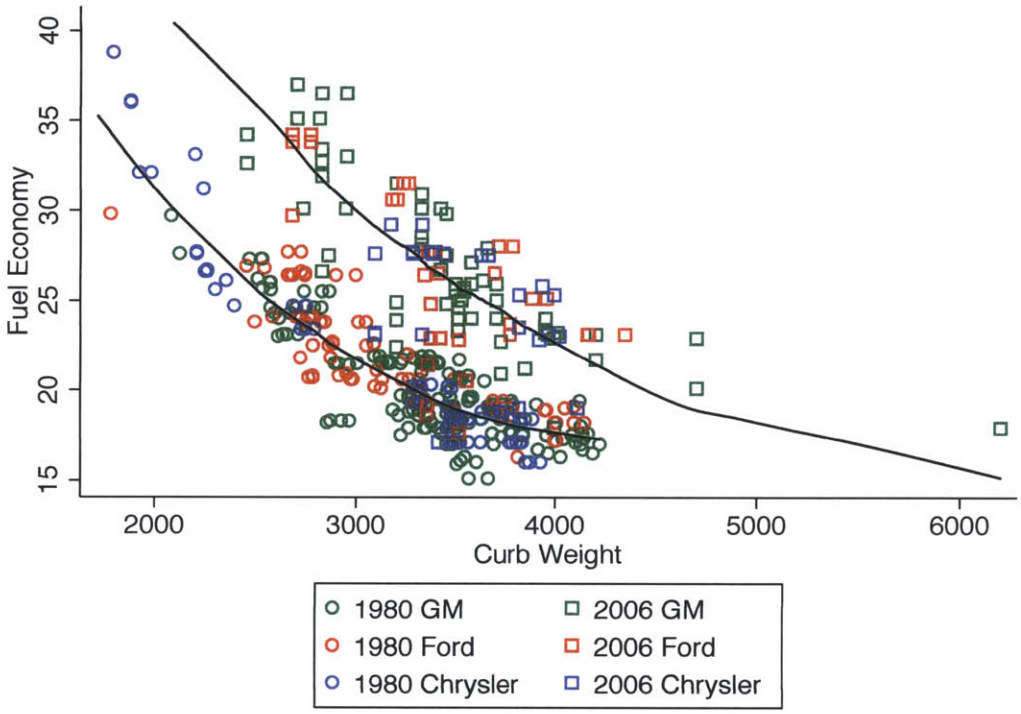


Individual Manufacturers

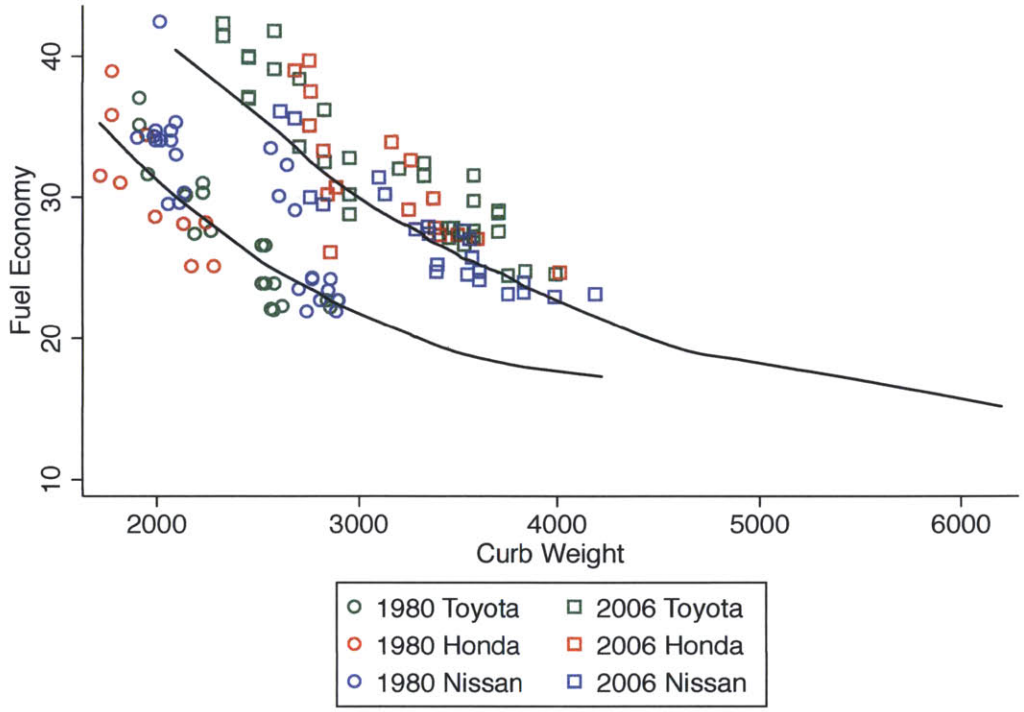
In the following series of plots, we show car models of three US manufacturers (GM, Ford, and Chrysler) and three Japanese manufacturers (Toyota, Honda, and Nissan) compared to industry average in 1980 and 2006, again with fuel economy vs curb weight, horsepower, torque, and 0-60 acceleration times. By examining these plots, it makes it clear to us the strategies of various manufacturers in capturing various parts of the market.

Fuel Economy vs Curb Weight

US manufacturers' car models are shown in the plot below. In 1980, GM seemed to have focused little on fuel economy, but produced heavier cars compared to its domestic competition. Chrysler produced lower weight and higher fuel economy cars in 1980, whereas they shifted to fewer models that matched the industry average in 2006. Ford stayed more or less consistent from 1980 to 2006.



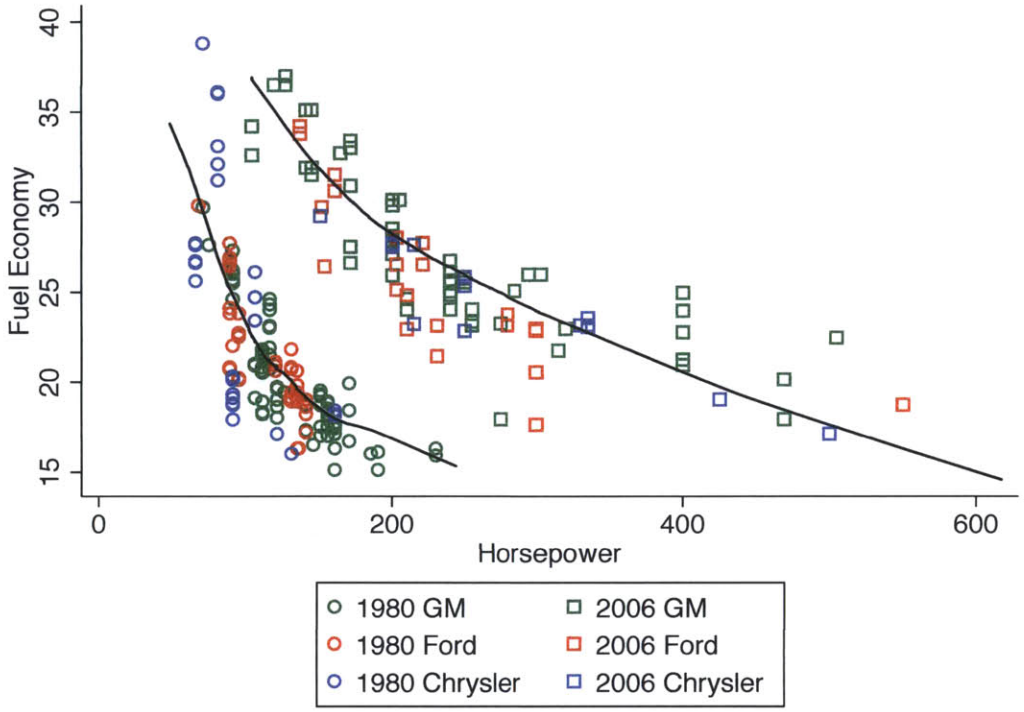
Honda only produced lower weight and higher fuel economy cars in 1980 compared to wider range models in 2006. Nissan produced cars with 2000 pounds and 3000 pounds only in 1980, whereas it decided to produce cars with a range of 2000 to 4000 pounds in 2006. Toyota stayed more consistent over the years.



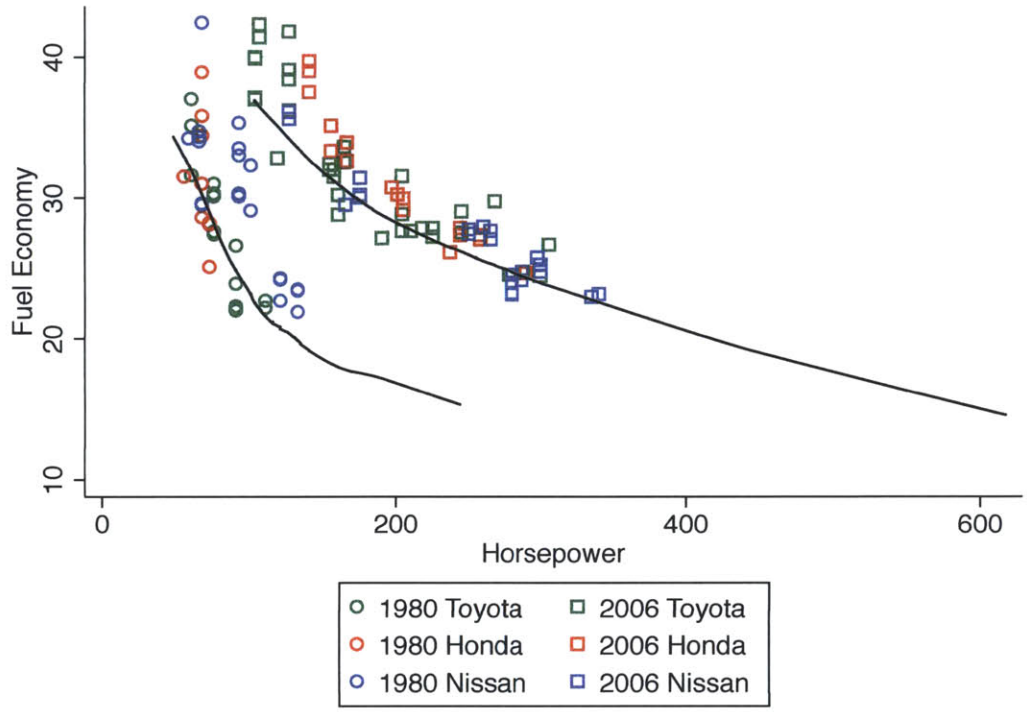
It is interesting to note the contrast between the US manufacturers and Japanese manufacturers. US manufacturers tended to prefer heavier cars compared to Japanese.

Fuel Economy vs Horsepower

The plot below shows that US manufacturers produced cars with higher horsepower in 2006 compared to 1980, while fuel economy has improved overall. GM continued producing cars of wider range through the years, whereas Chrysler changed its strategy in 1980 of producing lower horsepower and higher fuel economy in 1980 to mid to higher horsepower and lower fuel economy in 2006.

