



VOL. 2, NO. 10
OCTOBER 2007

Economic Letter

A stylized world map in shades of teal and blue, serving as a background for the journal's title and subtitle.

Insights from the
FEDERAL RESERVE BANK OF DALLAS

What's Driving Gasoline Prices?

by *Stephen P. A. Brown and Raghu Virmani*

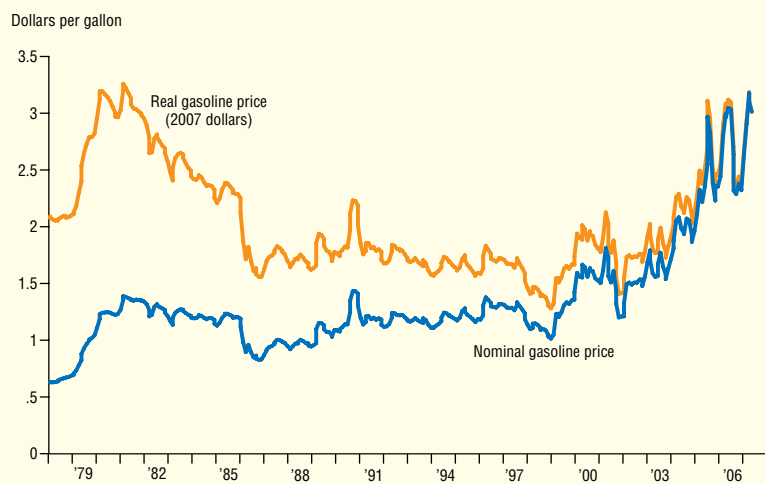
Anyone who regularly fills a car's gas tank knows U.S. pump prices have been high and volatile in recent years, whether measured in current or inflation-adjusted dollars (*Chart 1*). Most motorists are well aware that crude oil prices have surged to one record after another; yet the ups and downs in gasoline prices sometimes seem confusing. This spring, gasoline was getting more expensive at a time when oil prices were falling. Just a few months later, oil had been bid back up, but gasoline prices didn't seem to respond.

These apparent disconnects prompted our examination of the forces that determine gasoline prices. Our econometric models confirm the traditional result that crude oil prices dominate movements in gasoline prices, but they also show that seasonal and nonseasonal movements in consumption, refinery production, imports and inventories influence gasoline prices in the short term.

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Chart 1
Retail Gasoline Prices Rising



SOURCES: *Oil and Gas Journal*; Bureau of Labor Statistics.

Including these other factors with crude oil price provides a nearly complete picture of gasoline pricing in the U.S. market.

This year, some nonseasonal factors have been out of their normal ranges, contributing to gasoline price volatility and creating market conditions where prices are rising for gasoline and falling for oil, or vice versa. These events are unlikely to recur, so any disconnects should prove short-lived. Our most complete model suggests gasoline prices will retain their seasonal variations but decline slightly in the next few years, a result generally consistent with recent readings in the futures markets.

In an era of high energy prices, gasoline looms as an important pocketbook issue for American consumers, even though it now represents a smaller portion of household budgets than in the 1980s (see box titled “How Gasoline Prices Affect American Budgets,” page 4). A more complete understanding of what’s driving gasoline prices may reduce confusion about how energy markets work.

Crude Oil and Gasoline Prices

Most of the fuel crises Americans remember were the result of spikes in crude oil prices. Sharp rises in gasoline prices followed the Arab oil embargo in the mid-1970s, the Iranian revolution and subsequent Iran–Iraq war in the late 1970s and early 1980s, and the disruption of Kuwaiti oil production after Iraq’s 1990 invasion.

In recent years, higher crude oil prices have meant steadily rising gasoline prices. Demand for oil has increased worldwide, particularly in the rapidly expanding Chinese and Indian economies. Meanwhile, new supplies have been slow to develop—at least in part because large portions of world oil resources are in the hands of national oil companies or in countries where markets aren’t particularly free.¹

This quick historical survey reminds us of the close link between crude oil and gasoline prices. Constructing an econometric model using just those two factors, we find that spot gasoline prices eventually rise 2.8 cents for every \$1 increase in spot

prices for West Texas Intermediate (WTI), a benchmark crude.² The model explains nearly 98 percent of U.S. gasoline prices.

