Case Study: Forecasting Gasoline Prices

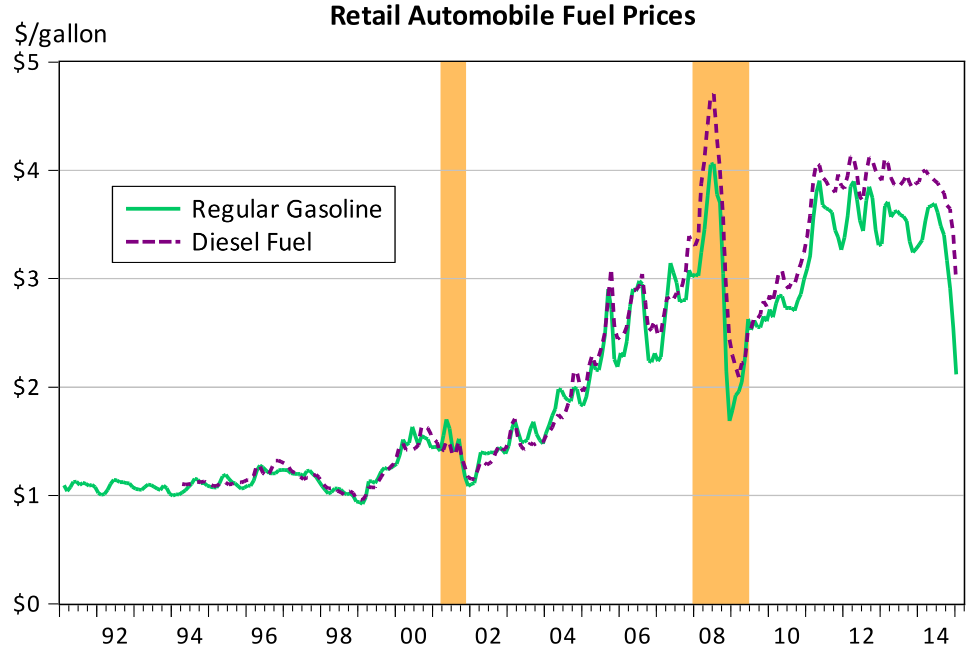
Energy prices are difficult to forecast because so many non-market forces can play a role in their determination. Geopolitical conflicts, natural disasters, and changing cultural norms toward energy use and conservation can influence the demand and supply of fossil fuel resources. In addition, government subsidies, tax breaks, and local and regional incentive programs can distort behavior and bring about equilibrium prices different from those of an unconstrained market.

This case study will introduce you to some basic methods for visualizing data for the purposes of predicting future directions in the price of gasoline. While it is not the purpose of this study to teach you sophisticated methods of statistical analysis, and no prior course work in statistics is assumed, a variety of modeling approaches will be presented for the purposes of evaluation and comparison of different forecast scenarios.

Exploratory Data Analysis

Let's begin by examining a plot of gasoline and diesel fuel prices for the period 1991 through January 2015.[1] The highlighted areas in 2001 and 2008-09 indicate periods of economic recession in the U.S. As you look at this chart, what features do you notice? Are there persistent trends (periods where the data increases or decreases over time); cycles in the data (regular patterns in the data); or unusual observations?

Retail Automobile Fuel Prices



1991 through January 2015

Here are a few observations that we can use to familiarize ourselves with these data, from most obvious to perhaps more subtle lessons.

- While the data on regular gasoline prices begins in 1991, reported prices for diesel fuel don't begin until 1994
- The price of these two fuels generally move together over time (highly correlated)
- Beginning around 2007 and continuing until the present, the price of diesel fuel seems to be persistently higher on average than the price of gasoline
- There wasn't much of a trend in prices prior to 1998, but following the recession that occurred in 2001, until sometime in 2008, automobile fuel prices rose steadily

[1]National averages of regular retail gasoline and on-highway diesel fuel including taxes. Source: US Energy Information Administration.

