Gasoline Prices and the American Auto Industry: Repeated Environmental Shocks in a Unique Framework

Douglas C.M.K. Chun
University of La Verne

Nolan Kido
Chaminade University of Honolulu

Organizational theory suggests organizations may incorporate lessons learned from past experiences into current behaviors and strategies, but not all lessons are integrated equally. We investigate the actions of the American automakers to repeated external shocks in the form of sharp gasoline price increases during the periods of 1973-1974 and 1978-1980 in an attempt to distinguish reactions to these stimuli from reactions to other environmental factors. We find that firms display a quick response to the initial oil shock and respond faster to the subsequent shock and that the auto manufacturers' product mix is highly correlated with the price of gasoline.

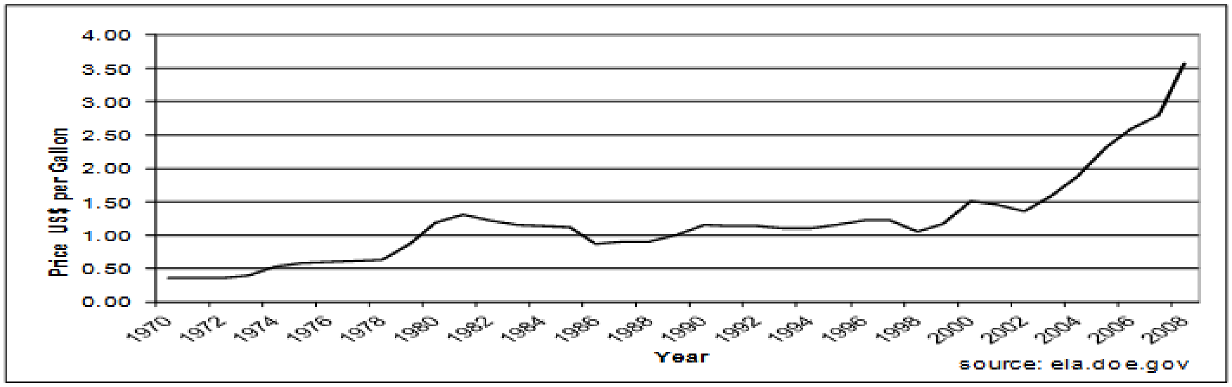
INTRODUCTION

Detroit automakers have been criticized for "not learning from their mistakes" (New York Times (2008): A32) and being slow to react to changes in their external environment (Crain (2007); Naughton (2006)). In late 2008, American automobile manufacturers were faced with record-high gasoline prices and record-low demand for their fuel-inefficient cars. The automakers' very survival depended on their response to this crisis. However, this was not the first gas price shock Chrysler, Ford, and General Motors have had to weather. On two separate occasions—once in 1973-1974 and again from 1978-1980—the automobile industry faced sharp increases in gasoline prices. In 1979, General Motors President Elliott Estes said, "The impact of 1979's fuel shortages and high prices is likely to last longer than it did after the 1973-74 crises. By ignoring gas guzzlers and turning to smaller, fuel efficient cars, consumers seem to be reasserting themselves as our #1 taskmaster" (Ward's Automotive Yearbook (1979): 13). Estes was correct, but did his company—or the other American car companies—learn any lessons from these incidents?

In a similar pattern to the 2007-2008 oil price shock, the two prior oil shocks were preceded by record sales of large cars and followed, after fuel prices had leveled off, by record production of large cars. Even if automakers could not have anticipated the oil crisis prior to 1973, the certainly would have been able to learn following the experience. The lessons taken from the response to the first oil crisis should have improved the companies' response to subsequent crises.

The most recent price spike peaked with the national average price of a gallon of gasoline hitting $4.05 on July 14, 2008. Since that time, gasoline prices have dropped as far $1.68 as of January 5, 2009, before rising again to the high $3 range and it is unlikely that prices will drop to pre-2002 levels (Kraus, 2008; Tuttle, 2014; U.S. Energy Information Administration, 2014). This unique industrial history provides an opportunity to perform an empirical analysis on the learning capabilities of the Big Three auto companies.

FIGURE 1
AVERAGE ANNUAL US GASOLINE PRICE PER GALLON 1970-2008



This paper examines the effect of two separate environmental shocks on the three American automakers. We define a gasoline price shock as being a 20% or greater increase in the price of gasoline on a year-over-year basis (see Table 1 in Appendix). Based on this definition, there were two prior environmental shocks—one in 1973-1974 and one in 1978-1980—and we can use the data from the automakers' response to these shocks to examine the extent of organizational learning within those firms. We identify trends in the auto companies' production strategies as their product mix shifts from larger vehicles to smaller vehicles following each price shock. Additionally we investigate whether American automobile manufacturers react to environmental shocks and attempt to test the speed of their reaction.

LITERATURE REVIEW

Organizational learning theory suggests that some organizations incorporate lessons learned from the past into routines to guide their future behavior (Greve, 1998). Organizations learn from experience and make changes to practices, strategies, and structures depending upon their performance (Baum & Dahlin, 2007). However, the adaptation of new routines entails a change in behavior and the very act of changing behavior increases risk by departing from previously successful strategies (March, 1991). Firms do not always make changes in spite of performance feedback indicating that they should and decision makers may become committed to strategies and methods that are likely to fail (Staw, Sandelands, & Dutton, 1981). Thus prior research indicates that organizations attempt to learn from past experience, but do not necessarily learn lessons which are useful in dealing with future problems, and occasionally adopt bad habits and learn the wrong lessons from prior experience.