The close fit between raw material and final product prices reflects the realities of petroleum refining, a capital-intensive and high-volume process. Crude oil is the dominant input into refineries, and gasoline accounts for more than half of U.S. refinery output. Other refinery inputs contribute little to the variation in gasoline prices. We measure spot prices, which don’t include the distribution, retailing and marketing costs folded into the prices Americans pay at the pump.

In general, the most dramatic movements in the country’s gasoline prices have been associated with similar changes in crude oil prices (Chart 2A).³ A more detailed look at the past three years, however, shows the two prices have diverged on several occasions—for example, in late 2005 and early 2006 and in the summer of 2007 (Chart 2B). We’ll see whether we can close those gaps by looking at other factors that influence gasoline prices.

Seasonality and Gasoline Prices

Most U.S. gasoline is used in passenger automobiles, so when we drive determines when we use gasoline. The busiest American driving season is Memorial Day weekend through Labor Day weekend, with gasoline consumption the highest during those months (Chart 3).

In 2006, the seasonal differential in gasoline consumption was about 10 percent from the February low to the peak of the summer driving season.

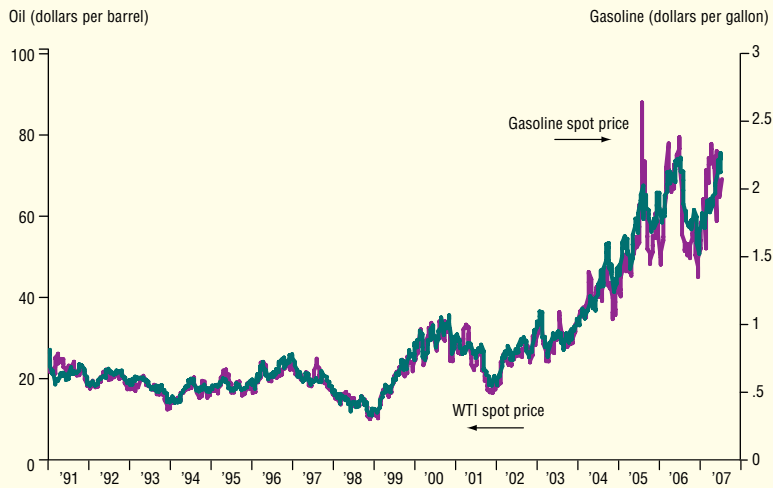
A shorter driving peak occurs during the Thanksgiving holiday as Americans travel to visit family members. December also shows some spikes in consumption for the winter holiday season. After that, consumption falls to its annual low in February.

The seasonal driving patterns show up in gasoline prices. They generally rise relative to oil prices toward

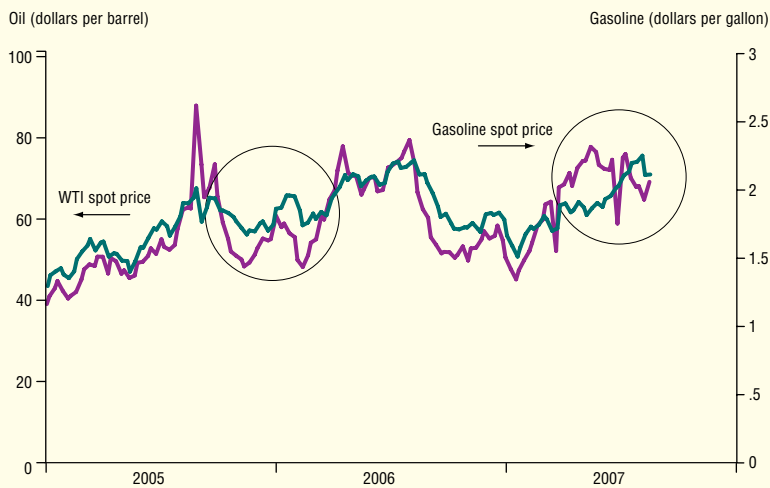
Chart 2

Crude Oil Prices Heavily Influence Gasoline Prices

A. They Move Together over the Long Term...



B. ...but a Closer View Shows Disconnects



SOURCE: Wall Street Journal.