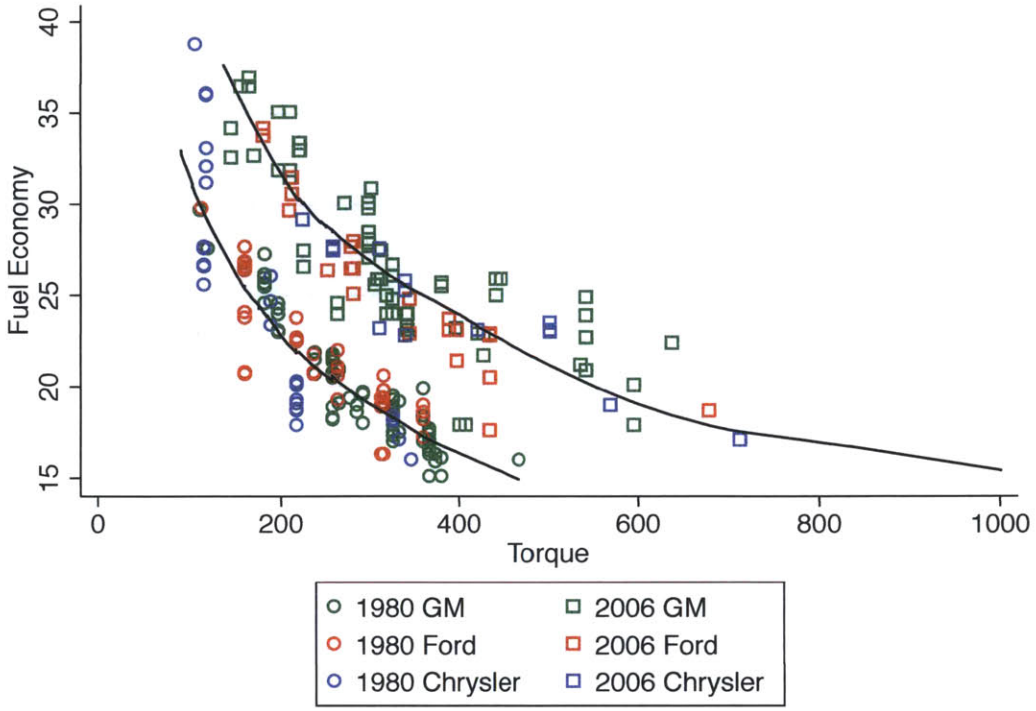


Japanese manufacturers also show a similar trend. Specifically, Nissan, which had some models of lower horsepower in 1980, pushed towards higher horsepower and lower fuel economy models in 2006 compared to Toyota and Honda. Again, compared to US manufacturers, Japanese manufacturers limited themselves to lower horsepower models.

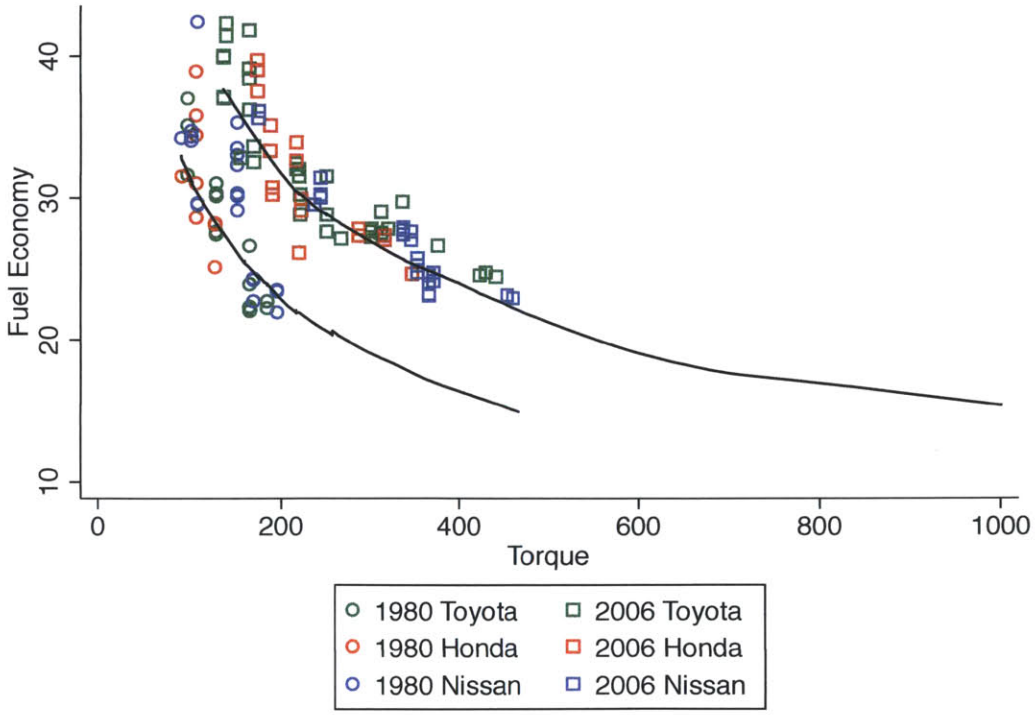


Fuel Economy vs Torque

Similar to horsepower, US models moved from lower torque models in 1980 to higher torque models in 2006 while improving the fuel economy over this time period. Chrysler seemed to have focused more on higher torque models compared to its US rivals in 2006.

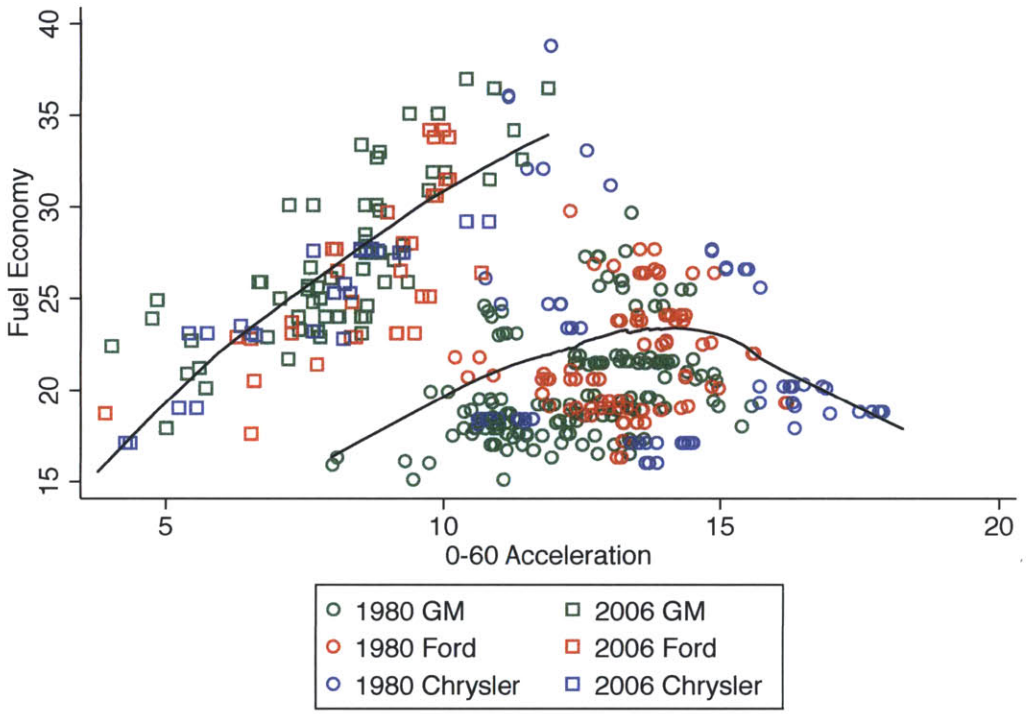


Japanese manufacturers stayed at lower torque models compared to their US counterparts. Nissan, similar to Chrysler produced higher torque models than Toyota and Honda, while Honda stayed to the lower end.

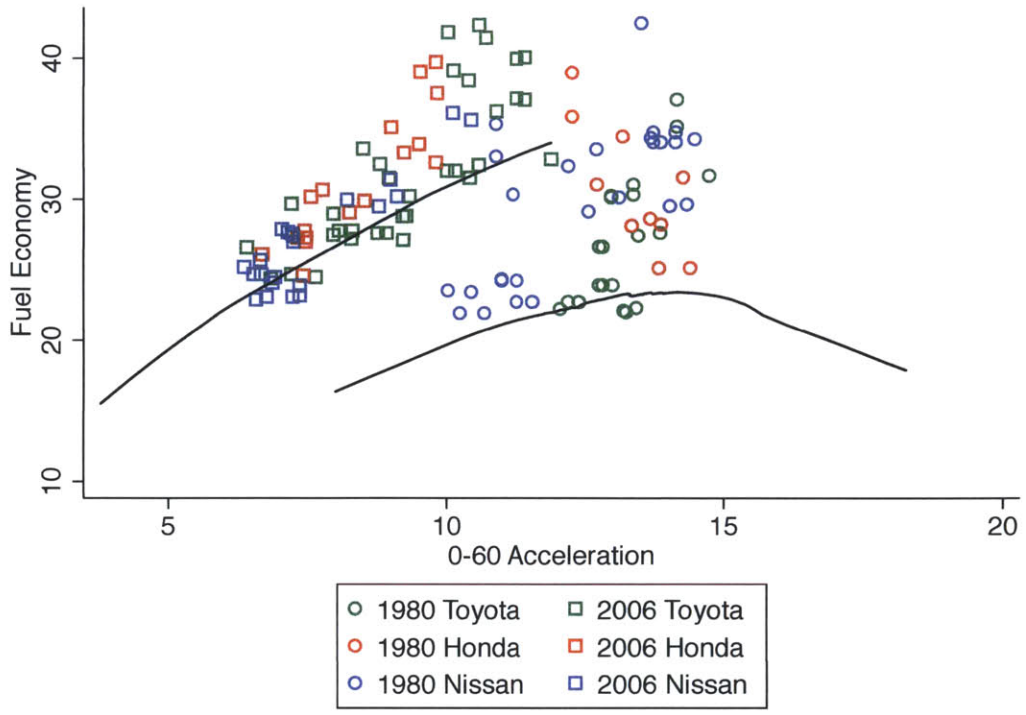


Fuel Economy vs 0-60 Acceleration Times

US manufacturers improved the 0-60 acceleration times from 1980 to 2006 while improving the fuel economy. Chrysler and Ford had no models below 10 seconds in 1980, whereas had models below 5 seconds in 2006 – a clear change in strategy.



Japanese manufacturers have not been as aggressive compared to US manufacturers in both 1980 and 2006. Nissan led the pack in both years in terms of acceleration, while Toyota and Honda focused on lower accelerations and higher fuel economy.



Light Trucks

Now, we look at the light truck models, that include pickup trucks, SUVs, etc.