Blind commitment to strategies leading to stagnation or decline and learning the wrong lessons are not the only possible negative outcomes from misinterpretation of environmental conditions. Another serious mistake would be to interpret feedback in a way that justifies inaction (Millikent & Lant, 1991), otherwise known as inertia. Learning, does not always lead to change, and not all shocks inspire change in a firm.

Although there are many factors that would lead to inaction in a firm, it is unclear would it take to break this inaction in the face of information that indicates change would be helpful to the firm. While Morrison (2002) and Nohrstede ((2005)) noted that not all shocks lead to change, Cyert and March (1963) suggested that although organizations are basically inert, external shocks can stimulate learning and lead to change. A view incorporating both inertia and change is suggested by Weick and Quinn (1999), who proposed that episodic organizational changes are infrequent, discontinuous, and intentional and are frequently triggered by external events. This concept provides an allowance for the fact that not all shocks lead to change. We suggest that perhaps multiple shocks, separated by periods of relative calm, would wear down the barriers to change and result in routines that are reinforced and defined in greater detail with each incident.

HYPOTHESES

The first hypothesis takes a positive stance in strategic management theory; that the process from which industry structure emerges is dynamic and evolutionary (Hariharan & Prahalad, 1994). Companies are assumed to be able to spot market trends and environmental conditions and react accordingly. Because past experience demonstrates a strong correlation between increases in the price of gasoline and higher demand for fuel efficient cars, we hypothesize that in an environment of high (relative to the immediate past) gas prices, fewer cars with V-8 engines should be produced and more cars with V-6 and V-4 engines should be produced.

> *Hypothesis 1a) Past experience with gasoline shocks will result in a faster, more pronounced reaction from American automobile companies in the form of more four and six cylinder models and greater overall production of four and six cylinder vehicles.*

At the opposite end of the spectrum is the possibility that a firm could learn from its experiences, but through its own selective bias, an inability to see the changes that are occurring in the environment, simple misinterpretation of the environmental signs, or because of internal politics, ignore the previous lessons. Sometimes lessons to be learned from experience are not necessarily clear, and the ambiguity and paucity of their experience may cause firms to learn the wrong thing (Baum & Ingram, 1998). In this case, misinterpretation of the environmental shocks could lead to the dismissal of the strategic implications of a long term increase in retail gasoline prices.

> *Hypothesis 1b) Competitive inertia will cause American automobile companies to ignore market trends toward smaller, more efficient cars and to continue to emphasize power and size over fuel economy in their product mix.*

If the auto companies had learned the wrong lesson, it is also possible that they had decided that oil shocks would not occur again or at least would not occur for some time. The benefits of continuing to exploit older, more trusted technology may seem more inviting than attempting to develop new ones in an area in which the firm is less familiar (Levitt & March, 1988). While the technologies involved in producing large cars are always being updated, American automakers are certainly more familiar with producing large cars than small ones. This large car "comfort zone" may, in turn, lead the firms to the assumption that customers will return to old purchasing habits and thus remain focused on large car production.

> *Hypothesis 1c) Competitive inertia will result in reversions to greater large car production when the public is less focused on fuel economy*.

METHODOLOGY

Dependent Variable

We use the number of cylinders in a car's engine as installed in the factory as a definitive proxy for an automakers' focus. Using alternative specifications, we examine both the raw number and the percentage of vehicles produced at each cylinder class (4, 6, or 8) by the three American auto manufacturers in the U.S. market for domestic sales during each year from 1966 to 1988. We use the percentage of vehicle produced at each cylinder class as the primary dependent variable throughout the paper.

Explanatory Variable

As the price of gasoline is the main focus in this study, we use the price of the lowest grade of retail gasoline sold during a period as the standard measure for gas prices. Since our study ends in 1989, leaded regular gasoline was used throughout our analysis. We examine both nominal and real gas prices (see table 1 above) and retain the nominal price due to quantitative similarity.

Control Variables

Because sales of automobiles generally increase with population, both the percentage, year-over-year population growth and the total population in the United States for each given year were tested as control variables (see table 1 above). Due to quantitative similarity, the total population in the U.S. for a given year was retained for use throughout our paper.

There is large variation in the automobiles produced by American manufacturers throughout the duration of our study. As we are concerned primarily with the number of cylinders in each vehicle's engine, we extract variation due to the make and model differences by including a control variable for every different make and model produced during a given year.

In some specifications, we also include control variables for the horsepower and engine rpm for every vehicle by cylinder and by year. Because data on horsepower and rpm are less complete than data on number of cylinders, we include these control variables only in univariate analysis where their presence does not threaten model viability.

The individual manufacturing company was initially included to test for differences in the reaction speed or timing between the three companies. Because the firms had different management and therefore different strategies, we expected differences in their reactions and reaction times. However, as initial models demonstrated very little between-company variation, we report only the models displayed below. In addition, since the amount of variation between companies is dwarfed by the amount of variation due to other factors, we see (figures 2-4 below) very similar response across companies.