Memorial Day and are higher during the summer months. They generally fall after Labor Day and are lower during the winter months.

Gasoline production, imports and inventories are all adjusted to meet seasonal variations in U.S. gasoline demand. In spring, refiners begin shifting their product mix toward gasoline

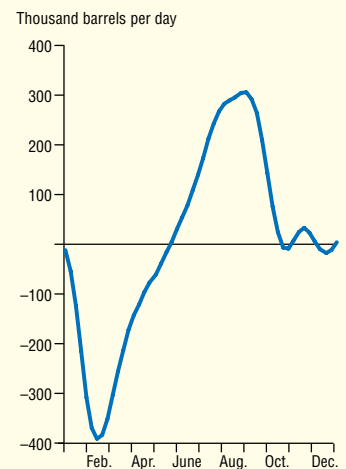
to build inventories in advance of summer. Gasoline production typically remains high during the summer months. The rising summer gasoline prices in the U.S. also attract imports.

The summer buildup impacts gasoline prices in other ways. As refiners shift their product mix toward gasoline, they must more extensively

In 2006, the seasonal differential in gasoline consumption was about 10 percent from the February low to the peak of the summer driving season.

Chart 3

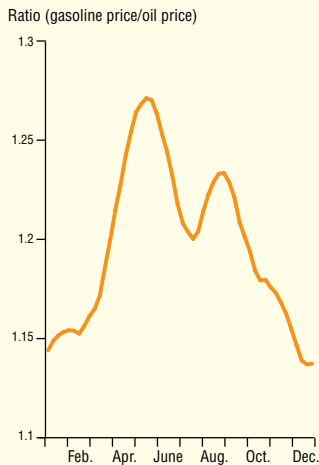
Gasoline Consumption Varies Throughout Year (Seasonal variation from annual average)



SOURCES: Energy Information Administration, Department of Energy; authors' calculations.



Chart 4
Crack Ratio Shows
Seasonality



SOURCES: *Wall Street Journal*; authors' calculations.

process the crude oil, pushing up production costs. Storing gasoline from the spring to the summer also adds to the costs. After Labor Day, the product mix begins to shift away from gasoline as refiners build up their winter supplies of heating oil. The forces pushing up gasoline prices then unwind.

The interaction of consumption, refinery production, imports and storage over the course of each year leads to a regular seasonal pattern of gasoline prices relative to crude oil prices. We measure it by the crack ratio, which captures the seasonal element

of the relationship between gasoline and crude oil prices (*Chart 4*). It is calculated by multiplying the spot price of a gallon of regular unleaded gasoline by 42, the number of gallons in a barrel, and dividing the result by the spot price of WTI, which is quoted in barrels.⁴ With oil at \$75 a barrel, the gasoline price swing from winter lows to the Memorial Day high would be 27 cents a gallon.

To determine whether seasonal factors affect gasoline prices, we incorporated the crack ratio into our earlier model of U.S. gasoline prices, which was limited to the relationship

In 2005, Hurricanes Katrina and Rita shut down over a fourth of U.S. refinery capacity and sent gasoline prices skyrocketing.

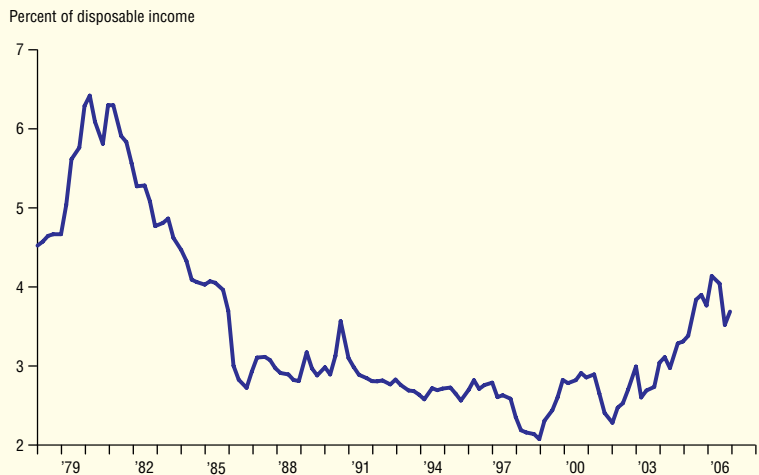
How Gasoline Prices Affect American Budgets

U.S. gasoline prices surged to an all-time high a few days before Memorial Day weekend, with a national average of \$3.23 a gallon for unleaded regular. According to the U.S. Energy Information Administration, the previous inflation-adjusted high was \$3.22, set in May 1981.