- Economic recessions seem to have a negative impact on fuel prices, particularly during the Great Recession of 2007-2009
- During 2011-2013, the price for diesel fuel was noticeably more stable (smaller variance) than gasoline prices
- Given the fact that we are at present in a period of economic expansion with relatively low unemployment, the large drop in fuel prices at the end of 2014 into 2015 seems unusual (an irregularity)

Forecasting using official projections

So how might we go about forecasting gas prices for 2015 and, say, the next decade or so? These are in fact two very different questions. Short-term forecasts, for the next year or two, are likely to depend on factors that are more easily predictable (e.g., known supply disruptions or the strength of demand due to lower unemployment and rising incomes). Longer term, historical averages often make better forecasts.

The first place to begin in the case of fuel prices is to look at the source agency, the Energy Information Administration (EIA) of the U.S. Department of Energy. The EIA is one of a few government agencies that provide forecasts for their data. The table at right provides the EIA's baseline ("reference") forecasts for average gasoline prices (all grades, not just regular) and imported oil in inflation-adjusted dollars. However, there are several practical reasons why these forecasts might not be suitable for our needs:

- The gasoline price forecasts includes all grades of gasoline, not just regular
- The forecast horizon begins in 2013; 2012 is the last historical observation
- But, as noted above, fuel prices changed dramatically at the end of 2014

There are some useful bits of information in these forecasts, however, including:

- As early as 2013, the EIA was foreseeing a decline in gasoline prices
- Imported oil prices are forecast to remain below $100 per barrel for most of the decade ahead
- We could apply the EIA's forecasted percent changes to the current historical data to calculate forecasts for the next 10 years, perhaps making some subjective adjustments for the very near-term forecast for, say, 2015
- The EIA provides several alternative forecasts based on different assumptions about factors related to energy prices (e.g., higher oil prices, stronger economic growth, etc.) that may be useful for determining our own forecast scenarios

Energy Price Forecasts from the EIA[f]

Year	Gasoline		Imported Oil	
	$/gal	% chg	$/barrel	% chg
2012	3.66	0.752%	101.10	-3.223%
forecasts				
2013	3.550	-2.929%	101.557	0.452%
2014	3.369	-5.099%	97.996	-3.506%
2015	3.177	-5.702%	88.925	-9.256%
2016	3.072	-3.319%	85.161	-4.234%
2017	3.027	-1.450%	83.725	-1.686%
2018	3.021	-0.220%	84.183	0.547%
2019	3.035	0.463%	85.841	1.970%
2020	3.077	1.399%	88.069	2.596%
2021	3.121	1.420%	90.439	2.691%
2022	3.169	1.562%	92.963	2.791%
2023	3.220	1.607%	95.379	2.599%
2024	3.261	1.274%	97.679	2.411%
2025	3.291	0.894%	100.012	2.389%

[f] Taken from data table A3 at http://www.eia.gov/forecasts/aeo/

Forecasting using educated guesses

Series with persistent trends are much easier to predict when the forecast horizon includes periods over which "normal" events can be assumed. Real GDP in this country, for example, has a long-run rate of growth of about 2.8% per year. Therefore, a baseline forecast of 2.8% annual growth beginning in 2015 could provide a reasonable baseline ten-year forecast for GDP even though we know that an economic downturn is possible during this period.

From the chart on page 1, however, we see that we're not so fortunate when it comes to forecasting gasoline prices. The only period of time that exhibited a somewhat constant rate of growth was during the five-year period preceding the Great Recession. From 2002-2007 gasoline prices grew at an average rate of 15.86% per year.[2] For a variety of reasons, it's unlikely that we'll see gasoline prices grow at this annual rate during the next decade.

According to a recent article in *The Economist* magazine (December 8, 2014) there are at least four reasons why oil and gas prices are so low right now: (1) overall economic activity in the majority of developed countries (U.S. excluded) is relatively weak reducing demand for oil and refined petroleum products like gasoline; (2) markets don't seem to be much concerned with geopolitical risks generally, and recent disruptions in supply coming from conflicts in oil-rich Iraq and Libya in particular; (3) the U.S. has recently become the world's largest oil producer and is thus less reliant on imported oil; and (4) the Organization of Petroleum Exporting Countries (OPEC) doesn't want to sacrifice their market share by reducing production to prop up the price of oil right now since this would mainly benefit other countries like Russia and Iran. As a result, the outlook for oil prices is to remain well below the psychological threshold of $100 per barrel for the foreseeable future.

