Valuation of Fuel Flexibility in a Vehicle Fleet

Don MacKenzie

Technology & Policy Program
Sloan Automotive Laboratory

Massachusetts Institute of Technology

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ABSTRACT

The value of introducing gasoline fuel flexibility for mitigating cost uncertainty in a fleet of cars is evaluated. Specifically, the ability to use either E85 (ethanol) or gasoline in a fleet of identical midsize cars is considered. Decision tree analysis and lattice analysis indicate that such flexibility may deliver value, but for current midsize car offerings it is likely not worth the cost of acquiring the flexibility. A fleet manager would spend less over a 4-year timeframe by choosing a gasoline-only vehicle, especially one with class-leading fuel economy. If manufacturers offered fuel flexibility at a lower incremental cost and with better fuel economy, it would be a more valuable investment.

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Overview

The system analyzed is a fleet of identical light-duty vehicles, such as those that might be used by a government or business for general transport of personnel. Principal design variables include the number of miles driven per year, fuel economy, and fuel type. Costs are dependent upon the purchase prices (or leasing costs) of the vehicles and the fueling costs. The key uncertainties are the relative prices of gasoline and ethanol-based fuels, and the flexibility under consideration is the acquisition of vehicles that can operate on either gasoline or ethanol.

Key Design Parameters

Fuel Type. Vehicles may operate on gasoline, diesel, ethanol, natural gas, propane, or electricity. More pertinently, a number of vehicles on the market today are capable of operating on more than one fuel type. It is this type of fuel flexibility that is at the center of this analysis. Vehicles capable of operating on either gasoline or ethanol – known as flexible-fuel vehicles or FFVs – are by far the most common vehicles in this class. Flexible-fuel vehicles have a single fuel tank and can use any mixture of ethanol and gasoline from zero to 85 percent ethanol by volume. The latter mixture is known as E85, and is available at approximately 1,300 locations nationwide, more than two-thirds of which are in eight corn-belt states (United States Department of Energy, 2007).

Fuel Economy. The fuel economy ratings of new vehicles offered in the United States in model year (MY) 2007 range from 10 miles per gallon to 46 miles per gallon. For some fuel types (e.g. gasoline) the range of models covers this entire spectrum quite thoroughly, i.e. you can find a gasoline vehicle with just about any level of fuel economy between 10 and 46 MPG. The choice of FFV models is more limited, so FFVs are only available at discrete levels of fuel economy. (United States Environmental Protection Agency, 2007)

Pattern of Use. The pattern of use for the vehicle fleet is important because the number of miles each vehicle is driven annually influences the annual fuel costs, and the time that vehicles are retained determines the number of years over which fuel costs are to be evaluated. In addition, the fleet's ability to use certain alternative fuels may depend on whether the fleet is centrally fueled (as for a municipal fleet) or fueled by drivers whenever and wherever they need to fill up. For purposes of this analysis, it was assumed that vehicles are centrally fueled, so it would be feasible for the fleet operator to secure an option to purchase a bulk quantity of E85 for use in her fleet.

Sources of Uncertainty

It behooves the fleet manager to equip himself with a fleet that is readily adapted to changing conditions. Some particularly important sources of uncertainty for fleet operators are outlined below.

Fuel Prices. Fuel prices are notoriously volatile, and have been especially so over the past 5 years. While the Energy Information Administration projects fuel prices in its Annual Energy

Outlook reports, these projections have consistently failed to predict the increases experienced during the current run-up. (Figure 1) It is hard enough to predict the price of gasoline next week, let alone next year or in 5 years. It is essential to account for this uncertainty in modeling future fueling costs.

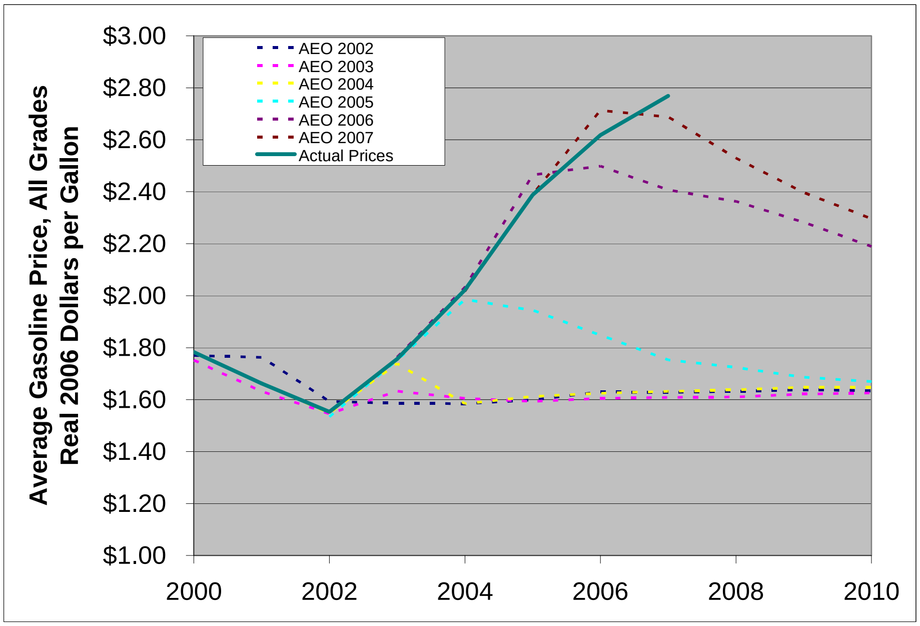

Figure 1: Department of Energy projections have failed to predict increases in gasoline prices even one year ahead. (Department of Energy, Energy Information Administration, 2001, 2003, 2004, 2005, 2006, 2007)

Fuel Policies. While related to fuel price, fuel policies are worth considering separately, because the policy environment around motor vehicle fuels is extremely uncertain. Possible fuel-sector policies include taxes, required reductions in average lifecycle carbon emissions, and mandates to use renewable fuels. Trying to define these policies is a source of further uncertainty. Would taxes be assigned on a volumetric, energy content, or carbon basis? What exactly is a "renewable" fuel? Will the current subsidy for ethanol be extended or allowed to expire? These policies would all have effects, either direct or indirect, on the costs of using certain fuels. Of particular note, they have the potential to affect the *relative* prices of different fuels.