Despite this year's record gasoline prices, we still spend less of our take-home pay on gasoline than we did in the early 1980s. At today's higher incomes, gasoline expenditures claim less than 4 percent of U.S. after-tax personal income (*see chart*). The comparable figure for 1981 was more than 6 percent.

Since 2002, the share of disposable income used to purchase gasoline has risen steadily. Increasing per capita gasoline consumption has been a factor, but most of the hike comes from rising gasoline prices. At today's incomes, retail gasoline prices would have to reach about \$5.50 a gallon before they took the same share of U.S. household budgets as they did in 1981.

Gasoline Expenditures Remain Below Highs



SOURCES: Energy Information Administration, Department of Energy; Bureau of Labor Statistics; Bureau of Economic Analysis.

between gasoline prices and crude oil. Adding the new data produced a tighter fit than the one we achieved with WTI alone (*Chart 5A*).

For our first model, the average weekly error was 5.36 cents a gallon. In this one, which accounts for seasonality, the error falls to 4.67 cents a gallon. The instances where crude oil and gasoline prices diverge have shrunk a bit, but they remain (*Chart 5B*).

Nonseasonal Factors

At times, gasoline consumption, production, imports and inventories break away from their normal seasonal patterns. These movements result in gasoline prices that temporarily deviate from the path determined by crude oil prices and normal seasonality.

In 2005, for instance, Hurricanes Katrina and Rita shut down over a fourth of U.S. refinery capacity and sent gasoline prices skyrocketing at a time when the driving season was coming to an end and oil prices were rising only slightly.

Earlier the same year, prolonged cold weather in the Northeast caused refineries to delay their switch from the winter product mix that includes more heating oil to the summer product mix that centers on gasoline. The result was lower inventories and higher prices for gasoline.

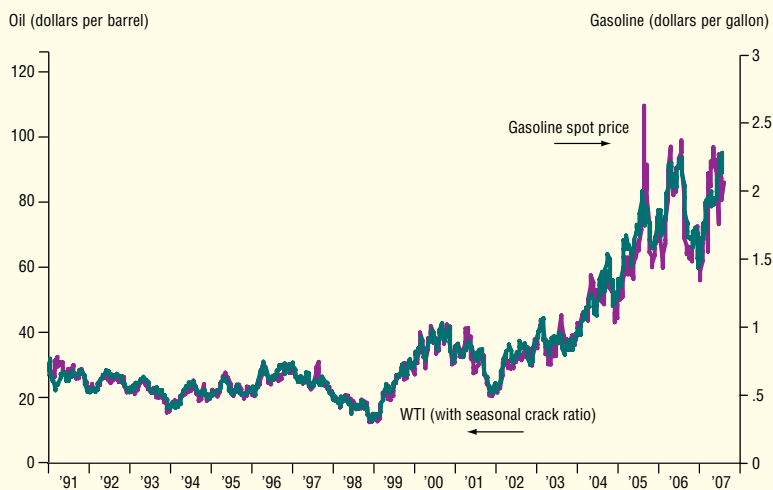
In early 2007, gasoline consumption began rising well ahead of the normal seasonal pattern. At the same time, refinery outages meant that suppliers were slow to increase gasoline production. The result was earlier-than-usual increases in gasoline prices, although the peak still occurred a few days before the Memorial Day weekend.

These aberrations suggest non-seasonal movements may provide additional insight into gasoline prices. To see their impact, we bolstered our econometric model of U.S. gasoline prices by adding nonseasonal movements in consumption, production, inventories and imports to the WTI price and the seasonal crack ratio.