Given the economic climate described above, while gasoline prices in the U.S. have probably bottomed out, an educated guess about the near-term outlook probably has gasoline prices averaging around $2.50 per gallon this year and rising to perhaps $2.75 per gallon in 2016, $3.00 per gallon in 2017 and back to something like an average of $3.25 per gallon from 2018 to 2025, roughly in line with where gas prices stood in 2012-2013 (see again the chart on page 1).

Model-based forecasting

Another alternative for obtaining forecasts is to buy them. There is an entire industry devoted to economic consulting and forecasting. Swiss Re, a global reinsurance company, for example is currently forecasting oil prices to average $80 per barrel this year, rising to $100 in 2016. The forecasts of these companies are typically based on statistical models that capture a number of explanatory factors influencing demand and supply.

Here at Colby the economics department's senior seminar in economic forecasting (EC473) produces a newsletter titled the *Colby Economic Outlook (CEO)* containing short-term forecasts for the U.S. using a medium-sized macroeconomic model of about 100 equations, in addition to

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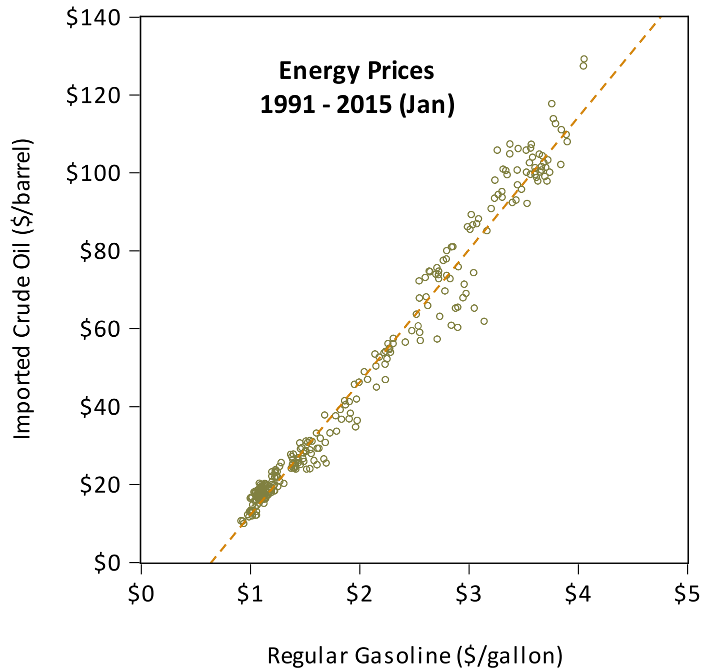
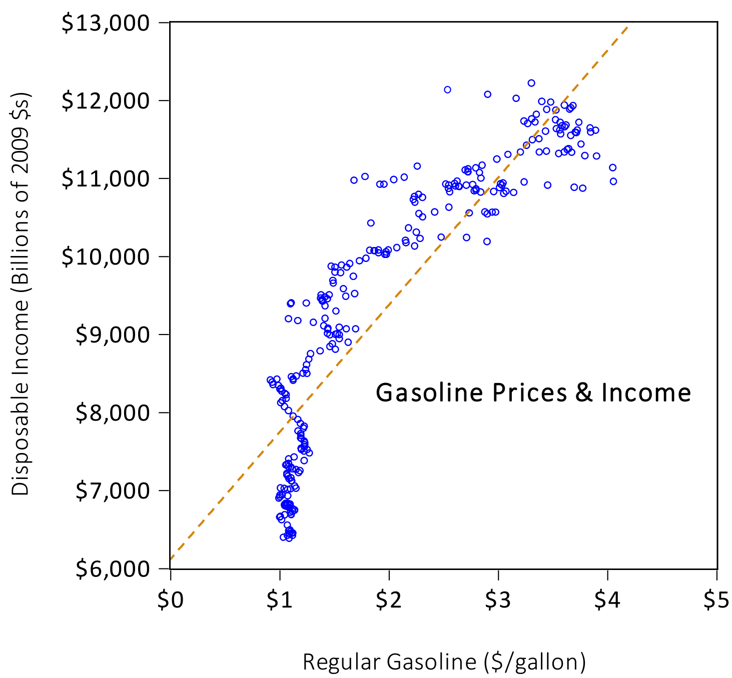
[2] Compound annual growth rate over 5 years $\left({P_{2007}}/{P_{2002}}\right)^{\frac{1}{5}} - 1 = 0.1586\ or\ 15.86\%$ per year.

a separate model for the Maine economy.[3] This year's edition of the *CEO* predicts that gasoline prices will remain roughly constant throughout 2015 and rise by just 1% in 2016.