Fleet Policies. Past federal legislation has targeted government fleet operators with requirements to operate alternative fuel vehicles. It is possible that future legislation could do the same. Similarly, a municipal fleet could be subject to an effort by city council to "green" its operations, and a corporate fleet could be subject to a resolution brought by activist shareholders. All of these changes would have the potential to change the calculus around operating the fleet.

Uncertainties Targeted in this Analysis

Although there are many variables that must be considered in determining the best choice of vehicles for a fleet, this analysis is focused on the choice between buying gasoline-fueled vehicles and gasoline/ethanol FFVs. There are a number of possible uncertainties that affect the cost effectiveness of each choice, but paramount among these are the costs of the two fuel choices.

The Price of Gasoline. The price of gasoline is notoriously volatile, and projections of future prices can be considered only rough estimates at best, as demonstrated by the retrospective in Figure 1. Figure 2, below, shows the increase in real average gasoline prices over the past 14 years, which forms the basis of the stochastic gasoline price models developed later.

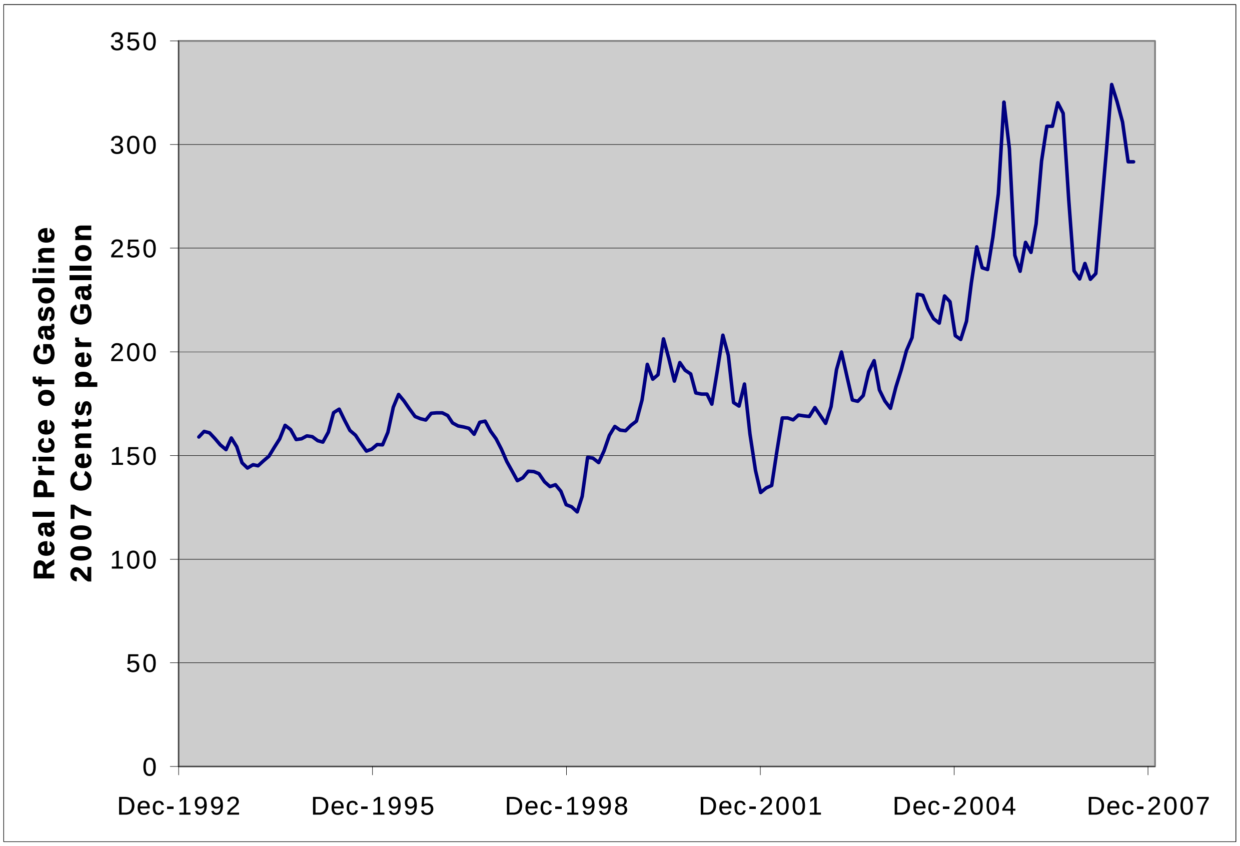

Figure 2: Monthly Average Gasoline Prices, 1993 – Present (United States Department of Energy, Energy Information Administration, 2007a)

The Price of E85. E85 is a blend that consists nominally of 85 percent ethanol and 15 percent gasoline. Since the heating value of ethanol is only 66 percent that of gasoline, the heating value of E85 is about 71 percent of that of gasoline. (U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, 2007b) Therefore E85 should, on the basis of energy content, be worth about 29 percent less than gasoline as a transportation fuel, assuming that vehicle energy efficiency is the same for both fuels. The relative cost of using gasoline or E85 to fuel a flexible-fuel vehicle therefore depends on the price of gasoline and the ratio of E85 price to gasoline price.

The Alternative Fuels Price Report, published (approximately) quarterly by the Department of Energy's Office of Energy Efficiency and Renewable Energy, tracks the prices of E85 and gasoline as reported voluntarily by participating fueling stations. This analysis focuses on results for the Midwest, where E85 is most prevalent and the largest sample sizes. Nevertheless, given how the data are collected, this may not be the most robust assessment of the relative prices of gasoline and E85, though it is the best that could be found. Based on the data in these reports, the ratio of the price of E85 to that of gasoline was plotted against time, as shown in Figure 3. Historically, the price of E85 has been between 80-90 percent of the gasoline price prevailing at the time. Thus, it does not currently make financial sense to use E85.