US vs Asian vs Other Manufacturers

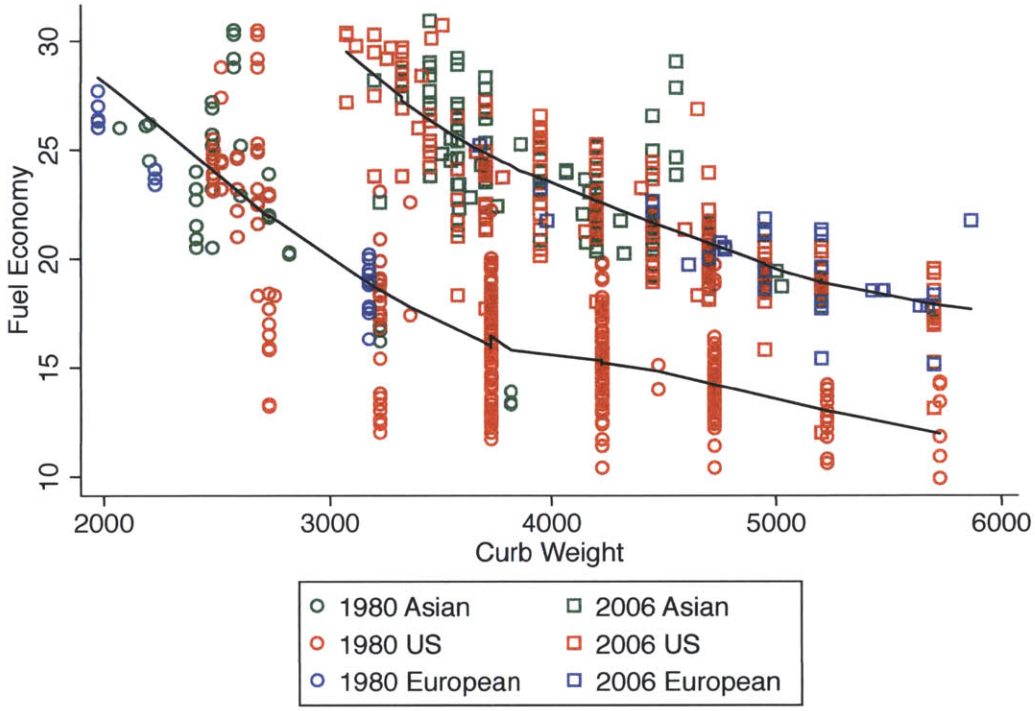
Similar to the visual analysis we have done earlier for the passenger vehicles, we perform the analysis for light trucks. We look at how US manufacturers as a group produced light truck models in 1980 and in 2006 compared to Asian and the rest of the manufacturers as well as the industry as a whole. Each one of the four plots below show two curves, one for 1980 and one for 2006 for the industry average. Circles indicate specific models in 1980 and squares indicate models in 2006. Further, models from US, Asian, and other manufacturers are depicted using green, red, and blue markers.

Overall, European and Asian manufacturers produced very few models in 1980, and expanded in 2006.

Fuel Economy vs Curb Weight

The plot below shows that Asian and European manufacturers produced relatively low number of trucks both in 1980 and 2006 compared to US manufacturers. In 1980, Europeans produced lightest trucks, Asians produced light to medium trucks, and US produced light to heavier trucks. Interestingly, Europeans switched to heavier trucks in 2006, whereas Asians remained focused in the lighter segment, while producing a few models in the medium weight area.

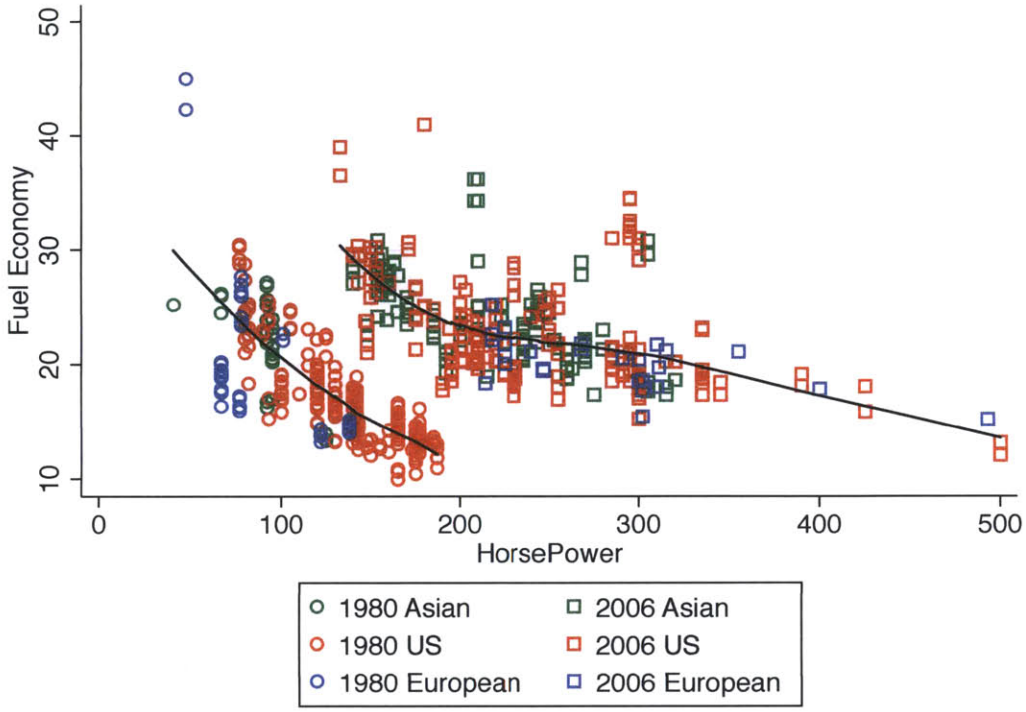
As far as the fuel economy goes, it is not clear who focused on higher fuel economy. All the manufacturers produced higher and lower fuel economy models compared to the industry average.



Fuel Economy vs Horsepower

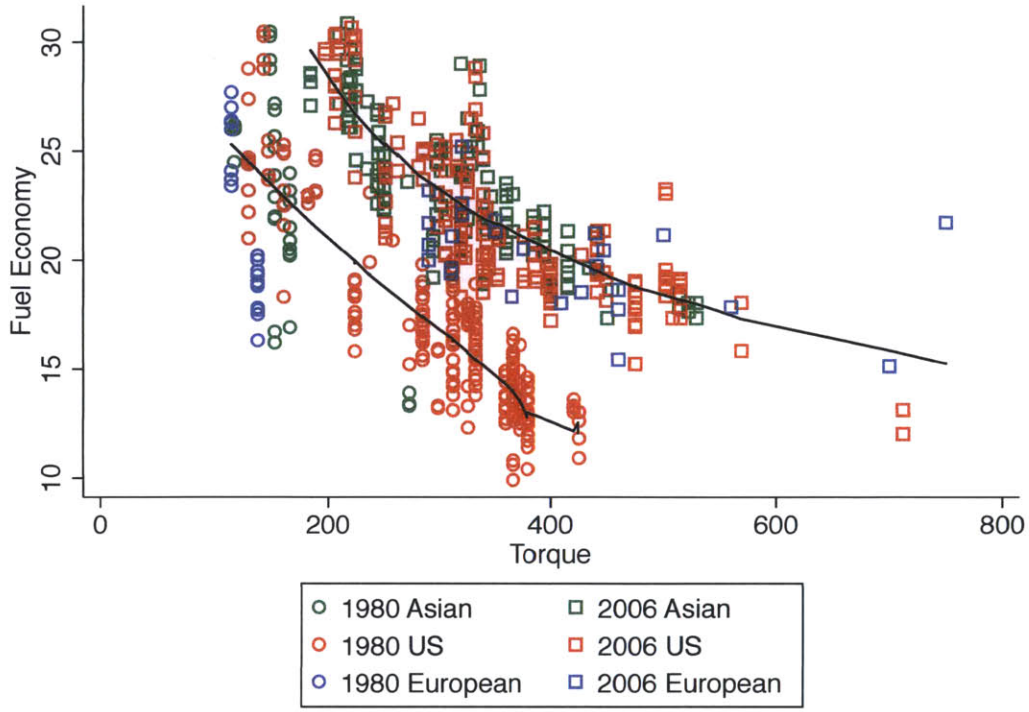
The plot below shows that the horsepower of the cars went up significantly from 1980 to 2006. Again, in 1980, Asians and Europeans focused on lower horsepower models compared to US. In 2006, however, Europeans produced medium to high horsepower models, whereas Asians produced more of "middle-of-the-pack" horsepower trucks.

In 1980, Europeans produced some models that are most fuel-efficient trucks for a given horsepower compared to Asian and US manufacturers. In 2006, however, Europeans focused more on higher horsepower. US manufacturers produced lower horsepower models than the rest as well as higher fuel efficiency trucks.



Fuel Economy vs Torque

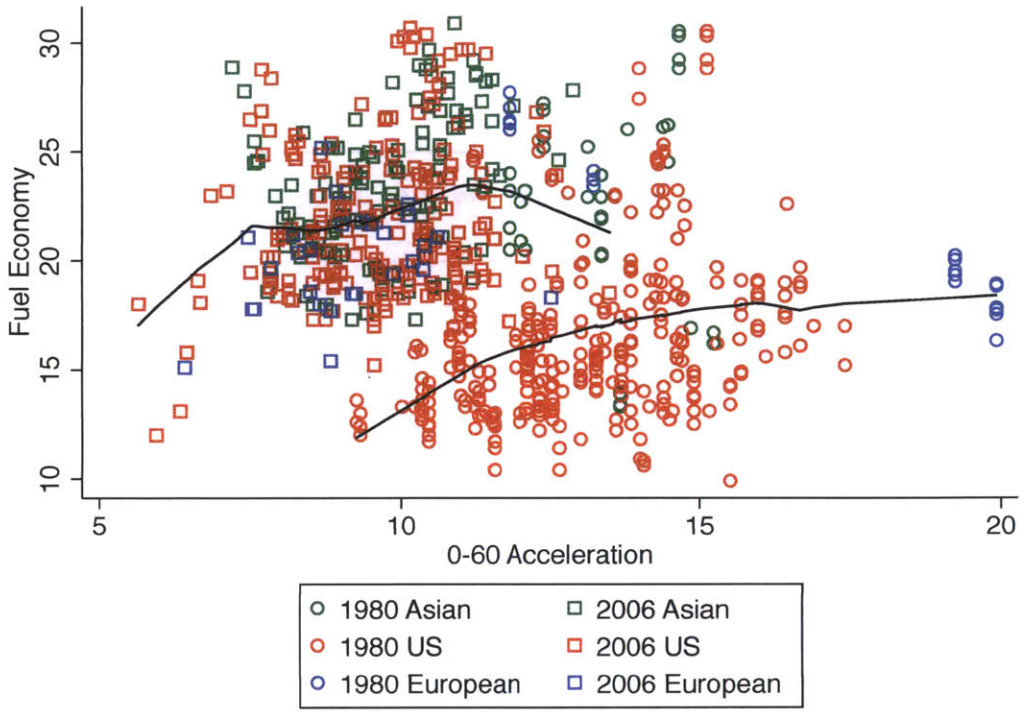
As shown in the plot below, European manufacturers focused on lower torque models only in 1980, while ignoring that market completely in 2006. Asian manufacturers went from mostly lower torque models in 1980 to wide variety of models with different torques except for the highest torque models in 2006. US manufacturers produced most models both in 1980 and 2006.