FIGURE 2
GM UNIT PRODUCTION BY CYLINDER

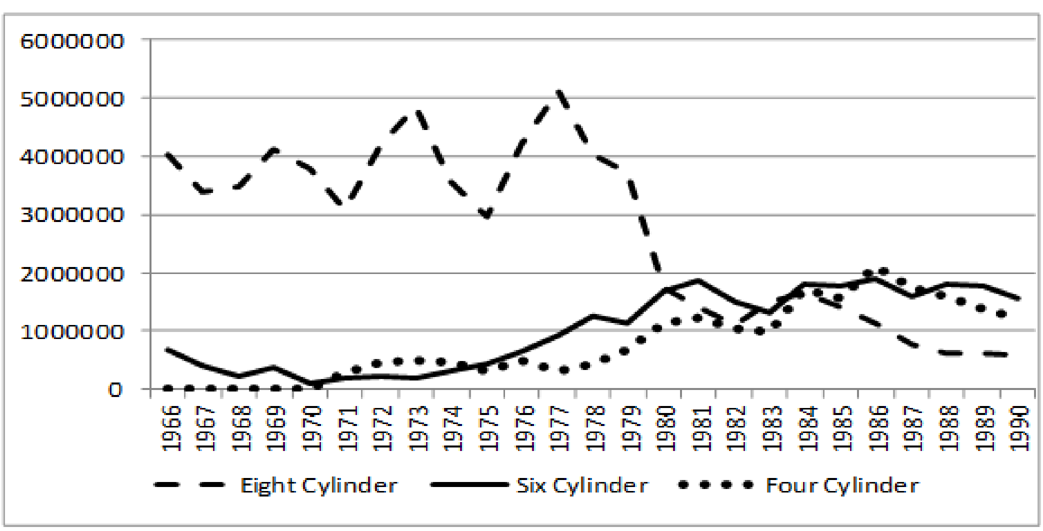


FIGURE 3
FORD UNIT PRODUCTION BY CYLINDERS

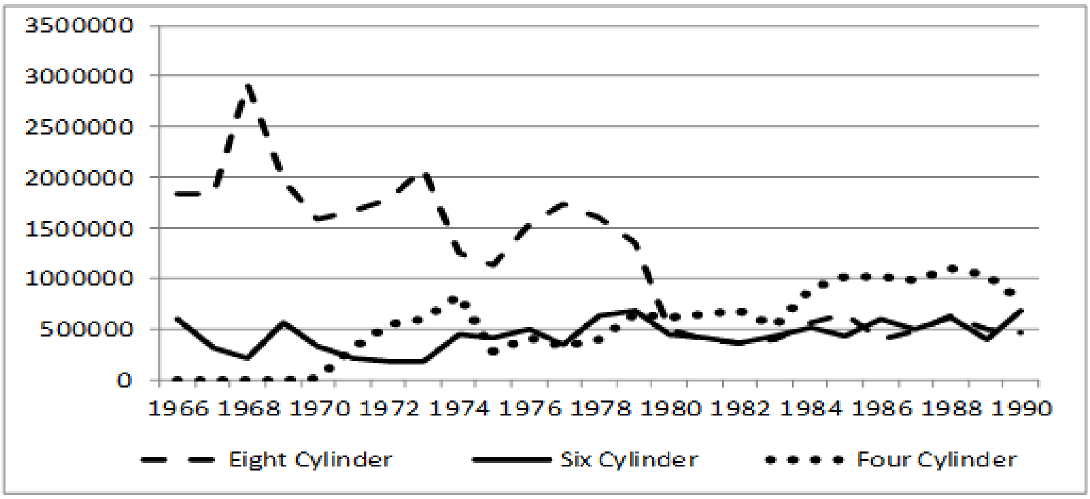
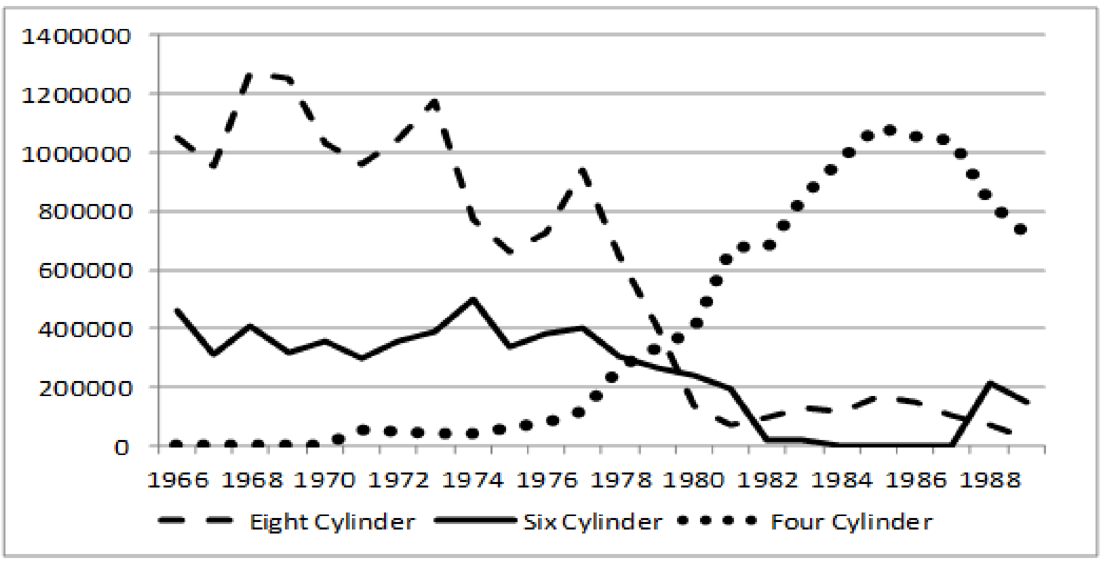