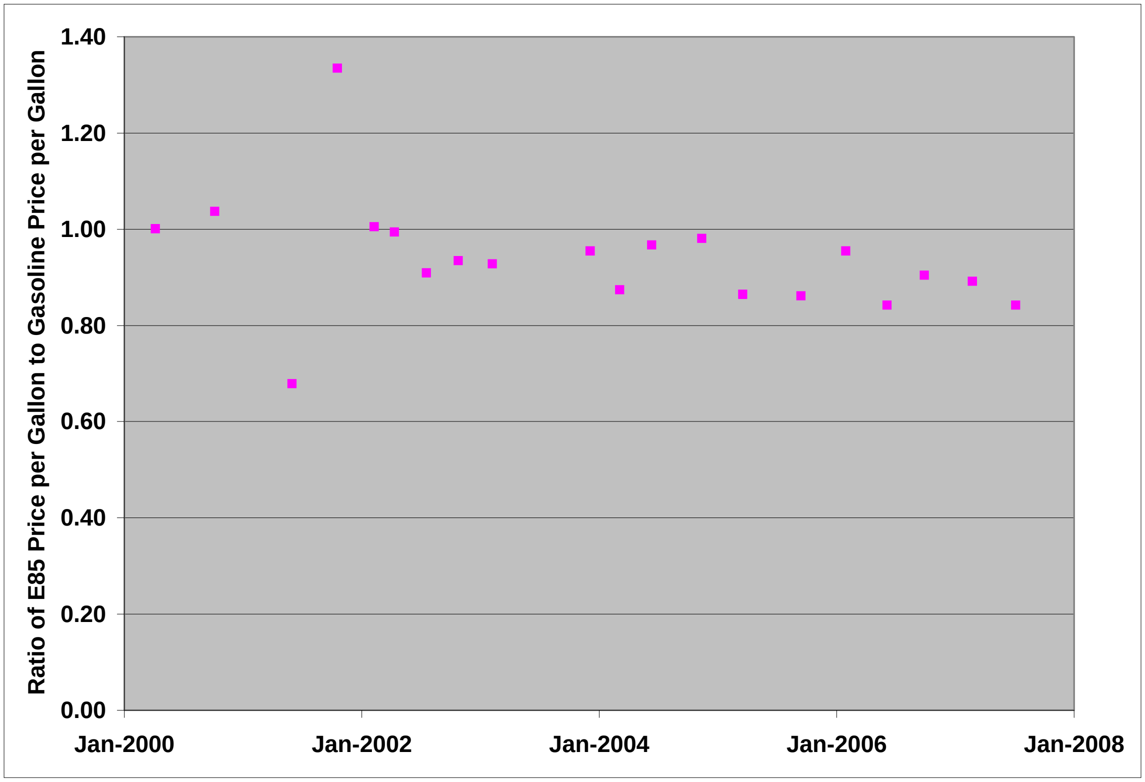

Figure 3: The ratio of E85 price to gasoline price has been between 0.8 and 0.9 since 2002. (United States Department of Energy, Office of Energy Efficiency and Renewable Energy, 2007b)

System Design

Model A model can be constructed to enable evaluation of the overall costs of a vehicle fleet, based on vehicle purchase or leasing costs, and fueling costs, and maintenance costs. Professional fleet operators maintain extremely detailed models of this nature, but something much simpler is used in this analysis. The model emphasizes the basic tradeoff between fuel cost and capital cost, enabling the valuation of fuel flexibility by accounting for uncertainties in future fuel prices. Notably, maintenance costs are assumed to be equal for gasoline vehicles and

FFVs, and so are omitted from this analysis. Annual fueling costs (per vehicle) are calculated according to

$$Cost = (VMT / MPG) \times P_{Fuel}$$

Where VMT is the vehicle-miles traveled in a year by a single vehicle, MPG is the fuel economy achieved by the vehicle when using a certain fuel (expressed in miles per gallon), and P_{Fuel} is the per-gallon price of that fuel.

System Concepts Three system concepts were evaluated, representing three different vehicle-fuel systems, all of which employ a midsize car. The systems evaluated were as follows:

1. Fixed design, low cost. The first system concept was a fleet of low-cost, conventional gasoline vehicles operating on regular gasoline. The vehicle chosen was the 2008 Hyundai Elantra, which is a typical high-volume midsize car model. With a rated fuel economy of 28 mpg (city/highway combined) and a starting manufacturer's suggested retail price (MSRP) of $13,525, (United States Environmental Protection Agency, 2007; Hyundai USA, 2007) it is among both the most fuel-efficient and lowest-priced high-volume midsize cars currently available.
2. Flexible design. The second system concept is a fleet comprising flexible-fueled midsize cars, capable of operating on any mixture of gasoline and ethanol up to 85 percent ethanol by volume. The vehicles may cost more up front, but will offer the option of choosing between two fuels throughout their lives, potentially reducing fueling costs. The only flexible-fueled midsize car on the market in model year (MY) 2008 is the Chrysler Sebring. The 2008 Chrysler Sebring Signature series sedan with flex-fuel capability has an MSRP of $23,280 and is rated at 22 mpg when operating on gasoline and 16 mpg when operating on E85 (because of E85's heating value being lower than that of gasoline). (Chrysler, 2007; United States Environmental Protection Agency, 2007)
3. Fixed design, reference. The final system concept will be based on a conventional gasoline-powered Chrysler Sebring, to better isolate the effects of the flexible-fuel capability. The 2008 Sebring Signature Series with gasoline-only engine is rated at 24 mpg and has an MSRP of $21,930. (Chrysler, 2007; United States Environmental Protection Agency, 2007)

In all cases the annual fueling cost were calculated by assuming that the vehicle is driven 20,000 miles per year and achieves the rated fuel economy.

Systems Analyses

The system was evaluated using decision analysis and lattice analysis techniques. Although these two analytical methods used the same raw data and evaluated the same choices, the approaches used were distinct are reported separately.

Decision Analysis. A two-stage decision analysis was conducted using three gasoline price scenarios and two ethanol price scenarios for each vehicle system choice. Each gasoline price scenario is a crude approximation of “high,” “mid,” and “low” gas prices, based on a mean-reversion model using a mean reversion speed of 0.06 and a relative volatility of 10%. It is further assumed that the long-term mean price is not constant, but increases at 1.3 cents per year, consistent with long-term projections and historic data. (United States Department of Energy, Energy Information Administration, 2007a and 2007b) Two hundred iterations of the mean reversion model were run for the 2008-09 timeframe, starting from the actual average gasoline price in September, 2007. The “high” gas price scenario was based on the mean price for the top quartile of prices resulting from the iterated mean reversion model, and it was assigned a 25% probability. The “mid” scenario was based on the average of the middle two quartiles, and was assigned a 50% probability. The “low” scenario was based on the bottom quartile and was assigned a probability of 25%.

The mean reversion model was run again for 2010-2011, starting from the average December, 2009 gasoline prices corresponding to the “high,” “mid,” and “low” gasoline prices for the 2008-09 stage. This reflects the fact that the probabilities of different gasoline prices in the second stage depends on the prices in the first stage. Table 1 summarizes the high, mid and low gasoline prices used in each stage of the decision analysis.