Fuel Economy vs 0-60 Acceleration Times

As can be seen in the plot below, European trucks from 1980 were the slowest trucks, and became faster in 2006.

Fuel efficiency was better as well for European models and Asian models in 1980, while they were more comparable to US models in 2006.

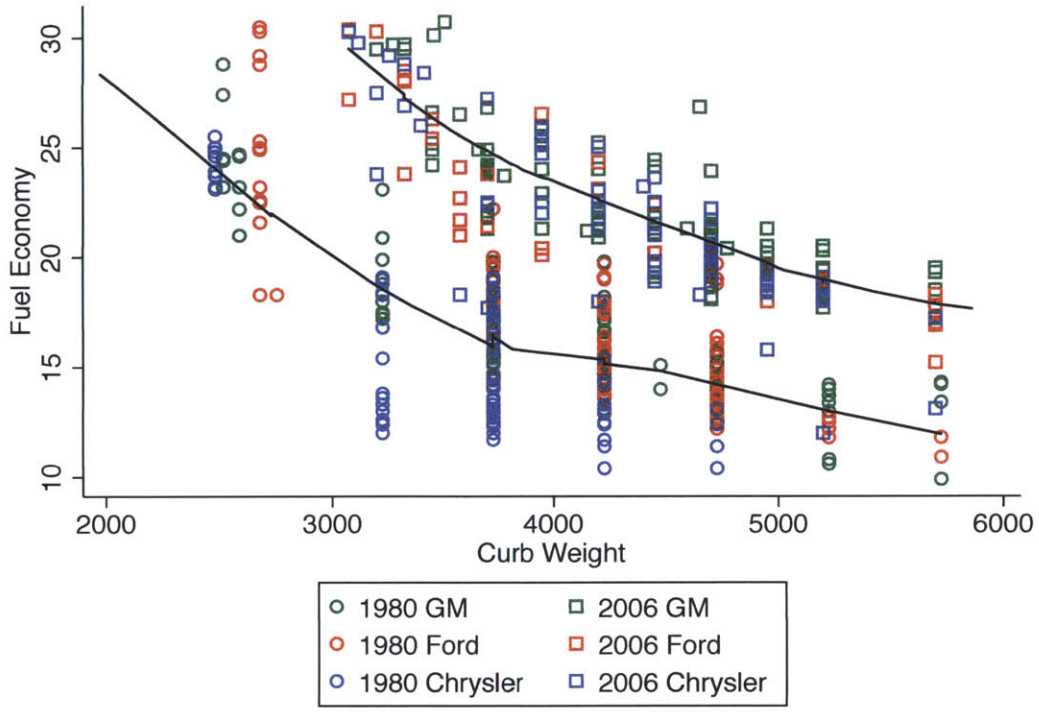


Individual Manufacturers

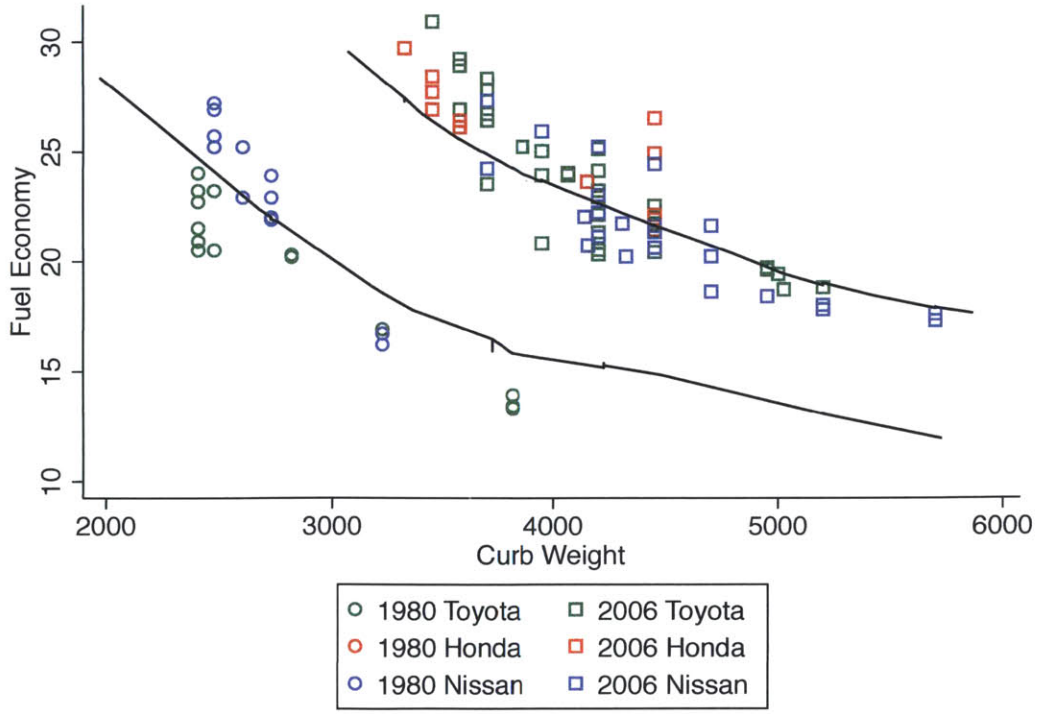
We now look at the individual manufacturers from US and from Japan, and see if there are any trends in the model characteristics for the light trucks.

Fuel Economy vs Curb Weight

In the plot below, GM, Ford, and Chrysler all produced similar models in both 1980 and 2006. As one can imagine, the reason is that they are directly competing with each other in the same market place.

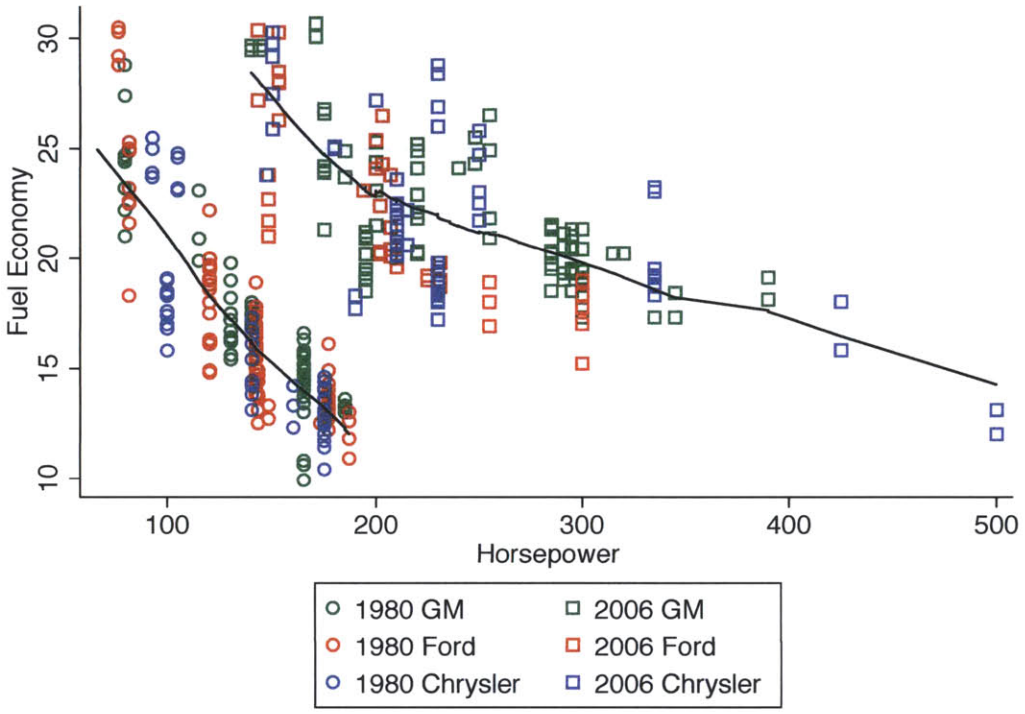


Japanese manufacturers produced very few trucks in 1980. Specifically, Honda did not have any models. Both Toyota and Nissan focused on smaller trucks in 1980. In 2006, Honda entered the market as well. Nissan started producing larger trucks, whereas Toyota covered the entire range.

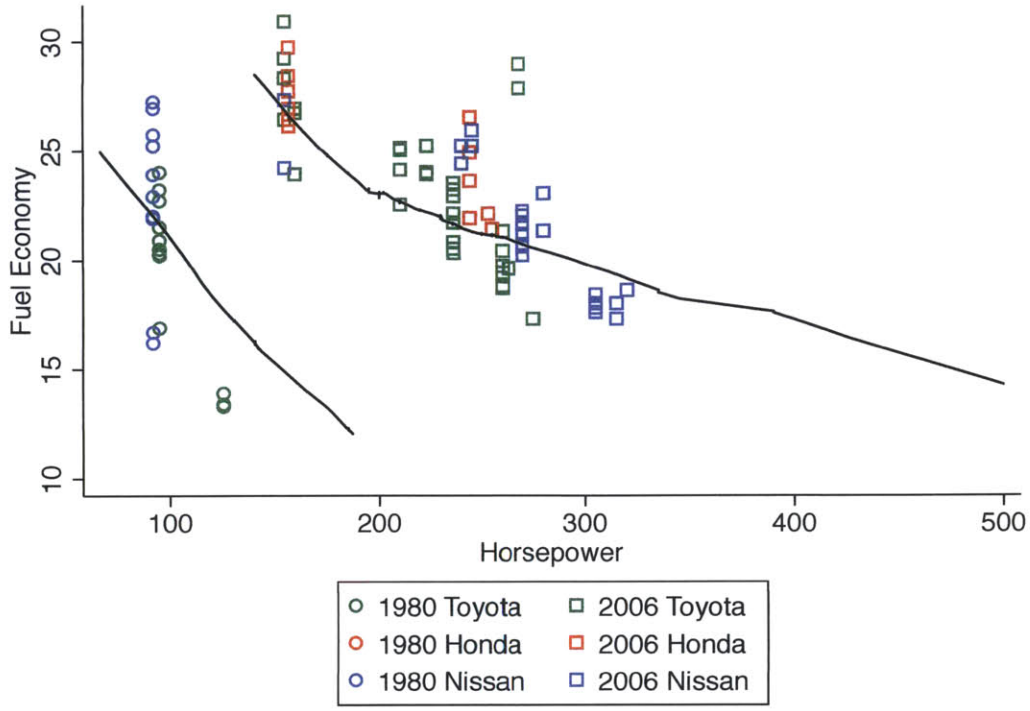


Fuel Economy vs Horsepower

US Manufacturers produced wide variety of trucks as far as the horsepower was concerned.