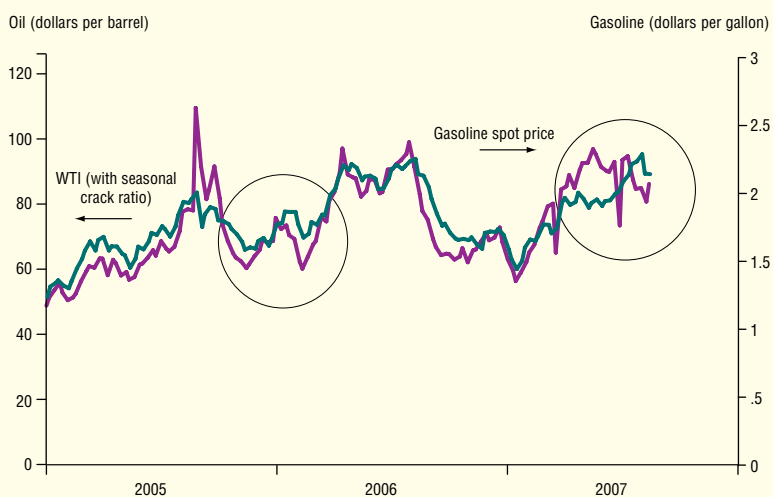
Chart 5

Crack Ratio Improves Fit of Oil, Gasoline Prices

A. With Seasonal Factors, They Move Together...



B. ...and Disconnects Begin to Shrink



SOURCES: *Wall Street Journal*; Energy Information Administration, Department of Energy; authors' calculations.

We also measure international markets' influence on U.S. gasoline prices. Although major global crude oil prices such as WTI in the U.S., Brent in Europe, Bonny in Africa and Dubai Fateh in the Middle East move together in the long run, regional geopolitical events and market conditions can cause them to deviate from each other. At such instances, differences

in global oil prices can influence U.S. gasoline prices (*see box titled "Global Markets and Gasoline Prices," back page*). To recognize this influence, the model also includes the price of Brent crude oil, which is produced in the North Sea.

Our final model incorporates a wide-ranging set of forces shaping U.S. gasoline prices—the cost of WTI

The outlook for crude oil prices can change significantly with economic conditions or geopolitical events.

and Brent crudes, the normal seasonal variations and nonseasonal influences from consumption, production, inventories and imports. Following standard econometric practices, we represent the price variables in natural logs and use error-correction processes to explain the relationship between the two crude oil prices and the U.S. spot price of gasoline.

The model shows that higher crude oil prices—WTI or Brent—result in higher gasoline prices. Gasoline prices have normal seasonal ups and downs and respond positively to nonseasonal increases in consumption and negatively to nonseasonal gains in production, imports and inventories. As estimated, the model explains more than 99 percent of gasoline price levels and 56 percent of the weekly changes in gasoline prices (*Chart 6A*).

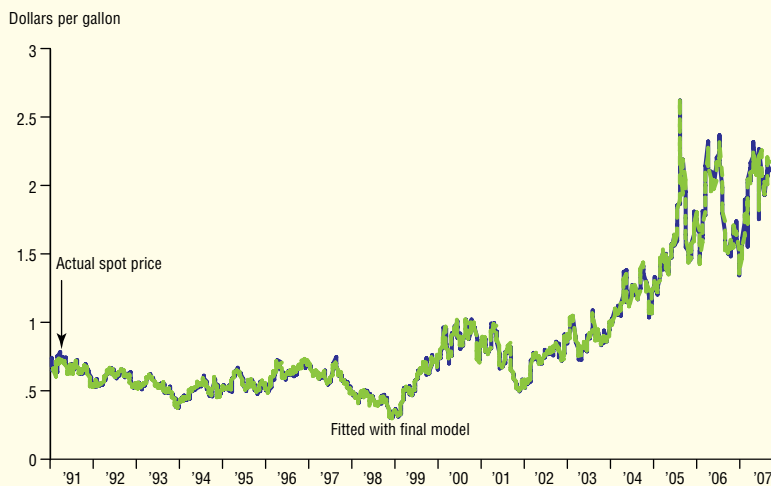
This more comprehensive model performs much better than the previous two. The average weekly error has been cut to 2.44 cents a gallon, compared with 5.36 cents when we use only crude oil and 4.67 cents when we add seasonality. Where crude oil and gasoline prices diverge in the other models, they now track quite well (*Chart 6B*).