FIGURE 4
CHRYSLER UNIT PRODUCTION BY CYLINDER



Data

Data on industry trends, features of makes and models being sold by American car manufacturers each year, and production data for each make and model were from Ward's Automotive Yearly™ from 1966-1989. Ward's Automotive provides detailed industry data as well as information on market trends in the American auto market. Industry trends were corroborated through news filings found in LexisNexis academic database. Information on historical gasoline prices was from the Energy Information Administration (EIA) of the Department of Energy.

RESULTS

Table 2 (See appendix) displays the results from a pooled time-period MANOVA with three left-hand side variables (**4cylpercent**: the percentage of production consisting of four cylinder engines, **6cylpercent**: the percentage of production consisting of six cylinder engines, and **8cylpercent**: the percentage of production consisting of eight cylinder engines,) and three right-hand side variables (**nomgas**: the nominal price of gasoline in dollars, **uspop**: the total population of the United States in a given year, and **fullname**: the specific make and model of each car produced during a specific year).

Panels A, B, C, D, and E differ only by the amount of lag between nominal price of gasoline and the percentage production by cylinder. Panel A has zero years of lag, while panels B, C, D, and E have one, two, three, and four years of lag respectively. We establish a direct relationship between the nominal price of gas and the percentage production by cylinder with lag periods ranging from zero to three years. Only in panel E (four year lag) are we unable to reject the null hypothesis of no relationship between nominal gas prices and percentage production by cylinder. In all panels, the coefficient of nominal gas price is negative for eight cylinder production percentage showing an inverse relationship between the price of gas and the production of eight cylinder vehicles. For all significant results, the coefficients of four and six cylinder percentage production are positive, thus demonstrating a direct relationship between the nominal price of gas and production of these fewer cylinder vehicles. Type III F values are included to show the relative proportion of explanatory power for the nominal gas variable for each cylinder percentage production. Results from control variables are omitted due to space constraints.

Since data issues restrict the use of horsepower and rpm control variables to univariate ANOVA models, we present the results of the univariate ANOVA models run by cylinder in table 3 (See appendix). For each model, the following specification was employed:

“X”cylpercent = nomgas uspop fullname “X”hp “X”rpm, (1)

where “X” refers to four, six, and eight cylinders respectively.

The same five panel structure—involving lags ranging from zero to four years in duration—as in Table 2 is displayed. All panels including lags show significantly reduced explanatory power when compared to panel A. The results from the eight cylinder production percentage models are particularly striking. After controlling for the technological improvements as proxied by horsepower and rpm, the inverse relationship between the nominal price of gas and the percentage of eight cylinder vehicles produced is stronger than in table 2. In addition, the coefficient for the nominal gas price variable is consistently negative across all panels.

Having established a clear relationship between the nominal price of gas and the production mix of U.S. automakers, we use table 4 (see appendix) to test the speed of reaction as related to multiple external shocks. Using the two oil price shocks as previously defined, we create three distinct time periods for analysis. Panel A shows the time period we define as “before the first price shock” (1966-1973), panel B shows the time period we define as “after the first price shock, but before the second price shock” (1974-1978), and panel C shows the time period we define as “after the second price shock” (1979-1988). Across all panels we use a zero-year lag specification based on the results from previous tables.

As with prior tables, we are primarily concerned with the eight cylinder production percentage. Interestingly, in panel A, the nominal price of gas is positive and non-significant. This implies little connection between the price of gas and the percentage production of eight cylinder vehicles in the time period before the first price shock. In panel B, the coefficient for the nominal price of gas becomes negative and significant for the percentage production of eight cylinder vehicles. Thus after the first price shock, we see an immediate relationship between an increase in the price of gas and a decrease in the percentage production of eight cylinder vehicles. In panel C, the coefficient for the nominal price of gas for the percentage production of eight cylinder vehicles is larger and more significant than in panel B. In addition, the type III F value in panel C is significantly larger than the corresponding type III F value in panel B.

We interpret the results of table 4 as demonstrating that the automakers response after the second price shock is significantly larger than their response after the first price shock. When comparing results across panels, the price of gas became an increasingly larger factor in the percentage production of eight cylinder vehicles and a $1 increase in the nominal price of gas caused an increasingly larger corresponding decrease in the percentage production of eight cylinder vehicles. The non-significance of nominal gas in panel A also implies a lack of concern as to the price of gas on the part of U.S. automakers prior to the first shock.

