Paper #5-2

COMMODITY PRICE VOLATILITY

Prepared for the
Macroeconomic Subgroup

On September 15, 2011, The National Petroleum Council (NPC) in approving its report, *Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources*, also approved the making available of certain materials used in the study process, including detailed, specific subject matter papers prepared or used by the study's Task Groups and/or Subgroups. These Topic and White Papers were working documents that were part of the analyses that led to development of the summary results presented in the report's Executive Summary and Chapters.

These Topic and White Papers represent the views and conclusions of the authors. The National Petroleum Council has not endorsed or approved the statements and conclusions contained in these documents, but approved the publication of these materials as part of the study process.

The NPC believes that these papers will be of interest to the readers of the report and will help them better understand the results. These materials are being made available in the interest of transparency.

The attached paper is one of 57 such working documents used in the study analyses. Also included is a roster of the Subgroup for which this paper was developed or submitted. Appendix C of the final NPC report provides a complete list of the 57 Topic and White Papers and an abstract for each. The full papers can be viewed and downloaded from the report section of the NPC website (www.npc.org).

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COMMODITY PRICE VOLATILITY

Overview of commodity price volatility and related effects on the U.S. economy

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1. Executive summary

In considering how the United States' major sources of energy, specifically oil and natural gas, affect the macroeconomy, it is imperative to explore commodity price volatility. Regular price variability, provided there exists a means of mitigating risks through well-functioning forward markets, need not be disruptive; however, high price volatility, and particularly unexpected price swings, can significantly dampen economic activity. In general, low price elasticity of demand, low price elasticity of supply, high income elasticity of demand, and lumpiness of capital investments can all contribute to greater price volatility. Such volatility may result in widespread inflation, decreased consumer confidence and decreased capital spending, which, in combination, represent the pre-cursors to stagflation. Further, these side effects of uncertain commodity prices may diminish the ability of the government and/or the Federal Reserve to stimulate or retract the economy via controlled methods. The United States' ability to secure and develop reliable sources of energy has been a policy concern given limited commodity supply and global dynamics, but after the sharp rise and fall of commodity prices in 2008, economic impacts of volatility have also become a prominent consideration.

In this paper, we address commodity price volatility and the related effects on the macroeconomy, stock returns, and producers and consumers of oil and gas. We also deconstruct commodity price volatility to determine how commodity prices react to specific factors. Finally, we provide a brief overview on the correlation between oil and natural gas prices. In writing this paper, we did run into a couple of gating items. First, this topic is incredibly broad and could easily be crafted into a full study by itself. Second, while our initial focus was on commodity price volatility, we found that there is limited information on pure volatility implications. Unless specifically noted herein, we have used the term "volatility" interchangeably with the concept of fluctuating commodity prices or commodity price changes.

Our significant findings are as follows:

- Traditionally-defined commodity price "volatility", a measure that evaluates the standard deviation of the log returns, is a healthy signaling mechanism for market participants about supply and demand information
- Another, somewhat related, topic is the accuracy (or inaccuracy) of commodity price expectations. Commodity price expectations have experienced a great deal of variability and this plays an important role in the types of investments that market participants (e.g., utilities, utility regulators, and utility rate-payers) are willing to make
- Factors that can mitigate volatility (both in the traditional definition of the term and in the sense of accuracy of price expectations) include:
  - Increased elasticity of supply – for example, increased shale gas production, increased storage capacity and flexibility, ability to import/export supplies to/from external buyers/sellers
  - Increased elasticity of demand – for example, transparency of pricing to allow greater consumer responsiveness to prices
- Changes in demand, either in the short run or long run, can be more quickly balanced when a market's supply has higher elasticity. A higher elasticity of supply means that a given change in price will result in a large increase in supply. A more elastic supply curve (flatter supply curve) mitigates the extent of demand changes on price
- The emergence of shale gas is making the supply curve of natural gas in the United States more elastic. Prices are lower because supply is relatively abundant. As consumption grows, natural gas prices are unlikely to rise substantially because natural gas production capacity can easily be added. Because shale gas wells are subject to sharp decline rates after hydraulic fracturing, production from these resources will be sensitive to price movements