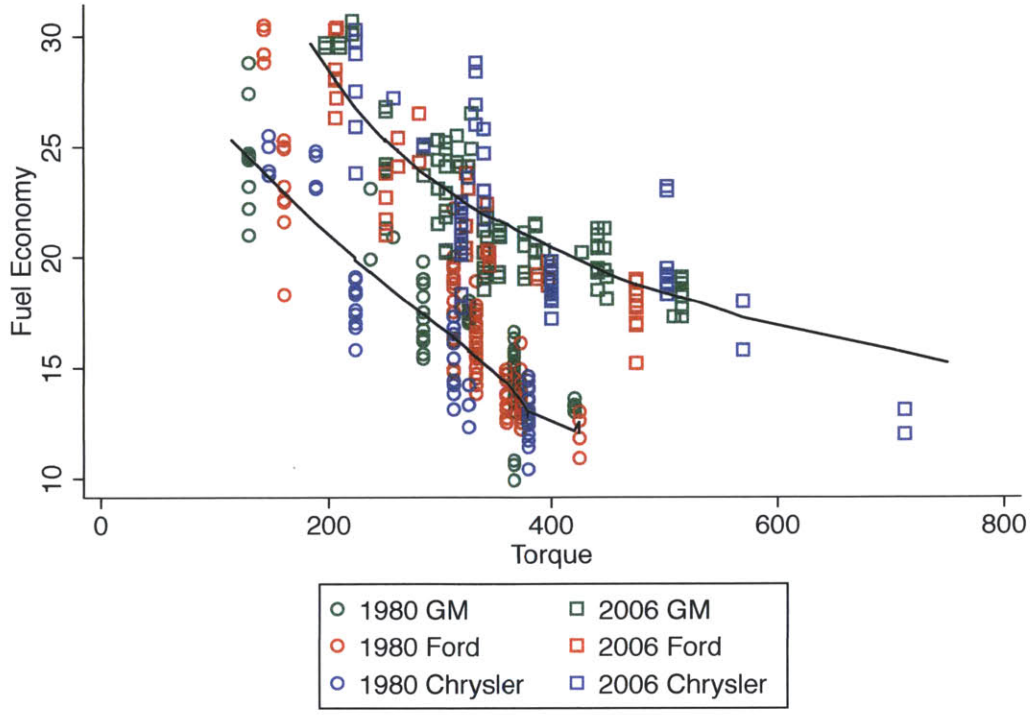


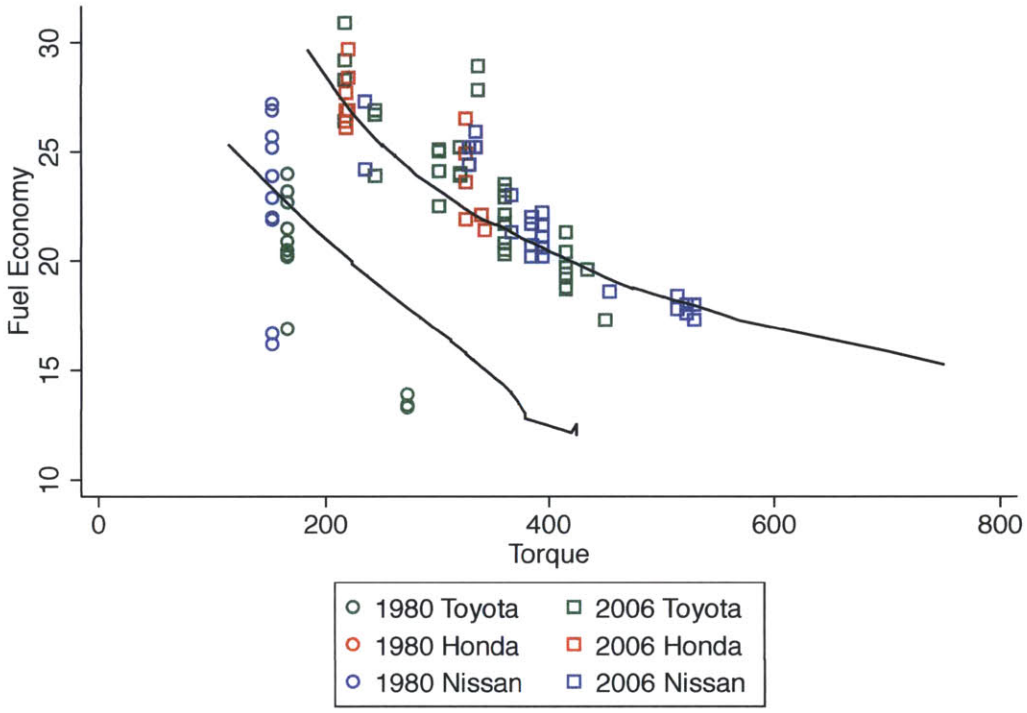
Japanese models only included models with two different values for horsepower in 1980. In 2006, they produced more variety, but very limited compared to their US counterparts.



Fuel Economy vs Torque

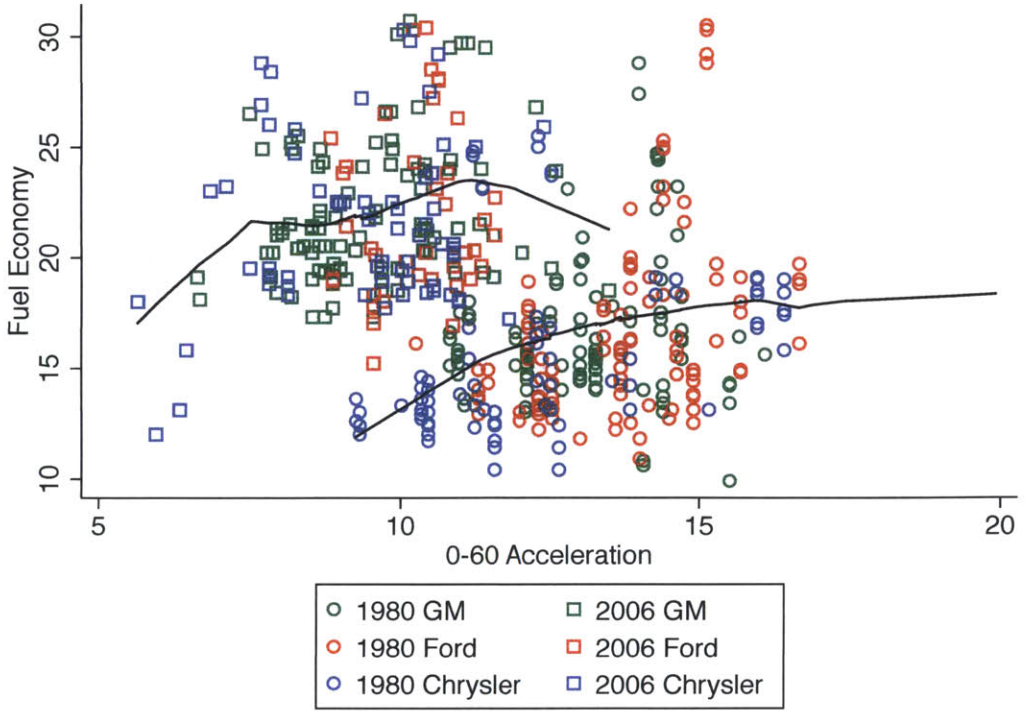
The US and Japanese truck plots for fuel economy and torque are shown below. The results are very similar to horsepower plots above.



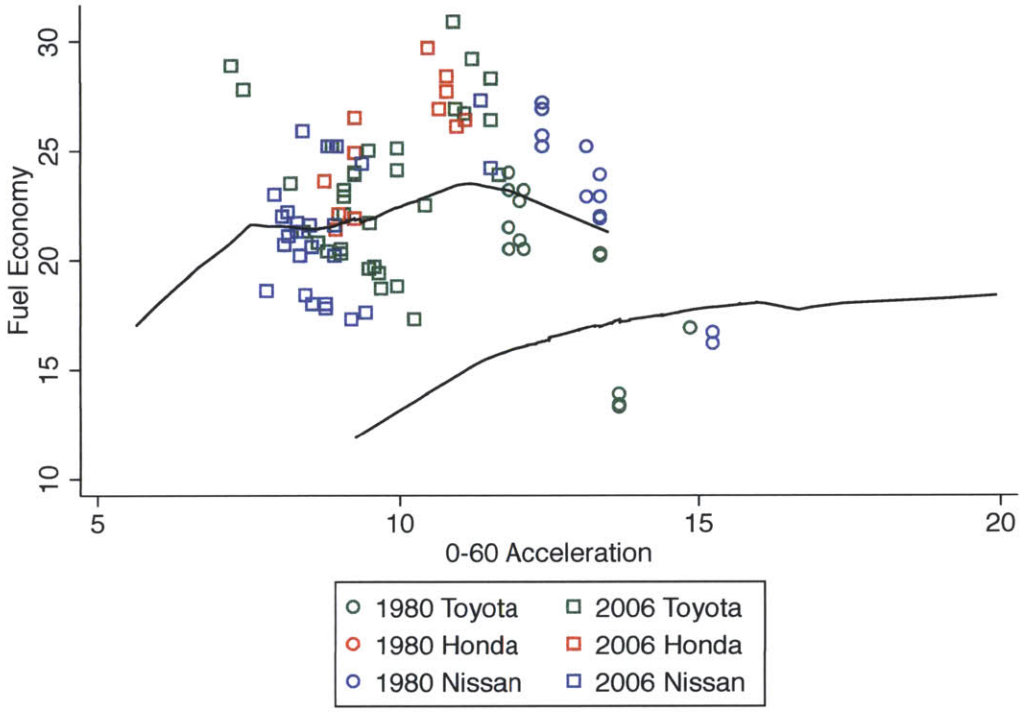


Fuel Economy vs 0-60 Acceleration Times

US manufacturers produced truck models with a wide variety of acceleration times.



Japanese, unlike their car models, produced lower fuel economy models in 1980 compared to the industry average, while keeping the acceleration times in the middle of the pack. In 2006, fuel economy for Japanese trucks improved, but their acceleration times were mid to high compared to the industry.



Quartile Analysis

Passenger Vehicles

It is helpful to look at the car models grouped in quartiles. For example, if we look at all the car models that fall in the lowest quartile based on curb weight and see how the US manufacturers designed those models with respect to their average fuel economy compared to Asian manufacturers and over time (in 1980 vs in 2006), we may gain some knowledge of the different manufacturers' strategies.