Taken alone, it is possible the results from table 4 demonstrate nothing more than a constant increase in the price of gas. Table 5 (see appendix) displays the results from a specification identical to that in table 4 with the one exception of the time periods being shifted by one year across all panels. If the alternative explanation was correct and our findings were little more than a consistent response to constantly increasing gas prices, we should see identical results in table 4 and table 5. However, as the results demonstrate, changing the time periods by one year eliminates significant results in panels B and C and creates a significant result in panel A. Because the results of the model are so sensitive to the specific time periods chosen, the simplest explanation is that the American automakers learned from their experience in the first price shock and employed a stronger response after the second shock.

LIMITATIONS

The inclusion of several factors would greatly improve our understanding of the American car industry's decline, including technological advances in engine power and the number of cylinders necessary, changes in consumer perception as to what is "acceptable" in each product segment, and market share of foreign makes. This study is also limited in terms of applicability, as the study was done in the American market place and on American brands only.

DISCUSSION

While not surprising from a theoretical point of view, these findings run contrary to the perception of the Big Three's reaction to environmental stimuli. Although American car companies are frequently described as focusing exclusively on large cars (Amend, 2008; Teahen Jr., 2007), the results indicate that U.S. auto manufacturers learned from past experience and changed their production mix. The fact that American car makers retained the large car image in spite of production increases in small cars and production decreases in large cars raises further questions. There may be other factors involved in creating a negative "halo effect" surrounding American car companies and the perception of lack of responsiveness to market demands. Coombs (2006) suggests that a favorable reputation prior to a crisis would result in a better post-crisis reputation than if the firm had a neutral or poor reputation prior to the same crisis. In this case, the American firms improved their products during a crisis. It may be that this negative halo would harm an improving company as much as a positive halo would protect a declining one. This could be an interesting topic for future research.

Our results have some interesting implications when viewed in relation to organizational learning theory. First, contrary to common perceptions of US auto makers, as Cyert and March (1963) suggested, external shocks did seem to stimulate changes in organizational behavior. That is, gasoline prices correlated with changes in the production behavior of the American car companies, and the degree and speed of their reactions increased in the second incident.

Second, our results are in line with the observations of both Baum and Dahlin (2007) and Baum and Ingram (1998), in that the firms appeared to make changes based on past experience by increasing the production of smaller cars and decreasing the production of larger cars. However, judging by data on loss of market share to foreign car makers and the current financial problems of the U.S. automakers, it may be that the American car companies did not learn the "correct" lesson. Perhaps in interpreting their experiences, they learned the wrong thing.

Third, competitive inertia, as suggested by Miller and Chen (1994), may have led to an inability to adapt to other threats that have appeared in these firms' markets in the past 30 years and this failure lead to their current financial situation, product status, and brand reputation problems that American car companies are experiencing.

CONCLUSION

The results of this study show a strong connection between the increase in gasoline prices and a decrease in the production percentage of eight cylinder automobiles by U.S. manufacturers. We also show an increase in the degree of change between the first and second external shock, implying organizational learning had occurred within the American automakers, and that recurring events reinforce learned behaviors. Much work remains to show the specific lessons American automobile companies learned from the gasoline price shocks and if these lessons aided them in speeding their reaction times and improving their decisions. While far from comprehensive, we hope our results provide a contribution to the literature and provide fertile ground for future research.

REFERENCES

Amend, J. (2008). Survey Says Americans Favor Foreign Car Brands. *Ward's Dealer Business*.

Baum, J. A. C., & Dahlin, K. B. (2007). Aspiration Performance and Railroads' Patterns of Learning from Train Wrecks and Crashes. *Organization Science, 18*(3), 368-385.

Baum, J. A. C., & Ingram, P. (1998). Survival-Enhancing Learning in the Manhattan Hotel Industry, 1898-1980. *Management Science, 44*(7), 996-1016.

Coombs, W. T., & Holladay, S. J. (2006). Unpacking the halo effect: reputation and crisis management. *Journal of Communication Management, 10(2)*, 123-137.

Crain, K. (2007). The best and worst time for change. *Automotive News*.

Cyert, R. M., & March, J. G. (1963). *A Behaviorial Theory of the Firm*. Englewood Cliffs, NJ: Prentice Hall.

Greve, H. R. (1998). Performance, Aspirations and Risky Organizational Change. *Administrative Science Quarterly, 43*(1), 58-86.

Hariharan, S., & Prahalad, C. K. (1994). Strategic Windows in the Structuring of Industries: Compatibility Standards and Industry Evolution. In H. Thomas, D. O'Neal, R. White & D. Hurst (Eds.), *Building the Strategically -Responsive Organization*. Chichester, U.K.: John Wiley & Sons.

Kraus, C. (2008). Drivers Take to the Road Again as Gas Prices Fall, *The New York Times*.

Levitt, B., & March, J. G. (1988). Organizational Learning. *Annual Review of Sociology, 14*, 319-340.

March, J. G. (1991). Exploration and Exploitation in Organizational Learning. *Organization Science, 2*(1), 71-87.