Model-based forecasts typically employ a structural approach to data analysis by defining theoretical relationships among variables and then collecting data to statistically estimate the strength of those relationships for purposes of prediction and simulation. Since gasoline is a refined product of crude oil it's reasonable to 'theorize' that gasoline price and crude oil prices are related. This relationship is confirmed in the chart at right as the observations on the price of gasoline and crude oil are closely clustered along a straight line.



Gasoline demand also appears to be dependent on the strength of the economy. Take a look again at the chart on page 1 and in particular the periods 2002-2007 and 2009-2011. For consumer goods, basic economic theory identifies income as a primary determinant of household spending and thus we might consider disposable income as a possible explanatory variable for gasoline prices. Indeed, as illustrated in the graph at left, there does appear to be a fairly significant relationship between observations on disposable income (inflation-adjusted) and gasoline demand.[4]



Less obvious from the graph, but clearer from the data, is the fact that while gasoline prices are 'volatile' (pun intended) in the sense that they can vary greatly over time, they don't vary a lot on a month-to-month basis. When gasoline prices change they tend to change in the same direction

[3] See http://www.colby.edu/econ/wp-content/uploads/sites/73/2015/02/CEO2014_1214.pdf

[4] If gasoline prices and income were statistically unrelated, a straight line fit through the data would have no slope, i.e., would be horizontal.

for one or two months before reversing course. In other words, there is some persistence in the behavior of gasoline prices – this month's gasoline price reflects to a large extent the price of gasoline last month. Thus, we now have a potential model to consider for predicting changes in gasoline prices. We can summarize these relationships algebraically using the following linear model of gasoline prices:

$$P_t^{gas} = \alpha + \beta_1 \cdot P_t^{oil} + \beta_2 \cdot Income_t + \beta_3 \cdot P_{t-1}^{gas} + \varepsilon_t$$

Analytically, this equation proposes that the price of gasoline this month $\left(P_t^{gas}\right)$ depends linearly on the price of imported oil this month $\left(P_t^{oil}\right)$, disposable personal income this month, and the price of gasoline last month. We include an error term (ε_t) in our model to reflect that fact that there are other things that explain gasoline prices but we're going to assume that these are random effects that are either unmeasurable or that we cannot anticipate with much certainty (e.g., things like geopolitical conflicts, natural disasters, consumer preferences for hybrid vehicles, etc.). In the equation above, β_1 provides a measure of the *ceteris paribus*[5] effect of a change in oil prices on changes in gasoline prices. Similarly, β_2 measures the *ceteris paribus* effect of a change in income on gasoline prices. Mathematically, we're simply saying that β_1 and β_2 are partial derivatives of this equation.

Estimating the model above using econometric methods provides the following results:

$$\hat{P}_t^{gas} = 27.5 + 2.015 \cdot P_t^{oil} + 0.003 \cdot Income_t + 0.263 \cdot P_{t-1}^{gas}$$

Each of the model's parameter estimates is statistically significant and, overall, this equation explains 99% of the variation in gasoline prices historically. For purposes of estimation, gasoline prices are in units of cents per gallon. Thus, holding constant income and last month's gasoline prices, a one dollar increase in the price per barrel of imported oil raises gasoline prices by 2 cents per gallon on average. Similarly, a one hundred billion dollar increase in disposable income, holding oil prices and last month's gasoline prices constant, corresponds to a 0.3 cent per gallon increase in gasoline prices. And, when gasoline prices rise by a penny per gallon this month we can expect a 0.263 cent per gallon increase next month, all else fixed.