Gasoline Price Outlook

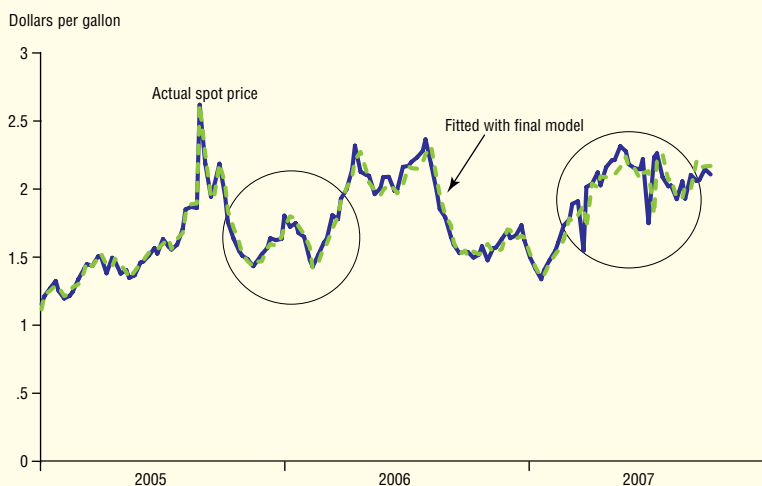
Armed with a model that explains gasoline prices, we're able to assess the outlook for U.S. gasoline prices over the next few years and compare it with the price path suggested by the futures market.

Chart 6
Full Model Creates Tightest Fit

A. Spot Gasoline Prices Are in Sync...



B. ...and Disconnects Nearly Disappear



SOURCES: *Wall Street Journal*; Energy Information Administration, Department of Energy; authors' calculations.

We start with assumptions for oil prices, seasonality and nonseasonal factors. We use futures market values for WTI and Brent for our crude prices. We generate a short-term outlook by assuming that the nonseasonal fluctuations in consumption, production, imports and inventories will persist. For the long-term outlook, we assume

the nonseasonal fluctuations will wane as these influences abate and normal seasonal patterns assert themselves.

The short-term outlook generated with the model shows a general consistency between the futures prices for gasoline and crude oil (*Chart 7*). The model shows that the currently low gasoline inventories may continue

to keep gasoline prices a bit higher than is normal during the fall. The long-term outlook generated with the model is generally consistent with the futures prices for gasoline and crude oil (Chart 8).

The outlook for crude oil prices can change significantly with economic conditions or geopolitical events, but in October the futures market anticipated a decline from this year's high levels over the next few years. WTI is expected to slide from \$87 a barrel to \$75 by the end of 2010.

Using those crude oil prices, our model suggests that spot gasoline prices will rise by 20 cents in the next few months, then decline by about 35 cents a gallon over the next three years, with seasonal variations during each year of about 27 cents a gallon. Retailing costs will mean slightly higher actual pump prices, of course, but the general outlook suggests a decline in gasoline prices, although they will remain relatively high.

The U.S. economy has continued to grow, with strong consumer spending and relatively tame inflation, despite rising and volatile gasoline prices in recent years. Household budgets won't get much relief, but continued high gasoline prices probably aren't going to be an unbearable burden for the economy as a whole.

Brown is director of energy economics and microeconomic policy and Virmani is an economic analyst in the Research Department of the Federal Reserve Bank of Dallas.

Notes

¹ See "Running on Empty? How Economic Freedom Affects Oil Supplies," by Stephen P. A. Brown and Richard Alm, Federal Reserve Bank of Dallas *Economic Letter*, April 2006.

² We use spot prices to represent the overall U.S. gasoline market. Although pump prices may respond more quickly to rising spot prices than they do to falling spot prices, movements in pump prices are the direct result of movements in spot prices. See "Crude Oil and Gasoline Prices: An Asymmetric Relationship?" by Nathan

Chart 7

Gasoline Prices Stable in Short Term



SOURCES: *Wall Street Journal*; Energy Information Administration, Department of Energy; FutureSource; authors' calculations.