Miller, D., & Chen, M.-J. (1994). Sources and Consequences of Competitive Inertia: A Study of the US Airline Industry. *Administrative Science Quarterly, 39*, 1-23.

Millikent, F. J., & Lant, T. K. (1991). The effects of an organization's recent history on strategic persistence and change: The role of managerial interpretations. In P. Shravistova, A. Huff & J. E. Dutton (Eds.), *Advances in Strategic Management*. Greenwitch, CT: JAI Press.

Morrison, J. B. (2002). The Right Shock to Initiate Change: A Sensemaking Perspective. *Academy of Management Proceedings*, F1-F6.

Naughton, K. (2006). Putting Detroit in the Shop: American automakers have to move faster to make cars Americans will actually buy. *Newsweek*.

Nohrstedt, D. (2005). External shocks and policy change: Three Mile Island and Swedish nuclear energy policy. *Journal of European Public Policy, 12*(6), 1041-1059.

Staw, B. M., Sandelands, L. E., & Dutton, J. E. (1981). Threat-Rigidity Effects in Organizational Behavior: A Multilevel Analysis. *Administrative Science Quarterly, 26*(4), 501-524.

Teahen Jr., J. K. (2007). Where did Big 3 car owners go? Guess: Only great products will lure buyers

back to GM, Ford, Chrysler. *Automotive News*.
Times, N. Y. (2008, November 6, 2008). Fill 'Er Up. *The New York Times*.
Tuttle, B. (2014). Gas Prices Will Fall in 2014. But You May Pay More at the Pump Anyway. *Time*, 1. Retrieved from U.S. Energy Information Administration. (2014, Nov. 14, 2008). U.S. gasoline prices this Thanksgiving are the lowest since 2009. *Today in Energy* Retrieved Nov. 18, 2014.
Ward's Communications, I. (1979). *Ward's 1979 Automotive Yearbook*. Detroit, Michigan: Ward's Communications Inc.
Weick, K. E., & Quinn, R. E. (1999). Organizational change and development. *Annual Review of Psychology, 50*(1), 361.

APPENDIX

TABLE 1
NOMINAL AND CPI ADJUSTED GASOLINE PRICES

Year	Nominal Gas Price ($ / gallon)	CPIU (1982-1984 = 1)	Real Gas Price ($ / gallon, adjusted for CPIU)	Real Gas Price Change From Previous Year
1966	0.321	0.324	2.053	-
1967	0.332	0.334	2.059	0.27%
1968	0.337	0.348	2.009	-2.43%
1969	0.348	0.367	1.968	-2.00%
1970	0.357	0.388	1.907	-3.11%
1971	0.364	0.405	1.865	-2.21%
1972	0.361	0.375	2.000	7.22%
1973	0.387	0.443	1.813	-9.34%
1974	0.524	0.493	2.204	21.59%
1975	0.572	0.538	2.205	0.05%
1976	0.595	0.569	2.167	-1.73%
1977	0.620	0.606	2.121	-2.11%
1978	0.630	0.652	2.003	-5.56%
1979	0.860	0.726	2.456	22.59%
1980	1.245	0.824	3.133	27.55%
1981	1.378	0.909	3.143	0.33%
1982	1.259	0.965	2.704	-13.97%
1983	1.204	0.996	2.507	-7.29%
1984	1.176	1.039	2.347	-6.39%
1985	1.165	1.076	2.245	-4.34%
1986	0.890	1.097	1.682	-25.10%
1987	0.911	1.136	1.663	-1.11%
1988	0.909	1.183	1.593	-4.24%

TABLE 2
POOLED MANOVA

4cylpercent 6cylpercent 8cylpercent = nomgas uspop fullname

Panel A:**No lag (Years 1966-1988)**

Cylinders	N	Coefficient of nomgas	R^2	TypeIII F	Sig
4 cylinder	**2492**	**0.0725**	**0.9568**	**34.30**	**0.0001**
6 cylinder	**2492**	**0.0998**	**0.7945**	**19.73**	**0.0001**
8 cylinder	**2492**	**-0.1723**	**0.8993**	**62.59**	**0.0001**

Based on overall Wilks' Lambda for nomgas (F_2, 1675 = 39.91, p<0.0001), we reject the null hypothesis of no overall effect of nomgas upon production by cylinder.

Panel B:**One year lag (Years 1967-1988)**

Cylinders	N	Coefficient of nomgas	R^2	TypeIII F	Sig
4 cylinder	**1666**	**0.0771**	**0.9580**	**26.32**	**0.0001**
6 cylinder	**1666**	**0.0991**	**0.7617**	**10.88**	**0.0010**
8 cylinder	**1666**	**-0.1762**	**0.8796**	**37.00**	**0.0001**

Based on overall Wilks' Lambda for nomgas (F_2, 1186 = 26.77, p<0.0001), we reject the null hypothesis of no overall effect of nomgas upon production by cylinder.

Panel C:**Two year lag (Years 1968-1988)**

Cylinders	N	Coefficient of nomgas	R^2	TypeIII F	Sig
4 cylinder	**1189**	**0.0629**	**0.9559**	**9.78**	**0.0018**
6 cylinder	**1189**	**0.0901**	**0.7483**	**4.64**	**0.0315**
8 cylinder	**1189**	**-0.1530**	**0.8685**	**14.72**	**0.0001**

Based on overall Wilks' Lambda for nomgas (F_2, 852 = 10.65, p<0.0001), we reject the null hypothesis of no overall effect of nomgas upon production by cylinder.