This is achieved by using the following STATA code.

```
#delimit;
egen curbwt_quartile = xtile(curbwt) if d_truck==0, nq(4) by(year);
lowess mpg curbwt, generate(mpg_curbwt_lowess_1980), if d_truck==0 & year==1980 & outlier ==
    0 & fuel == "G" & mpg<50;
lowess mpg curbwt, generate(mpg_curbwt_lowess_2006), if d_truck==0 & year==2006 & outlier ==
    0 & fuel == "G" & mpg<50;
gen curbwt_lowess_diff_1980 = mpg - mpg_curbwt_lowess_1980;
```

```
table curbwt_quartile, c(mean curbwt_lowess_diff_1980 sd curbwt_lowess_diff_1980), if
    d_truck==0 & year==1980 & outlier == 0 & fuel == "G" & mpg<50 & US == 1;
table curbwt_quartile, c(mean curbwt_lowess_diff_1980 sd curbwt_lowess_diff_1980), if
    d_truck==0 & year==1980 & outlier == 0 & fuel == "G" & mpg<50 & ASIAN == 1;
gen curbwt_lowess_diff_2006 = mpg - mpg_curbwt_lowess_2006;
table curbwt_quartile, c(mean curbwt_lowess_diff_2006 sd curbwt_lowess_diff_2006), if
    d_truck==0 & year==2006 & outlier == 0 & fuel == "G" & mpg<50 & US == 1;
table curbwt_quartile, c(mean curbwt_lowess_diff_2006 sd curbwt_lowess_diff_2006), if
    d_truck==0 & year==2006 & outlier == 0 & fuel == "G" & mpg<50 & ASIAN == 1;
```

The above STATA code can be explained as follows. First, we group each model of the car into one of the quartiles based on the curb weight of the car. We then generate average fuel economy vs curb weight curve of all the cars for the entire industry. We also generate, for each model of the car, the deviation from the average fuel economy (corresponding to its curb weight), positive numbers being better than the average, negative numbers being worse than the average. We perform this analysis in the year at the beginning of the data (1980), and at the end of the data (2006).

In this section, we examine the data using quartile analysis using the parameters curb weight, horsepower, torque, and 0-60 acceleration time. Please note that the above STATA code only shows the example for curb weight, whereas extending this code to do the other parameters is done by replacing curb weight with other parameters of interest.

For each of these parameters, we show the mean and standard deviations of the fuel economy (positive numbers being better than the industry average, and negative numbers being worse than the average) for each quartile for US and Asian manufacturers, and in 1980 and 2006. Positive numbers for the mean indicate that fuel economy is better than the industry average.

Fuel Economy vs Curb Weight

It is interesting to note that Asian manufacturers did not even produce models that fall in 3rd and 4th quartiles in 1980. In the comparable quartiles, Asian manufacturers performed better in fuel economy on an average. In 2006, US manufacturers produced their heavier car models with higher fuel economy than the industry average by a significant amount, but not as well as Asian manufacturers.

	Fuel Economy							
	1980				2006			
	US		Asian		US		Asian	
Curb Weight Quartile	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	0.2498069	2.242174	0.5771255	3.629991	-0.3653933	3.342821	-0.2520195	3.300496
2	-0.0118597	1.91633	0.8526041	2.553557	-0.3657707	3.206368	1.372309	2.45687
3	-0.0937747	1.310309			-0.7000722	3.20283	1.295913	1.795715
4	-0.0680102	1.159223			0.6440694	2.179419	0.8614915	0.8943554

Fuel Economy vs Horsepower

In 1980, Asian manufacturers produced models with clearly better fuel economy than US models when compared to the quartiles based on horsepower. However, in 2006, Asian models outperformed in the 3rd and 4th quartiles compared to both industry average as well as US models, whereas they underperformed in the 1st and 2nd quartiles (lower horsepower).

Horsepower Quartile	Fuel Economy							
	1980				2006			
	US		Asian		US		Asian	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	0.2143109	4.182676	0.6100826	3.392392	-0.0799775	3.39755	-0.4773668	2.97981
2	-1.295139	2.791667	1.529701	4.686491	-0.367804	4.550875	-0.7827604	1.858138
3	-1.115537	1.987137	2.570414	0.8085599	-0.9685181	4.36403	0.3835433	2.012028
4	-0.4093557	1.026126			0.1088537	2.320545	0.6132038	1.108606

Fuel Economy vs Torque

In the distribution of the models based on torque, Asian manufacturers only produced lower torque models in 1980. In the first quartile, they produced higher fuel economy models, but in the second quartile, they produced lower fuel economy models. In 2006, things got reversed. In the 1st quartile, Asian models had worse fuel economy, and in the other quartiles, they had better fuel economy.

Torque Quartile	Fuel Economy							
	1980				2006			
	US		Asian		US		Asian	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	0.8062689	4.237989	1.323965	4.030797	0.3048743	2.075773	-0.2825634	2.62635
2	-0.191884	1.937832	-1.077953	1.2466	-0.1610226	2.05127	-0.8724669	1.970832
3	0.2251463	0.9790941			-1.041501	1.288838	0.5996273	1.361231
4	0.0188433	0.9578004			0.215609	2.669926	0.9026968	0.7941341

Fuel Economy vs 0-60 Acceleration Times

Based on the acceleration times, Asian manufacturers produced better fuel economy cars in every category both in 1980 and 2006. Clearly, Asian manufacturers focused on optimizing fuel economy for a given acceleration.

0-60 Acceleration Times Quartile	Fuel Economy							
	1980				2006			
	US		Asian		US		Asian	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	-1.191194	3.788297	3.347677	4.905844	0.6447004	2.755628	1.617638	1.398666
2	-1.02604	4.487826	5.439997	5.007674	-0.9099927	2.29723	1.272243	2.056278
3	-1.979564	3.343056	7.141424	4.840593	-0.9041863	2.95728	1.172232	2.675548
4	-0.923572	2.798047	7.023029	3.783779	-0.9592058	4.763036	1.219124	4.16868

Light Trucks

Here we present the results of the quartile analysis done for the light trucks.

Fuel Economy vs Curb Weight

In the case of light trucks, Asian manufacturers produced higher fuel economy in lighter trucks, and lower fuel economy in heavier trucks.

Curb Weight Quartile	Fuel Economy							
	1980				2006			
	US		Asian		US		Asian	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	-0.6507335	3.005495	0.7933394	3.28037	-0.7132931	2.274085	0.2535039	1.963651
2					0.0596701	1.783605	-0.0696595	1.737944
3	0.385679	2.05986	-2.276353	0.3214306	-0.3042049	1.287522	0.928467	3.105154
4	-0.0048305	1.405283			-0.053646	1.431333	-0.5986082	0.3343548

Fuel Economy vs Horsepower

In 1980, Asians produced better fuel economy trucks in the 1st quartile, whereas in 2006, they were able to achieve that in 2nd and 3rd quartiles.

Horsepower Quartile	Fuel Economy							
	1980				2006			
	US		Asian		US		Asian	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	0.1635034	2.737234	1.232727	3.524915	-0.8401604	3.763797	-0.4828427	2.103575
2	0.126789	1.834506	-4.206182	0.3215143	-0.6879914	2.417036	1.569663	4.808697
3	0.1061041	1.526481			-0.2591166	2.527229	0.418569	2.477577
4	-0.2123156	1.000437			0.7853503	4.773789	-0.0561515	5.358344

Fuel Economy vs Torque

Horsepower and torque characteristics are very similar.

Torque Quartile	Fuel Economy							
	1980				2006			
	US		Asian		US		Asian	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	0.1151148	2.526257	0.6423634	3.710285	-0.1040466	2.09999	-0.3612044	1.63022
2	-0.04183	1.901686	-4.340338	0.3213772	-0.0093324	2.262394	0.8759907	2.665821
3	0.4211921	1.498054			-1.08031	0.9479443	0.1993285	1.112194
4	-0.1673847	0.9122134			0.0506701	1.374706	-0.5903808	0.7776663

Fuel Economy vs 0-60 Acceleration Times

In 1980, Asians substantially did better than their US counterparts in terms of average fuel economy in each of the quartiles. In 2006, the gap is lower, but still better than US models.

0-60 Acceleration Times Quartile	Fuel Economy							
	1980				2006			
	US		Asian		US		Asian	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	-0.3722732	2.73651	6.119542	1.397873	-0.1733245	2.764703	1.049134	2.794739
2	-0.6601435	2.833785	8.723341	1.753095	-1.017906	2.660204	0.5876657	2.386901
3	-0.4296549	3.610902	4.07814	4.405724	-0.2035493	3.610321	1.563022	4.067983
4	-0.3470575	3.819128	7.667242	6.573361	-0.9507861	3.357338	2.294076	2.949219

Yearly Data

We can also look at the data for each of the group of manufacturers (US and ASIAN) from year to year to see if there is a trend in their approach to bringing models to the market. The interesting parameters are obviously the fuel economy, curb weight, horsepower, torque, and 0-60 acceleration times.

Passenger Vehicles

The following STATA code generates averages of these parameters for all the models from US manufacturers for each year from 1980 to 2006:

```
table year, c(mean mpg mean curbwt mean hp mean torque mean accel), if d_truck==0 & outlier == 0 & fuel == "G" & mpg<50 & US == 1
```

A similar dataset can be generated for the models produced by ASIAN manufacturers using the following STATA code:

```
table year, c(mean mpg mean curbwt mean hp mean torque mean accel), if d_truck==0 & outlier == 0 & fuel == "G" & mpg<50 & ASIAN == 1
```

The two sets of data that was generated is tabulated below:

	US					ASIAN				
Year	Fuel Economy	Curb Weight	Horsepower	Torque	0-60 Accel	Fuel Economy	Curb Weight	Horsepower	Torque	0-60 Accel
1980	20.93281	3244.47	118.578	262.3416	13.010487	28.61892	2308.16	83.1757	135.2176	13.06038
1981	22.95462	3116.67	111.412	239.3373	13.23274	30.77089	2308.35	84.0127	138.662	13.023646
1982	25.181	2959.69	105.229	215.2108	13.222152	31.36625	2312.49	88.4875	143.02	12.778884
1983	26.70096	2873.06	104.984	205.4347	12.977373	32.25604	2382.55	90.8132	146.044	12.742686
1984	26.97919	2858.37	111.097	210.2473	12.417961	32.14157	2345.37	94.9213	151.0786	12.240806
1985	27.94257	2782.85	113.277	206.2671	12.05726	31.80084	2374.07	97.3529	153.8899	12.078859
1986	28.31901	2794.47	116.383	214.2956	11.886714	31.58333	2453.68	101.942	158.3642	11.919915
1987	28.76469	2764.22	118.083	214.4066	11.664085	31.33694	2484.15	105.185	159.3395	11.74986
1988	28.90374	2813.32	122.558	220.6782	11.479766	30.91933	2542.6	112.3	167.0847	11.467613
1989	28.51544	2874.57	128.776	226.5776	11.282144	31.31589	2533.68	112.689	162.0146	11.321994
1990	27.82195	2930.95	138.081	230.0171	10.848984	30.76042	2631.22	124.361	171.1833	10.892989
1991	27.89299	2921.67	140.502	234.283	10.702207	30.22222	2650.93	132.64	181.4085	10.401516
1992	27.72692	2957.27	144.643	237.9801	10.560756	29.93925	2704.08	137.925	188.1027	10.270048
1993	28.16287	3019.01	148.415	238.2699	10.654519	29.60846	2828.5	143.761	194.4507	10.315736
1994	27.84453	3032.88	159.351	247.4257	10.197098	29.5413	2853.15	147.13	198.7033	10.203441
1995	27.77619	3163.3	169.562	260.3429	9.9064762	30.09944	2866.59	150.028	201.0539	10.026658
1996	28.15182	3124.77	173.15	256.9759	9.6340249	30.47169	2798.83	149.795	202.841	9.8133654
1997	28.38571	3112.11	169.537	251.4229	9.7915807	30.46204	2882.34	151.124	205.2993	9.9453653
1998	28.56879	3113.27	172.866	251.2803	9.6838291	30.00769	2951.61	162.803	220.1624	9.5908382
1999	27.95871	3142.4	183.697	267.6839	9.3451841	30.37795	2874.75	156.89	212.9134	9.5870665
2000	28.3	3171.53	179.481	259.9481	9.4715071	30.53507	2829.74	152.179	202.6716	9.6547486
2001	28.1	3161.52	188.125	271.5764	9.1163629	30.50138	2864.4	152.559	204.2	9.7261062
2002	28.18284	3206.72	188.522	273.3881	9.1485853	30.2	2929.43	162.493	218.625	9.4469934
2003	28.19722	3289.86	187.796	272.0278	9.2463462	30.01223	2988.46	174.763	231.9281	9.0621956
2004	27.71732	3348.43	205.299	295.063	8.9107644	29.80059	3008.35	179.249	236.7811	8.9496161
2005	27.065	3404.39	220.717	307.275	8.5829796	29.82057	3007.66	183.006	239.6057	8.8351089
2006	26.35161	3480.06	239.96	334.0726	8.1981378	29.79877	3131.5	189.043	247.0982	8.9125229

It is clear the US manufacturers opted for lower fuel economy, higher curb weight, higher horsepower, and higher torque models on an average throughout all the years from 1980 to 2006 compared to their Asian counterparts. Average acceleration times, however, are very similar.