Just because this model fits the historical data [very] well doesn't mean that it will necessarily produce good forecasts. From the equation above, we see that in order to predict gasoline prices in the future we need forecasts of oil prices and income. If the forecasts for these two variables are poor then our predictions for gasoline prices will be poor as well.

Let's use the forecasts for imported oil from this year's *Colby Economic Outlook* as a baseline, and modify it to account for the information we have about oil prices that wasn't available last November when the *CEO* went to press. Oil prices ended 2014 at $60.57 per barrel and probably fell further to just about $50/bbl in January 2015. Last fall, most forecasts, including the *CEO*,

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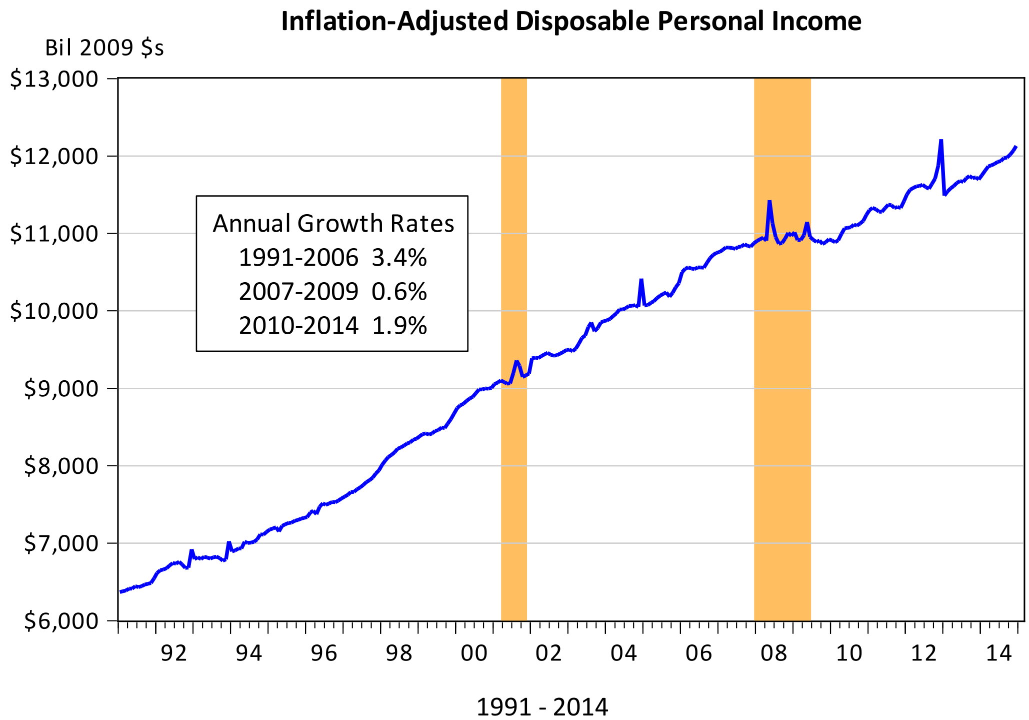
[5] *Ceteris paribus* is a Latin phrase which means "all else fixed." Here, we mean that β_1 measures the effect of a $1 per barrel change in P^{oil} holding constant disposable income and last month's gasoline price.

foresaw oil prices rising during 2015 and settling in at about $80 per barrel in 2016. Given the most recent evidence, this seems a bit aggressive. Let's instead assume that oil prices will rise more gradually, averaging about $65/bbl in 2015, $71/bbl in 2016, $77/bbl in 2017, and hitting $80/bbl in 2018 and holding steady for the remainder of the forecast horizon.

We also need a forecast for income through 2025. As you can see from the graph at right, income growth has been remarkably steady historically, particularly so when you consider the dramatic economic events of the past decade. Let's assume that the most recent rate of growth of personal income of 1.9% per year will continue over our forecast horizon.



With these explanatory variable forecasts we can then simulate our model to produce a forecast for gasoline prices for 2015-2025.

Year	Price
2015	$2.47
2016	$2.78
2017	$2.96
2018	$3.06
2019	$3.07
2020	$3.08
2021	$3.09
2022	$3.10
2023	$3.11
2024	$3.12
2025	$3.13