Panel D:**Three year lag (Years 1969-1988)**

Cylinders	N	Coefficient of nomgas	R^2	TypeIII F	Sig
4 cylinder	855	0.0331	0.9561	1.27	0.2593
6 cylinder	**855**	**0.1515**	**0.7352**	**5.53**	**0.0191**
8 cylinder	**855**	**-0.1845**	**0.8565**	**9.04**	**0.0028**

Based on overall Wilks' Lambda for nomgas (F_2, 607 = 4.79, p=0.0087), we reject the null hypothesis of no overall effect of nomgas upon production by cylinder.

Panel E:**Four year lag (Years 1970-1988)**

Cylinders	N	Coefficient of nomgas	R^2	TypeIII F	Sig
4 cylinder	610	-0.0323	0.9534	0.91	0.3402
6 cylinder	610	0.1162	0.7135	2.08	0.1500
8 cylinder	610	-0.0839	0.8304	1.16	0.2820

Based on overall Wilks' Lambda for nomgas (F_2, 430 = 1.20, p=0.3033), we cannot reject the null hypothesis of no overall effect of nomgas upon production by cylinder.

4cylinderpercent = percentage of four cylinder production for each specific make & model.
6cylinderpercent = percentage of six cylinder production for each specific make & model.
8cylinderpercent = percentage of eight cylinder production for each specific & model.
nomgas = the nominal price of gas in $ / gallon.
uspop = Census Bureau estimate of total U.S. population.
fullname = specific make & model by year.

Panel A displays the results from a pooled MANOVA with year X nomgas regressed against year X cylinder percentages. Panel B displays the results from year X nomgas regressed against year X+1 cylinder percentages. Panel C displays the results from year X nomgas regressed against year X+2 cylinder percentages. Panel D displays the results from year X nomgas regressed against year X+3 cylinder percentages. Panel E displays the results from year X nomgas regressed against year X+4 cylinder percentages.

Significant ($p<0.05$) results are bolded. Across all panels, there is a negative coefficient on the 8 cylinder percentage production and (for all significant values) there is a positive coefficient for the 4 and 6 cylinder percentage production. The results demonstrate an inverse relationship between the price of gasoline and the percentage production of 8 cylinder models.

Control variable results are omitted due to space constraints.

TABLE 3
POOLED ANOVA BY CYLINDER

"X"cylpercent = nomgas uspop fullname "X"hp "X"rpm

Panel A:**No lag (Years 1966-1988)**

Cylinders	N	Coefficient	R^2	TypeIII F	Sig
4 cylinder	**734**	**0.1621**	**0.9253**	**29.32**	**0.0001**
6 cylinder	**843**	**0.1722**	**0.8355**	**13.64**	**0.0002**
8 cylinder	**1100**	**-0.0902**	**0.9025**	**17.22**	**0.0001**

Panel B:**One-year lagged nomgas (Years 1967-1988)**

Cylinders	N	Coefficient	R^2	TypeIII F	Sig
4 cylinder	491	0.0589	0.9164	1.76	0.1857
6 cylinder	553	0.0710	0.7885	1.20	0.2747
8 cylinder	**743**	**-0.1167**	**0.7543**	**5.53**	**0.0190**

Panel C:**Two-year lagged nomgas (Years 1968-1988)**

Cylinders	N	Coefficient	R^2	TypeIII F	Sig
4 cylinder	321	0.0346	0.9395	0.36	0.5501
6 cylinder	**392**	**-0.1914**	**0.7704**	**4.09**	**0.0444**
8 cylinder	**559**	**-0.2241**	**0.7210**	**10.51**	**0.0013**

Panel D:**Three-year lagged nomgas (Years 1969-1988)**

Cylinders	N	Coefficient	R^2	TypeIII F	Sig
4 cylinder	195	0.0181	0.9610	0.04	0.8435
6 cylinder	275	-0.1824	0.7703	1.59	0.2090
8 cylinder	**431**	**-0.2993**	**0.7257**	**8.88**	**0.0031**

Panel E:**Four-year lagged nomgas (Years 1970-1988)**

Cylinders	N	Coefficient	R^2	TypeIII F	Sig
4 cylinder	113	0.1320	0.9779	1.98	0.1655
6 cylinder	181	0.1386	0.7822	0.65	0.4227
8 cylinder	340	-0.0529	0.7099	0.18	0.6726

All results for nomgas variable. Results from control variables omitted due to space constraints.

"X"cylinderpercent = percentage of four, six, and eight cylinder production for each specific make & model.
nomgas = the nominal price of gas in $ / gallon.
uspop = Census Bureau estimate of total U.S. population.
fullname = specific make & model by year.
"X"hp = horsepower by model for four, six, and eight cylinder vehicles by specific make & model.
"X" rpm = engine rpm by model for four, six, and eight cylinder vehicles by specific make & model.