Light Trucks

Similar analysis for the trucks results in the data as shown below in the table:

	US					ASIAN				
Year	Fuel Economy	Curb Weight	Horsepower	Torque	0-60 Accel	Fuel Economy	Curb Weight	Horsepower	Torque	0-60 Accel
1980	15.90963	4013.58	145.375	323.0816	12.954696	23.31818	2672.05	90	159.5091	13.461433
1981	17.42044	3961.12	135.188	303.2654	13.589738	24.92364	2788.45	94.0909	156.0145	13.44192
1982	18.52769	3905.82	130.877	290.3231	13.712476	25.44167	2756.9	91.8214	147.5619	13.601735
1983	19.94147	3749.24	122.897	267.9444	13.939626	25.7141	2766.67	93.2308	157.8731	13.507334
1984	19.89376	3822.78	121.849	262.5945	14.315281	25.91818	2795.08	94.0152	154.9197	13.563536
1985	19.50917	3676.62	134.346	286.9698	12.937228	26.47674	2762.86	98.4651	169.6861	12.978032
1986	20.12835	3675.05	134.766	282.9425	12.839223	26.03562	2760.34	101.452	171.8219	12.77353
1987	20.16772	3623.68	137.711	285.6074	12.566317	25.63626	2890.63	99.978	169.1253	13.323239
1988	19.81395	3801.71	155.51	310.7404	11.875336	24.82442	2995.52	110.105	181.4674	12.732862
1989	19.64716	3931.11	156.313	310.8475	12.086975	24.51277	3045.1	115.787	188.8532	12.437563
1990	19.75694	3923.45	157.803	311.0529	11.978594	24.66075	3114.78	119.523	188.843	12.311977
1991	19.23902	4045.42	165.377	326.1118	11.808135	23.42667	3282.74	121.678	200.5678	12.708276
1992	19.74389	4142.74	171.416	322.2568	11.697964	22.74524	3501.76	128.452	209.9417	12.843263
1993	19.80338	4160.47	172.52	323.8574	11.679055	22.50814	3502.33	130.733	211.2361	12.643362
1994	20.27276	4134.56	173.23	323.3121	11.597849	22.4427	3556.74	140.742	225.4798	12.065347
1995	19.64315	4266.81	179.685	335.4987	11.52317	22.57303	3580.62	149.326	232.8618	11.605081
1996	20.30346	4010.17	191.301	330.1879	10.542786	22.81667	3557.18	157.889	235.5472	11.01566
1997	20.08919	4269.43	201.264	357.3987	10.524318	23.22941	3495.44	153.235	236.8235	11.179224
1998	20.66667	4137.46	194.372	330.4645	10.547922	24.49184	3393.02	152.551	229.898	10.956266
1999	20.14587	4155.8	200.225	351.0367	10.370093	23.92569	3483.52	161.385	236.2936	10.671555
2000	20.49902	4240.3	207.25	350.3235	10.30908	22.98636	3597.88	166.982	254.1636	10.642087
2001	20.31215	4159.16	210.411	348.7944	10.002233	22.7525	3674.15	174.925	258.7417	10.437047
2002	20.30386	4210.47	215.876	350.4206	9.9030323	22.73731	3677.86	176.53	262.0821	10.358861
2003	20.72252	4168.65	218.95	347.2061	9.7582193	22.93902	3728.24	186.423	280.7236	10.050294
2004	21.04042	4242.96	229.879	354.2583	9.5157798	22.83235	3850.93	199.36	301.2353	9.8067827
2005	21.30153	4294.98	237.782	357.8812	9.4066141	23.82188	3838.51	210.297	304.4844	9.4092404
2006	21.61333	4490.24	241.048	360.5778	9.6061404	23.70667	4053.82	211.919	308.8518	9.7724057

Even for light trucks, the strategies are very similar as for the passenger cars. Initially, in 1980, Asian manufacturers produced higher fuel economy trucks with lower curb weight, lower horsepower, lower torque, but similar acceleration. As the years go by, US manufacturers improved fuel economy of their models, while Asian manufacturers increased the curb weight, horsepower, and torque of their models. In 2006, even though the differences are less pronounced, the differences did exist similar to 1980 models.

Regression Analysis

In the previous sections, we thoroughly explored the data and saw there are distinctive differences between US and Asian manufacturers' strategies in their approaches to the passenger car market. To be able to quantify the differences, we will run regressions on the data.

To set up the regression problem, we will first model the problem as follows:

$$\ln mpg_{it} = T_t + \beta_1 \ln w_{it} + \beta_2 \ln hp_{it} + \beta_3 \ln t_{it} + X'_{it}B + \varepsilon_{it}$$

Passenger Vehicles

We run the baseline regression for passenger vehicles in the entire industry using

```
xi: reg lmpg lcurbwt lhp ltorque d_manual time_d_manual d_diesel d_turbo d_super i.year,
  cluster(mfr), if d_truck==0&outlier==0;
```

Note that the dummy variables d_manual, time_d_manual, d_diesel, d_turb, d_super are used to control for the appropriate variables in the differences in the passenger car models.

Fuel Economy

In order to better understand the differences in various segments of the cars (such as cars with lower horsepower engines or cars with higher horsepower engines, we first divide the data into four quartiles based on the horsepower, using the following STATA code:

```
egen hp_quartile = xtile(hp), nq(4) by(year);
```

We then generate dummy variables denoting the first and fourth quartiles for US and Asian manufacturers, using the following STATA code:

```
gen hp_q1 = hp_quartile == 1;
gen hp_q4 = hp_quartile == 4;
gen hp_q1_us = hp_q1*US;
gen hp_q4_us = hp_q4*US;
gen hp_q1_asia = hp_q1*ASIAN;
gen hp_q4_asia = hp_q4*ASIAN;
```

We then add the dummy variables to the regression using

```
xi: reg lmpg lcurbwt lhp ltorque d_manual time_d_manual d_diesel d_turbo d_super i.year
  hp_q1_us hp_q4_us hp_q1_asia hp_q4_asia, cluster(mfr), if d_truck==0&outlier==0;
```

We can also look at the differences in the manufacturers' strategies in the first half of the data (1980-1992) and the second half of the data (1994-2006) using

```
xi: reg lmpg lcurbwt lhp ltorque d_manual time_d_manual d_diesel d_turbo d_super i.year
  hp_q1_us hp_q4_us hp_q1_asia hp_q4_asia, cluster(mfr), if d_truck==0&outlier==0&year<1993;
```

```
xi: reg lmpg lcurbwt lhp ltorque d_manual time_d_manual d_diesel d_turbo d_super i.year
  hp_q1_us hp_q4_us hp_q1_asia hp_q4_asia, cluster(mfr), if d_truck==0&outlier==0&year>1993;
```

Further, we can look at the differences in the manufacturers' strategies in the first five years of the data (1980-1984) and the last five years of the data (2002-2006) using

```
xi: reg lmpg lcurbwt lhp ltorque d_manual time_d_manual d_diesel d_turbo d_super i.year
  hp_q1_us hp_q4_us hp_q1_asia hp_q4_asia, cluster(mfr), if d_truck==0&outlier==0&year<1985;
```

```
xi: reg lmpg lcurbwt lhp ltorque d_manual time_d_manual d_diesel d_turbo d_super i.year
  hp_q1_us hp_q4_us hp_q1_asia hp_q4_asia, cluster(mfr), if d_truck==0&outlier==0&year>2001;
```

The results are shown in the table below.

Variables	Regression Coefficients					
	Baseline	1980-2006	< 1985	< 1993	> 1993	> 2001
lcurbwt	-0.3976935	-0.3747836	-0.4898609	-0.4807562	-0.2403173	-0.2184095
lhp	-0.324056	-0.3292586	-0.2631603	-0.3117071	-0.3309473	-0.3336272
ltorque	-0.0193133	-0.038563	-0.0293771	-0.0036767	-0.0817514	-0.1102992
hp_q1_us		0.0105951	0.0203046	0.0206769	0.0079559	-0.0051936
hp_q4_us		0.0494501	0.0139848	0.0449726	0.0583551	0.050818
hp_q1_asian		0.0101449	0.0311548	0.0144347	0.0135502	0.005224
hp_q4_asian		0.0630182	0.0397879	0.0592752	0.0656221	0.0759902
test _b(hp_q4_us) = _b(hp_q4_asian)		0.3051	0.3214	0.1906	0.7728	0.4535

These coefficients show that there are differences in the models' fuel economy between smaller horsepower models and larger horsepower models from both US and Asian manufacturers. The differences between US and Asian manufacturers, however, are small.

The numbers in the last row show the confidence level in the differences in 4th quartile models of US and Asian models' effects on the fuel economy. The small differences in the coefficients in "<1985", "<1993", are significant, whereas the others are not.

The above regression is repeated by looking at quartiles based on curb weight rather than horsepower, based on our observation that it is the biggest differentiator between US models and Asian Models. The results are in the table below.

Variables	Regression Coefficients					
	Baseline	1980-2006	< 1985	< 1993	> 1993	> 2001
lcurbwt	-0.3976935	-0.4022056	-0.503236	-0.5002146	-0.2734587	-0.2387833
lhp	-0.324056	-0.303267	-0.2466669	-0.2868582	-0.317789	-0.3267624
ltorque	-0.0193133	-0.0456049	-0.0392321	-0.0167031	-0.0730346	-0.0965538
curbwt_q1_us		0.0180281	0.02093	0.0273977	0.0094601	-0.0069748
curbwt_q4_us		0.0463196	0.0188078	0.0450765	0.0501945	0.0409322
curbwt_q1_asian		0.0171941	0.0269455	0.0196844	0.0206529	0.021342
curbwt_q4_asian		0.0697018	0.1797038	0.0810008	0.0564045	0.0232009
test _b(curbwt_q4_us) = _b(curbwt_q4_asian)		0.0656	0.1737	0.0168	0.7074	0.4569

As can be seen, the coefficients for heavier car models, there are significant differences between US models and Asian models. The differences have gone down for the second half of the data (after 1993), but the differences are still significant.