Table 1: Gasoline prices over two-stage decision analysis

	Stage 1 Prices		Stage 2 Average Prices		
	Stage Average	Dec 2009	Low	Mid	High
Stage 1 Low	$2.04	$1.84	$1.65	$1.75	$1.86
Stage 1 Mid	$2.31	$2.10	$1.86	$1.99	$2.10
Stage 1 High	$2.54	$2.28	$2.09	$2.26	$2.35

In addition to the gasoline prices, the E85 prices were assumed to be either “high” or “low.” Since 2002, E85 prices have varied between 84% and 100% of gasoline prices, on a volumetric (not energy-equivalent) basis, but have stayed mostly in the range of 85%-95% of the price of gasoline. Therefore the “high” E85 price was assumed to be 95% of the gasoline price.

An additional possible decrease in the price of E85 relative to gasoline comes from its lower lifecycle GHG emissions. E85 made from corn ethanol is generally estimated to have 8-15% lower GHG emissions than gasoline on an energy-equivalent basis. If one optimistically assumes that the 15% figure is correct and also assumes a (high) GHG price of $85 per tonne CO2-equivalent, then the corresponding decrease in the price of E85 is about $0.10 per gallon. Therefore the “low” E85 price was assumed to be 85% of the gasoline price minus a further $0.10/gallon. This would reflect a sudden implementation of a stringent carbon policy.

Figure 4 shows the portion of the decision tree corresponding to the purchase of a Hyundai Elantra, which follows directly from the first decision node (i.e. the decision of which vehicle to purchase). The complete decision tree consisted of two more sets of branches in parallel: one for the gasoline-only Sebring and one for the flex-fuel Sebring. The decision analysis indicates an expected total cost of $19,654 over four years for the Elantra, and $29,081 over four years for the gasoline-only Sebring.

The flex-fuel Sebring's portion of the decision tree is more complicated, because it includes chance nodes for both E85 price and gasoline price, as well as decision nodes for which fuel to use. Figure 5 shows the second stage analysis that follows from a first stage in which gasoline price was high and E85 price was low. A total of six sets of branches like that in Figure 5 were used in the second stage, each one stemming from a first-stage combination of high, mid, or low gasoline prices with high or low E85 prices. Working backwards through the tree and pruning appropriately, the expected total cost of the Sebring FFV was found to be $31,081 over four years.

It is interesting to note that under none of the scenarios explored in this decision analysis does E85 offer lower costs. The E85 branches were pruned from the decision tree, since even the FFV appears to always be better off just using gasoline. However it is also interesting that the penalty from using E85 is actually larger when gasoline prices are high, since higher prices increase the gap (in absolute dollar terms) between the energy-equivalent prices of gasoline and E85.

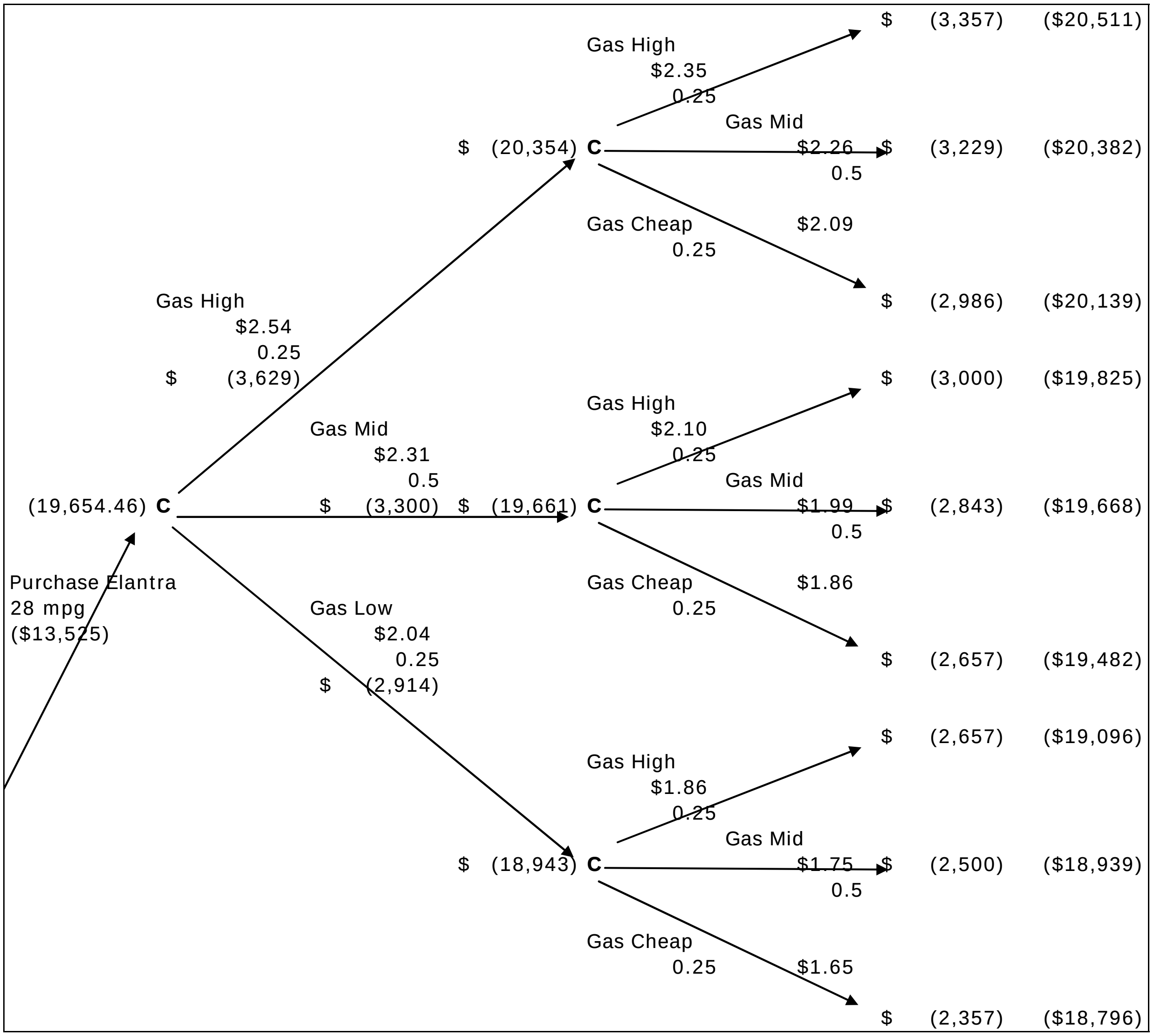

Figure 4: First and second stages of decision tree for purchase of a gasoline-only Elantra.