Panel A displays the results from three separate, pooled ANOVAs (one for each of four, six, and eight cylinder) with year X nomgas regressed against year X cylinder percentages. Panel B displays the results with year X nomgas regressed against year X+1 cylinder percentages. Panel C displays the results with year X nomgas regressed against year X+2 cylinder percentages. Panel D displays the results with year X nomgas regressed against year X+3 cylinder percentages. Panel E displays the results with year X nomgas regressed against year X+4 cylinder percentages.

Significant ($p<0.05$) results are bolded. Across all panels, there is a negative coefficient on the 8 cylinder percentage production. The results demonstrate an inverse relationship between the price of gasoline and the percentage production of 8 cylinder models even after controlling for technological improvements in horsepower and engine rpm.

TABLE 4
POOLED ANOVA BY CYLINDER FOR THREE TIME PERIODS

"X"cylpercent = nomgas uspop fullname "X"hp "X"rpm

Panel A:Separate, univariate, pooled ANOVA results by cylinder **(Years 1966-1973)**

Cylinders	N	Coefficient	R^2	TypeIII F	Sig
4 cylinder	12	-	-	-	-
6 cylinder	167	0.21080831	0.972102	1.68	0.1998
8 cylinder	416	0.23536992	0.980973	0.28	0.5993

Panel B:Separate, univariate, pooled ANOVA results by cylinder **(Years 1974-1978)**

Cylinders	N	Coefficient	R^2	TypeIII F	Sig
4 cylinder	80	1.3660607	0.972532	0.65	0.4285
6 cylinder	229	0.74909283	0.887779	0.24	0.6283
8 cylinder	**384**	**-0.09497257**	**0.961954**	**6.03**	**0.0150**

Panel C:Separate, univariate, pooled ANOVA results by cylinder **(Years 1979-1988)**

Cylinders	N	Coefficient	R^2	TypeIII F	Sig
4 cylinder	642	0.0630905	0.927685	1.89	0.1698
6 cylinder	**449**	**0.2116751**	**0.784319**	**6.23**	**0.0133**
8 cylinder	**300**	**-0.1571635**	**0.907582**	**15.76**	**0.0001**

All results for nomgas variable. Results from control variables omitted due to space constraints.

“X”cylinderpercent = percentage of four, six, and eight cylinder production for each specific make & model.
nomgas = the nominal price of gas in $ / gallon.
uspop = Census Bureau estimate of total U.S. population.
fullname = specific make & model by year.
“X”hp = horsepower by model for four, six, and eight cylinder vehicles by specific make & model.
“X” rpm = engine rpm by model for four, six, and eight cylinder vehicles by specific make & model.

Panel A displays the results from three separate, pooled ANOVAs (one for each of four, six, and eight cylinder) with year X nomgas regressed against year X cylinder percentages for the time period 1966-1973. Panel B displays the results for the time period 1974-1978. Panel C displays the results for time period 1979-1988.

Significant ($p<0.05$) results are bolded. The size of the coefficient of nomgas and the type III F value demonstrate the increasing explanatory power of nomgas upon eight cylinder production percentage.

TABLE 5
ROBUSTNESS CHECK: ADD ONE YEAR TO TABLE 4 MODELS ACROSS ALL PANELS

“X”cylpercent = nomgas uspop fullname “X”hp “X”rpm

Panel A:Separate, univariate, pooled ANOVA results by cylinder **(Years 1966-1974)**

Cylinders	N	Coefficient	R^2	TypeIII F	Sig
4 cylinder	18	-	-	-	-
6 cylinder	**194**	**1.6048**	**0.9598**	**24.90**	**0.0001**
8 cylinder	**526**	**-0.2658**	**0.9627**	**8.13**	**0.0048**

Panel B:Separate, univariate, pooled ANOVA results by cylinder **(Years 1975-1979)**

Cylinders	N	Coefficient	R^2	TypeIII F	Sig
4 cylinder	100	0.2549	0.9729	1.25	0.2705
6 cylinder	261	0.1316	0.8658	0.34	0.5628
8 cylinder	317	0.0118	0.9630	0.02	0.8826

Panel C:Separate, univariate, pooled ANOVA results by cylinder regression **(Years 1980-1988)**

Cylinders	N	Coefficient	R^2	TypeIII F	Sig
4 cylinder	616	-0.0223	0.9269	0.10	0.7570
6 cylinder	390	-0.2139	0.7724	1.39	0.2396
8 cylinder	257	-0.0499	0.9478	0.62	0.4337

All results for nomgas variable. Results from control variables omitted due to space constraints.

“X”cylinderpercent = percentage of four, six, and eight cylinder production for each specific make & model.
nomgas = the nominal price of gas in $ / gallon.
uspop = Census Bureau estimate of total U.S. population.
fullname = specific make & model by year.

“X”hp = horsepower by model for four, six, and eight cylinder vehicles by specific make & model.
“X” rpm = engine rpm by model for four, six, and eight cylinder vehicles by specific make & model.

Panel A displays the results from three separate, pooled ANOVAs (one for each of four, six, and eight cylinder) with year X nomgas regressed against year X cylinder percentages for the time period 1966-1974. Panel B displays the results for the time period 1975-1979. Panel C displays the results for time period 1981-1988.

Significant ($p<0.05$) results are bolded.