Pricing Effects

The pricing of a model of a car in the market is obviously related to the specifications of the model itself, such as fuel economy, weight, horsepower, and torque. We can obtain the effects of the specifications on the price using the following regression:

```
xi: reg lprice lmpg lcurbwt lhp ltorque d_manual time_d_manual d_diesel d_turbo d_super i.year,
  cluster(mfr), if d_truck==0&outlier==0;
```

Similar to before, we can also control for US and ASIAN models, small and large car models based on the curb weight, using:

```
xi: reg lprice lmpg lcurbwt lhp ltorque d_manual time_d_manual d_diesel d_turbo d_super i.year
  curbwt_q1_us curbwt_q4_us curbwt_q1_asia curbwt_q4_asia, cluster(mfr), if
  d_truck==0&outlier==0;
```

We can also look at the dependency for the first half of the data (before 1993), and the last half of the data (after 1993), using

```
xi: reg lprice lmpg lcurbwt lhp ltorque d_manual time_d_manual d_diesel d_turbo d_super i.year
  curbwt_q1_us curbwt_q4_us curbwt_q1_asia curbwt_q4_asia, cluster(mfr), if
  d_truck==0&outlier==0&year<1993;
```

```
xi: reg lprice lmpg lcurbwt lhp ltorque d_manual time_d_manual d_diesel d_turbo d_super i.year
  curbwt_q1_us curbwt_q4_us curbwt_q1_asia curbwt_q4_asia, cluster(mfr), if
  d_truck==0&outlier==0&year>1993;
```

	Regression Coefficients			
Variables	**Baseline**	**1980-2006**	**< 1993**	**> 1993**
lmpg	-0.62177	-0.5162839	-0.5865077	-0.4989231
lcurbwt	0.5573238	0.8688583	0.9165371	0.991459
lhp	1.326773	1.218826	1.278642	1.034906
ltorque	-0.6729607	-0.4857643	-0.8270578	-0.1331331
curbwt_q1_us		0.0928293	0.0420309	0.1502711
curbwt_q4_us		-0.2700715	-0.1609718	-0.3185723
curbwt_q1_asian		0.0890889	0.0444557	0.1641266
curbwt_q4_asian		-0.1198829	-0.1666983	-0.0785915
test _b(curbwt_q4_us) = _b(curbwt_q4_asian)		0.0111	0.9121	0.0025

It is interesting to note that the fuel economy is inversely correlated to the price of a car, whereas the weight and horsepower positively correlated to the car.

The car prices do not have any effect whether they are from US manufacturers or Asian manufacturers, interestingly enough, except for heavier cars from the US, in which case it is negatively correlated.

Technological Trends

Original Knittel's paper shows that the technological improvements over the years were the primary reason for the improvements in the fuel economy over the years. This is done by running the regression as follows:

```
xi: reg lmpg lcurbwt lhp ltorque d_manual time_d_manual d_diesel d_turbo d_super i.year,
  cluster(mfr), if d_truck==0&outlier==0;
```

The coefficients for i.year show the improvements in technology from year to year.

To see if there are any differences in these improvements in US and Asian manufacturers, we run the regression by controlling for year and manufacturer, as follows:

```
xi: reg lmpg lcurbwt lhp ltorque d_manual time_d_manual d_diesel d_turbo d_super i.US*i.year
  i.ASIAN*i.year, cluster(mfr), if d_truck==0&outlier==0&year;
```

The results show that the differences in technological improvements in US and Asian manufacturers are not significant, which means that the technological improvements are uniform in both US and Asian manufacturers.

Light Trucks

We also performed similar regressions as above to the light truck models. The results are presented in this section.

Fuel Economy

The table below shows the regression coefficients for the light trucks based on horsepower quartiles. The coefficients for the lower quartile based on horsepower from US vs Asian manufacturers are very similar. The coefficients for hp_q4_us and hp_q4_asian for the first half of the data do significantly differ (-5.6% vs -18%). This shows that Asian manufacturers were able to achieve better fuel economy in trucks with higher horsepower.

Variables	Regression Coefficients					
	Baseline	1980-2006	< 1985	< 1993	> 1993	> 2001
lcurbwt	-0.3632854	-0.36311	-0.455148	-0.3746648	-0.3242124	-0.2968799
lhp	-0.0467103	0.0210153	0.0578087	0.0732914	-0.0715934	0.1005738
ltorque	-0.2774368	-0.2901936	-0.2489401	-0.318729	-0.2298423	-0.4677607
hp_q1_us		0.0269117	0.0560777	0.0415142	0.0065277	-0.0283469
hp_q4_us		-0.0309619	-0.0538785	-0.0564966	0.0068172	0.0435146
hp_q1_asian		0.0055982	0.0199867	0.0093515	0.002713	-0.0412202
hp_q4_asian		0.0166282	N/A	-0.1836835	0.03782	0.0804265
test _b(hp_q4_us) = _b(hp_q4_asian)		0.061	N/A	0	0.2242	0.0551

The table below shows the regression coefficients for the light trucks based on curb weight quartiles. Again, the coefficients of fourth quartiles based on curb weight differ for US and Asian manufacturers for the early years.

Variables	Regression Coefficients					
	Baseline	1980-2006	< 1985	< 1993	> 1993	> 2001
lcurbwt	-0.3632854	-0.3659019	-0.4527381	-0.3639496	-0.3341848	-0.3935556
lhp	-0.0467103	-0.0466755	-0.0711963	-0.0592949	-0.0687241	0.1812902
ltorque	-0.2774368	-0.27818	-0.2260698	-0.2899035	-0.229365	-0.4599103
curbwt_q1_us		0.0014532	0.0097502	0.0111835	-0.0127702	-0.0312455
curbwt_q4_us		0.002718	0.0053345	0.0037405	-0.0009914	0.0287795
curbwt_q1_asian		-0.0031666	-0.0005846	-0.0032528	0.000381	-0.0284181
curbwt_q4_asian		-0.0220038	-0.178232	-0.275993	-0.0069303	0.0359518
test _b(curbwt_q4_us) = _b(curbwt_q4_asian)		0.5331	0.0034	0	0.8482	0.8295

Pricing Effects

The table below shows pricing regressed on other variables as performed for the passenger vehicles. In the case of trucks, it is interesting to note that curb weight is the most significant determinant of the price of the truck. Fuel Economy (so is torque) is negatively correlated to the price, even though the negative correlation reduced from the first half to the last half of the data.

Variables	Regression Coefficients			
	Baseline	1980-2006	< 1993	> 1993
lmpg	-0.18474	-0.1810293	-0.3267704	-0.0792279
lcurbwt	0.4801322	0.3533669	0.1875851	0.611805
lhp	0.3241113	0.3405111	0.1217151	0.5250815
ltorque	-0.2615312	-0.2882602	-0.2373506	-0.2427158
curbwt_q1_us		-0.0555292	-0.0473338	-0.0381582
curbwt_q4_us		-0.0015309	0.0299266	-0.0731569
curbwt_q1_asian		-0.1263166	-0.1555511	-0.059068
curbwt_q4_asian		0.2603299	-0.1506543	0.2359103
test _b(curbwt_q4_us) = _b(curbwt_q4_asian)		0.0112	0.0153	0.0263

The coefficients also seem to suggest that there are no significant advantages by the fact that a model is from US or from Asia. But, the Asian manufacturers were able to achieve more pricing advantage in the second half of the data than the first half for the heavier models. This shows that Asian manufacturers not only entered the market of light trucks, but were able to effectively compete with the US models by the end of this period.

Technological Trends

As with the passenger vehicles, both US and Asian models performed better over the years. However, there are no significant differences between US and Asian models.

Conclusion

We examined automotive sector data from 1980 to 2006 in a very thorough fashion. We showed that there are some similarities and some differences between what US manufacturers focused on compared to the Asian manufacturers over this period. The similarities are as follows:

- Both US and Asian manufacturers improved the fuel economy from 1980 to 2006.

- The technological improvements used by both the groups had similar impact on fuel economy over this period.

The differences are as follows:

- Asian manufacturers produced smaller cars (and trucks) in 1980.
- Asian manufacturers focused on higher fuel economy cars (and trucks) over this entire period, compared to US manufacturers who tended to produce larger cars with lower fuel economy.
- Asian manufacturers preferred fuel economy and acceleration, while US manufacturers preferred other parameters such as weight, horsepower, and torque at the cost of fuel economy and acceleration.

Clayton Christensen[2] describes Toyota as one of the examples of the disruptive companies in his books about disruption. He explains that Toyota caused the disruption by bringing smaller cars to the market at a lower price point, which the existing US and European companies ignored as the profit margins on these cars are low. We also know from the literature that Toyota introduced the Toyota Production System, which resulted in reliable cars, and the reliability was highly valued by the customers, which also might have helped with the disruption.

Studying the data from 1980 to 2006, we might have uncovered yet another reason for the disruption. The data showed that, on an average, Asian manufacturers introduced higher fuel economy models while keeping acceleration times comparable. It is possible that the fuel economy and acceleration are the two parameters that consumers valued in a passenger car model, and Toyota (and other Japanese manufacturers as well as other Asian manufacturers) focused on, and this may also have contributed to this disruption. If this is correct, this may be the most significant contribution of this thesis. Toyota Prius has been a run away hit thanks to the hybrid technology, which was able to achieve higher fuel efficiency, again part of the same strategy.

Asian manufacturers used similar strategy for the trucks as well. They focused on fuel economy and acceleration times. Over these years, they made significant improvements in their market position of the light trucks, but as we know in the market place, they were not able to achieve similar disruption as they did in the passenger car models.

There are exceptions, of course. We have seen, through the data analysis, specific manufacturers changed their strategy over time. Nissan, for example, started with very high fuel economy cars in 1980 to high performance cars (lower fuel economy) in 2006. Through the history, we know that Nissan came close to bankruptcy, and recovered under the leadership of Carlos Ghosn, resurged with their sporty, high powered, high performance cars and trucks.

Finally, TESLA is causing a major stir in the automotive market with the introduction of their fully electric car, Model S. Model S demonstrated, in the market place, that one could achieve high fuel economy

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[2] Christensen, Clayton, M. (1997), *The innovator's dilemma: when new technologies cause great firms to fail*, Boston, Massachussetts, USA: Harvard Business School Press.

while delivering high performance at the same time. Other manufacturers also introduced or in the process of introducing fully electric models in the recent times. At least at the outset, consumers seem to be more worried about the range of an electric car rather than the efficiency of electricity usage in a car. TESLA seems to be betting on longer range, high performance and luxury as the main differentiators compared to the other electric car models in the market place. It will be interesting to see where this market will end up in the next few decades.