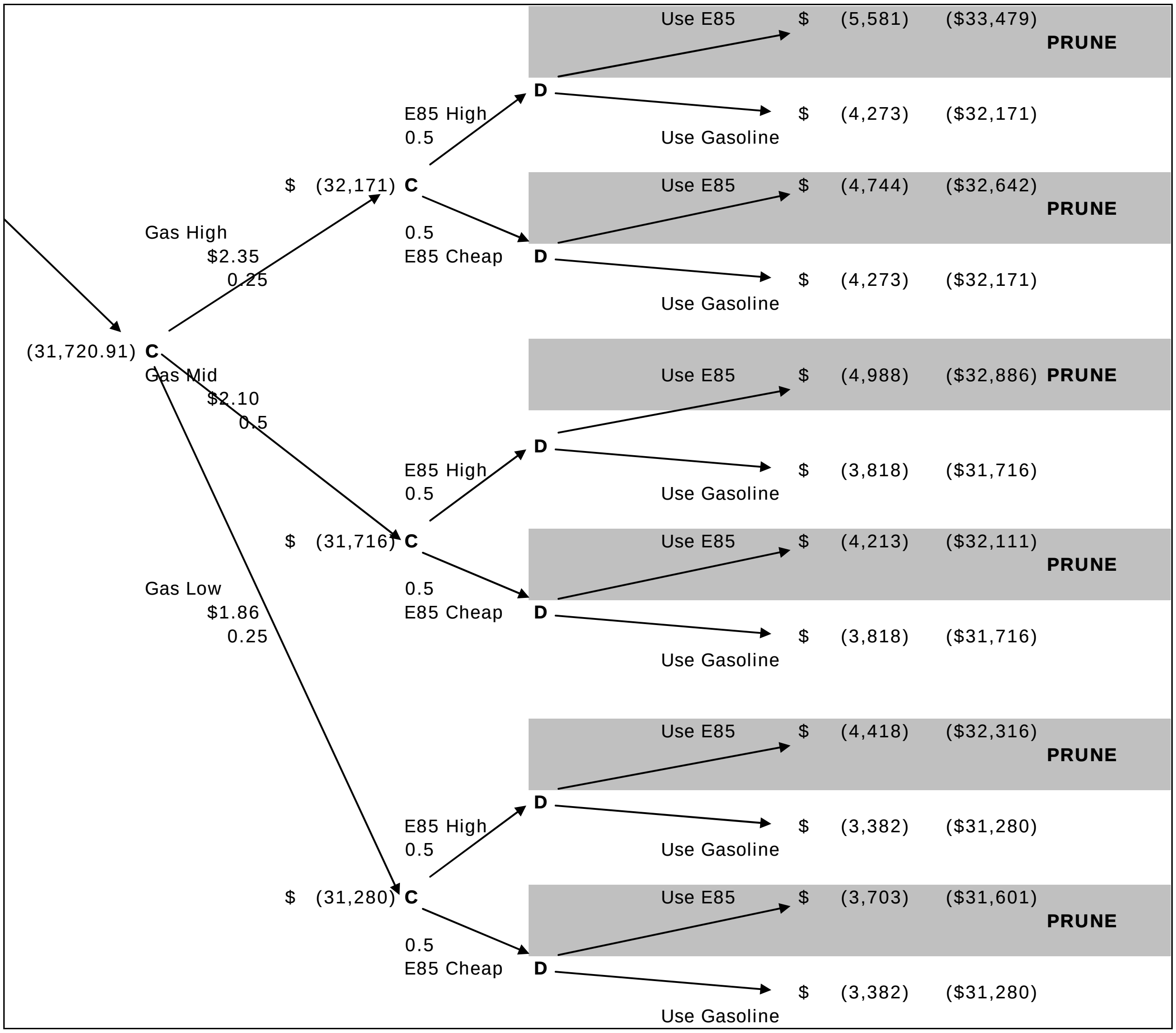

Figure 5: Second stage of decision analysis for flex-fuel Sebring, following a first stage in which gasoline price was high and E85 price was low.

Several changes in assumptions could shift the model towards favoring E85 usage, at least some of the time. If we believed that E85 prices would move closer to those of gasoline on an energy-equivalent basis, i.e. that the E85/gasoline price ratio would drop closer to 71%, then the E85 penalty would shrink. Additionally, if we believed that the price of carbon emissions could be higher than $85/tonne CO2-equivalent, or that advanced ethanol technologies could deliver GHG reductions of more than 15%, then the GHG advantage of E85 could grow beyond $0.10/gal.

The decision analysis does not necessarily tell the whole story. Future projections of gasoline prices made using a mean-reversion model will generally see gas prices reduced in the future, thus shrinking the gap between gasoline and E85, as noted above. As E85 becomes more mainstream, the price ratio for E85 to gasoline may draw closer to the energy-equivalent value of 0.71. Additionally, it may be instructional to entertain larger carbon prices or greater GHG reductions than those used here. Finally, it may be possible to secure an option to purchase E85 at a price higher than today's market rate, but low enough that it could be worth exercising the option if gasoline prices rise. We explore this latter possibility in the next section.

Lattice Analysis. As an alternative approach, a lattice analysis was performed to estimate the value of fuel flexibility for a vehicle fleet. Both gasoline prices and E85/gasoline price ratios were modeled using geometric Brownian motion models.

The gasoline lattice model was based on a regression of monthly average gasoline prices from April, 1993 through September, 2007. The regression indicated a drift – or average rate of growth – of 0.35% per month and a relative volatility of 10.0%. (Figure 6) A lattice model was constructed using these parameters, and the gasoline price outcomes and probabilities that resulted over the first 12 months are shown in Table 2 and Table 3. Similar lattices were constructed over 48 months, and the resulting price distribution is show in Figure 7.