Chart 8

Gasoline Prices Drift Lower in Long Term



SOURCES: *Wall Street Journal*; Energy Information Administration, Department of Energy; FutureSource; authors' calculations.

S. Balke, Stephen P. A. Brown and Mine K. Yücel, Federal Reserve Bank of Dallas *Economic Review*, First Quarter 1998.

³ One exception was the 2005 hurricane season, when hurricanes Katrina and Rita temporarily shut down a significant portion of U.S. refinery capacity.

⁴ With dramatically rising prices, we find the crack ratio shows more empirical consistency than the more commonly used crack spread—the spot price of gasoline multiplied by 42 less the spot price of WTI. Thus, it is better suited to econometric analysis.

Global Markets and Gasoline Prices

The world oil market is highly integrated, which means short-run opportunities for arbitrage are exploited swiftly and global oil and oil-product prices move together in the long run.

Just as world oil prices are tied to developments in major centers of supply and demand, regional gasoline prices are, in turn, linked to world oil prices. In our gasoline pricing model, we find that both North American (WTI) and European (Brent) benchmark oil prices exert significant influence on U.S. gasoline prices, as measured by the New York Harbor spot price.

Although international benchmark gasoline prices—such as New York Harbor spot and Rotterdam spot—generally move together, they occasionally exhibit short-run deviations from their normal relationship, creating arbitrage opportunities that, when acted upon, will eventually lead to a resumption of long-run trends.

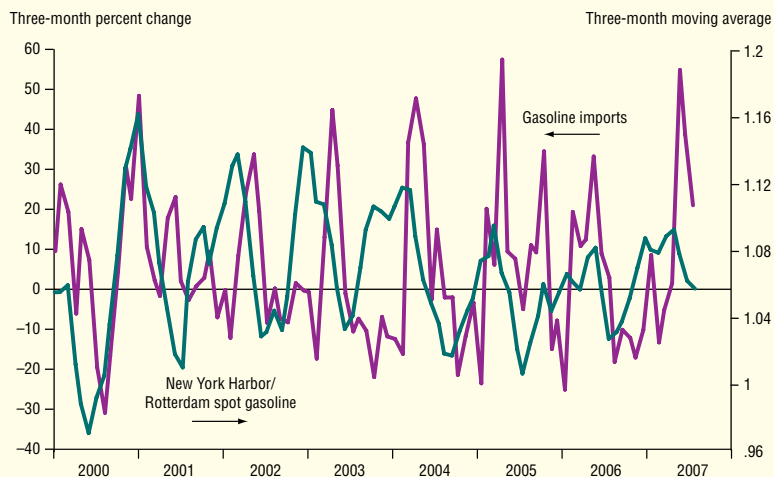
When prices for gasoline delivered at New York Harbor are higher than they are in Rotterdam, for example, European refiners seek to exploit the price differential by shipping gasoline to the North American market (*see chart*). In time, European gasoline in North American markets causes the New York price to fall relative to the Rotterdam price. The shipments continue to head westward until the arbitrage opportunity has been fully exploited and both prices are in sync.

Similarly, if the price of Brent falls relative to WTI, more imported crude oil finds itself in North American refineries, causing oil and refined product prices to fall in North America relative to those in Europe. It is the fungible nature of crude oil and refined products that allows oil producers and refiners to exploit short-run arbitrage opportunities and keeps the world oil market highly integrated.

The global nature of the market is also highlighted during unforeseen events and supply disruptions. During extraordinary production disruptions, gasoline imports play an important role in soothing markets, as they did when Hurricanes Katrina and Rita struck the U.S. Gulf Coast in 2005.

The devastating impact of these hurricanes temporarily shut down over a fourth of U.S. refinery capacity. In response, American gasoline imports from Europe tripled, with an unprecedented 50 tankers crossing the Atlantic in the first week of September 2005.

Global Price Differentials Spur Gasoline Imports



SOURCES: *Wall Street Journal*; Energy Information Administration, Department of Energy.

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