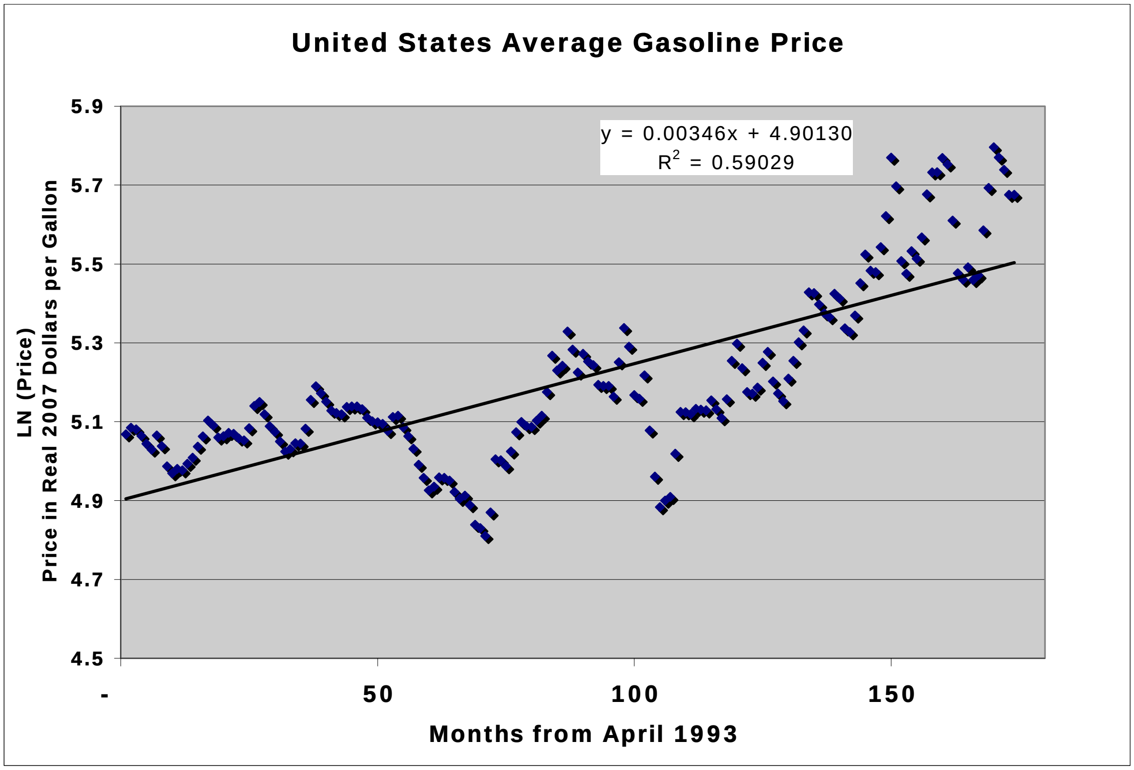

Figure 6: Monthly average gasoline prices are volatile (relative volatility = 10%), and have increased at an average of 0.35% per month since April, 1993. (United States Department of Energy, Energy Information Administration 2007b)

Table 2: Outcome lattice for gasoline price (cents per gallon) over 12 months

Month												
0	1	2	3	4	5	6	7	8	9	10	11	12
292	322	356	393	435	480	531	586	648	716	791	874	966
	264	292	322	356	393	435	480	531	586	648	716	791
		239	264	292	322	356	393	435	480	531	586	648
			216	239	264	292	322	356	393	435	480	531
				196	216	239	264	292	322	356	393	435
					177	196	216	239	264	292	322	356
						160	177	196	216	239	264	292
							145	160	177	196	216	239
								131	145	160	177	196
									119	131	145	160
										108	119	131
											97	108
												88

Table 3: Probability lattice for gasoline price over 12 months.

Month												
0	1	2	3	4	5	6	7	8	9	10	11	12
1.00	0.52	0.27	0.14	0.07	0.04	0.02	0.01	0.01	0.00	0.00	0.00	0.00
	0.48	0.50	0.39	0.27	0.17	0.11	0.06	0.04	0.02	0.01	0.01	0.00
		0.23	0.36	0.37	0.32	0.25	0.18	0.13	0.08	0.05	0.03	0.02
			0.11	0.23	0.30	0.31	0.28	0.23	0.18	0.13	0.10	0.07
				0.05	0.14	0.22	0.26	0.27	0.25	0.22	0.18	0.14
					0.03	0.08	0.15	0.20	0.24	0.24	0.23	0.21
						0.01	0.05	0.09	0.15	0.19	0.22	0.22
							0.01	0.03	0.06	0.10	0.14	0.18
								0.00	0.01	0.04	0.07	0.10
									0.00	0.01	0.02	0.04
										0.00	0.00	0.01
											0.00	0.00
												0.00

Figure 7: Probability distribution of gasoline price after 4 years indicates median estimate of $3.13 per gallon

The ratio of E85/gasoline price was based on regression of price data collected between February, 2002 and July, 2007. (Figure 8) The regression indicated that the price ratio has decreased at an average rate of 0.17% per month during this time, with a relative volatility of 5.3%. Notably, however, the price of E85 today remains at about 84 percent of the price of gasoline, or nearly 20 percent higher than would be expected based on its energy content. If the price ratio of E85 to gasoline dropped in the future, then it might become worthwhile to use E85 instead of gasoline. A very rough lattice model for the E85/gasoline price ratio was constructed, and the resulting lattices for a six-month period are summarized in Table 4 and Table 5. The lattice model indicates that there is approximately a 22 percent chance of the price ratio being less than 0.71 after 6 months. Figure 9 shows the probability distribution of the price ratio developed by the same lattice model extended over 48 months, and reveals a 46 percent chance of the E85/gasoline price ratio being less than 0.71 after 48 months.

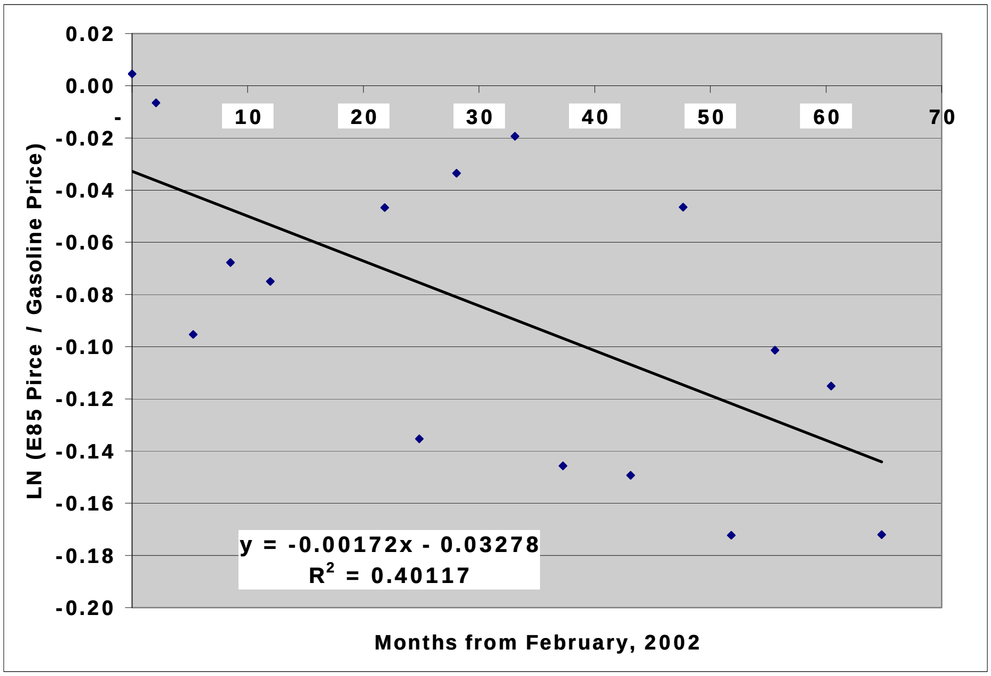

Figure 8: The ratio of E85 price to gasoline price has been decreasing at about 0.17% per month, but remains well above its energy-equivalent level of 0.71. (United States Department of Energy, Office of Energy Efficiency and Renewable Energy, 2007a)

Table 4: E85/gasoline price ratio outcome lattice over six months.

Month						
0	1	2	3	4	5	6
0.84	0.89	0.94	0.99	1.04	1.10	1.16
	0.80	0.84	0.89	0.94	0.99	1.04
		0.76	0.80	0.84	0.89	0.94
			0.72	0.76	0.80	0.84
				0.68	0.72	0.76
					0.65	0.68
						0.61

Table 5: E85/gasoline price ratio probability lattice over six months.

Month						
0	1	2	3	4	5	6
1.00	0.48	0.23	0.11	0.05	0.03	0.01
	0.52	0.50	0.36	0.23	0.14	0.08
		0.27	0.39	0.37	0.30	0.22
			0.14	0.27	0.32	0.31
				0.07	0.17	0.25
					0.04	0.11
						0.02

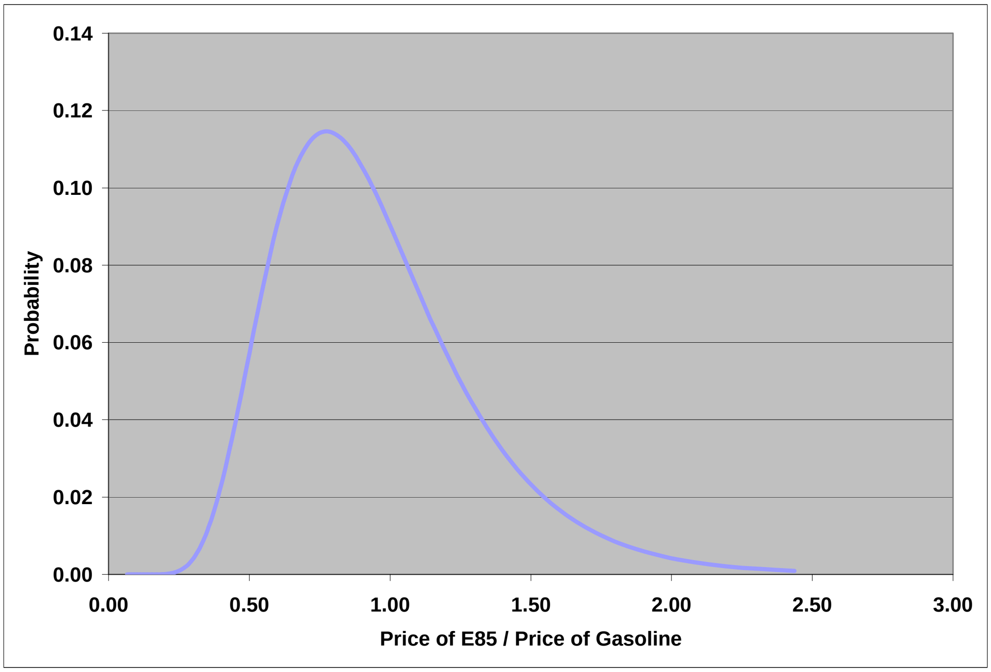

Figure 9: Probability Distribution of E85/gasoline price ratio after 48 months reveals 46% probability of price ratio < 0.71 (E85 cheaper on energy-equivalent basis).

Ideally, one might construct a two-variable lattice model that would account for uncertainties in both the future price of gasoline and the E85/gasoline price ratio. To simplify the analysis, let us suppose that it is possible for the fleet operator to secure an option with an E85 supplier to sell her a certain quantity of E85 at a defined strike price. This price would presumably be greater than the price of E85 today, but within the range of future fuel prices that are considered possible based on the gasoline price lattice. This E85 price can be specified in the lattice analysis spreadsheet model, so that the only uncertain future value in the model is the price of gasoline. In this case, then, the price of acquiring fuel flexibility would be the sum of the incremental cost of the FFV, plus the cost of securing the fuel purchase option.

Two permutations of the fuel purchase option were considered: one that entitles the fleet owner to purchase E85 at any time he chooses, and to go back and forth between E85 and gasoline as he pleases; and a second in which once the option is exercised, the fleet operator commits to continued use of E85. Furthermore, the options were evaluated over two time periods: 12 months and 48 months.

The value of the option represented by flex-fuel capability is calculated as the difference between the expected fueling cost without flexibility and the expected fueling cost with flexibility. The lattice analysis was used to evaluate the three system concepts described previously, as well as one using a hypothetical gasoline-only car rated at 22 mpg. The latter vehicle was considered in order to eliminate the effect of the efficiency differences and isolate the effect of the flex-fuel capability.

The following assumptions were used as an illustrative scenario:

- Option Price for Ethanol Purchase: $2.45 per gallon - equivalent to the September 2007 average gas price of $2.92 per gallon at the July 2007 E85-gasoline price ratio of 0.84. This would be a very low price for someone to agree to sell the fuel, given the way prices have been moving. It can be thought of as a floor on the strike price of E85.
- Miles driven per vehicle per year: 20,000 miles. This is considerably higher than the nationwide average of 12,000 miles per car per year, but is probably not unreasonable for a heavily-used commercial fleet.
- Discount Rate: 12% annually (equivalent to 0.95% per month, compounded monthly)

Table 6 presents a summary of the lattice analysis developed for the flexible-fuel Sebring when the fleet operator has a choice to continue using gasoline or to permanently switch to E85 at the strike price of $2.45 per gallon. The expected cost of fueling the FFV over 12 months is $2,489, while the expected cost of fueling a gasoline-only Hyundai Elantra over 12 months is $2,069, or $420 less than the FFV. Similar analyses were conducted for both option types over 12 and 48 months, for all vehicle types.

Table 6: Expected values of current and remaining months' fuel costs for a Chrysler Sebring FFV with option to switch permanently from gasoline to E85. Values in green indicate that the option has been exercised.

Month												
0	1	2	3	4	5	6	7	8	9	10	11	12
$2489	$2689	$2610	$2450	$2215	$1978	$1739	$1497	$1254	$1008	$759	$509	$256
	$2323	$2316	$2268	$2163	$1978	$1739	$1497	$1254	$1008	$759	$509	$256
		$1957	$1952	$1916	$1839	$1706	$1497	$1254	$1008	$759	$509	$256
			$1624	$1610	$1574	$1506	$1399	$1239	$1008	$759	$509	$256
				$1327	$1303	$1258	$1189	$1088	$948	$759	$509	$256
					$1069	$1034	$980	$902	$797	$658	$481	$256
						$847	$803	$740	$654	$542	$400	$221
							$658	$606	$536	$444	$327	$181
								$496	$439	$364	$268	$148
									$359	$298	$220	$121
										$244	$180	$99
											$147	$81
												$67

Tables 7-9 summarize the value of fuel flexibility compared to the inflexible cases under consideration. The results of this analysis indicate that it would not be worthwhile to pursue the option of flex-fuel capability based on current vehicle offerings.

The best course of action would be to purchase the more fuel-efficient gasoline-only Hyundai Elantra, which has lower expected fuel bills than the FFV Sebring over four years, and has a significantly lower manufacturer’s suggested retail price (MSRP) to boot. ($13,525 vs. $23,280)

Table 7: Option Values: Flex-Fuel Sebring vs. Gasoline Elantra

	Time Period	
Option Type	1 Year	4 Years
Single Switch	($420)	($290)
Back-and-Forth	($396)	($66)

Table 8: Option Values: Flex-Fuel Sebring vs. Gasoline Sebring

	Time Period	
Option Type	1 Year	4 Years
Single Switch	($75)	$1064
Back-and-Forth	($51)	$1288

Table 9: Option Values: Flex-Fuel Sebring vs. Hypothetical Gasoline Car

	Time Period	
Option Type	1 Year	4 Years
Single Switch	$145	$1926
Back-and-Forth	$168	$2150

If the Elantra were not feasible for some reason and a Sebring had to be purchased, it would still not be worthwhile to purchase the FFV version, at least when considering a timeframe of four years or less. Although the option has positive value over 4 years, the difference in MSRP between the gasoline-only Sebring and the FFV Sebring is $1350, so the price of acquiring the flexibility is greater than the value of the flexibility. Furthermore, the value of the flexibility would also have to cover the costs associated with securing the option to purchase E85 at a fixed price. As noted above, the option price would likely be high to secure a price as low as that used in these scenarios.

The final comparison shows that flex-fuel capability is not entirely without benefit. If there were a hypothetical gasoline-only car available on the market that was exactly the same as the FFV Sebring (apart from the FFV capability) it would be expected to cost about $2000 per vehicle more in fueling costs over four years, compared to the FFV. Since adding FFV capability has an incremental cost to the manufacturer of approximately $100, (Kahn Ribeiro et al. 2007) FFV capability *per se* is not a bad investment. However, the value of the flexibility tends to be overwhelmed by variation in fuel efficiency between vehicles and bundling of FFV capability with other options. In short, flex-fuel capability can deliver value, but it is only worth purchasing if the price is low and the fuel flexibility does not force a tradeoff with fuel economy.

Changes in vehicles usage patterns could alter the relative benefit of FFV capability. For one, a longer horizon for vehicle ownership increases the value of flexibility, as fuel prices are more uncertain in the long term. However, securing the option to purchase E85 at a fixed price would cost more as the window for exercising the option is increased. More subtly, if it was expected that a vehicle would be driven fewer miles per year early in its life, and more miles per year later in its life, then the relative importance of flex-fuel capability would increase compared to the importance of higher fuel economy. This is because the benefits of fuel economy are more certain in the near term, when fuel prices are known, but the benefits of flexibility increase with the long-term uncertainty of prices.

Conclusions

Among midsize cars currently being offered for sale in the United States, the ability to use gasoline or E85 interchangeably is not a worthwhile investment based on the usage patterns assumed in this analysis. A decision tree approach did not indicate any value whatsoever for fuel flexibility, while a lattice analysis determined a benefit to fuel flexibility that did not outweigh the increased fuel consumption and higher purchase costs.

The decision tree approach used aggregated “high” mid” and “low” gasoline price estimates and “high” and “low” ethanol prices, and so may have lost certain combinations of factors in which E85 was less expensive than gasoline on an energy-equivalent basis – and it is these situations that deliver value to the flexible system.

The lattice analysis may be more appropriate to situations in which prices are extremely volatile and decisions to employ flexibility can be taken quickly and for a low strike price. The lattice analysis revealed that there is value in fuel flexibility, but that current vehicle offerings are such that fleet managers would be better off choosing a high fuel economy car rather than a flexible-fuel car. Even if forced to choose between an FFV Sebring and a very similar gasoline-only Sebring, it would likely not be worth the additional purchase cost to buy the FFV.

Usage patterns play an important role in determining the value of flexibility. If a fleet manager were to consider a longer period of time, such as the full vehicle life, the value of fuel flexibility would be greater. Similarly, if a vehicle were expected to be driven more miles later in its like, then fuel flexibility would again be more valuable.

Much of the potential value of fuel flexibility can be easily lost through lower fuel economy. If automakers offered FFVs that had the same fuel economy as, and were priced more closely to, comparable gasoline-only vehicles, then the flexibility would be a worthwhile investment. This would be especially true if the incremental price of an FFV were closer to its production cost of ~$100. Absent such offerings in the market, fleet managers are better off seeking the known savings of better fuel economy and lower purchase price, rather than the uncertain savings of fuel flexibility.

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