which will dampen medium-term price volatility as operators make decisions regarding drilling these wells based partially on expectations for gas prices during the initial phase of the well when production (and therefore cash flow) is robust. Because shale gas resources are domestic and onshore, they are insulated to some extent from the international price movements that affect LNG and they are less subject to disruption than conventional offshore gas wells. Both should mean a reduction in short-term price volatility owing to supply factors. In short, more abundant shale gas can be expected to lead to more predictable natural gas prices and reduced price volatility

- Only storage or excess capacity in wells, the natural gas collection system and pipelines can provide a nearly flat supply curve that would dampen price volatility originating from short-term fluctuations in demand because supply would be better able to respond to short-term price fluctuations. The robustness of natural gas system to meet short-term fluctuations in demand has not been tested in the shale-gas era because industrial natural gas use has taken a cyclical downturn which has led to substantial excess capacity

2. Macroeconomic impacts of crude oil and natural gas price volatility

Background

Ever since the energy crisis of the 1970s, a number of studies have been performed which demonstrate a link between energy price fluctuations and the economy, with a particular emphasis on oil. Hamilton (1983), for example, demonstrated that significant oil price increases have preceded nearly every postwar recession up to his time. (The only exception was the recession of April 1960 through February 1961.) There is no consensus on what the dominant chain of causation is, and in fact there are probably several which potentially play at least minor roles in affecting the economy.

Most studies have focused on the impact of oil price shocks on the economy. Clearly, this trend has been motivated by the high profile that oil price shocks have had historically due to the combination of the often headline-grabbing causes underlying them and the strong circumstantial evidence that they actually have resulted in significant economic disruptions. There are, however, other reasons that explain why oil is a logical focus of these analyses. Energy sources derived from oil make up the majority of consumer energy expenditures and a significant share of expenditures by the production sectors. According to the U.S. Bureau of Economic Analysis, for example, motor vehicle fuels (predominantly gasoline) and lubricants have historically accounted for 45% to 60% of consumer energy purchases. Electricity accounts for about one-third of total energy expenditures – a tiny share of which is also produced with oil as a fuel source – and natural gas from 11% to 16%; petroleum-based fuels for home-heating have always averaged at least 4% of total energy costs, and at one time made up at least 10% of these. (These figures do not include spending on public transportation – which is also predominately fueled by oil derivatives such as gasoline and diesel.) Kilian (2008), using Bureau of Labor Statistics data from 2002, estimates that a little over a third of energy consumed by producers is from oil-derived fuels (gasoline diesel, and jet fuel). And according to the Energy Information Administration, during the sixty-year period from 1950 through 2009, 37% to 48% of total annual U.S. energy consumption was fueled by petroleum products, with petroleum always being the dominant energy source (averaging 41% of total consumption over that time frame), followed by natural gas (25%) and coal (22%). (The share of petroleum-based products has followed a somewhat parabolic trajectory during that timeframe: rising during most of the first three decades until peaking at 48% in 1977 and falling gradually since.) Hence, the volatility of petroleum prices as well as their dominant share as an energy source have together accounted for the almost exclusive focus that economists have placed upon oil price shocks in their analyses of the effects of energy prices on the economy.

Consumption Impacts

Clearly, there is a tangible impact upon consumption, as households are compelled to change spending patterns to accommodate the fact that energy prices have suddenly taken up a larger share of their budgets. The magnitude of this effect upon direct energy purchases, of course, will be inversely proportional to the consumer price elasticity of energy. But along with a direct reduction in energy expenditures, there will be a shift in spending patterns as well. A probable direction of this change will be away from energy-intensive goods to more energy-efficient appliances and also a general reduction in consumption of goods that consume energy. (The reduction will also affect complementary goods and services. For example, reduced driving might result in a collateral reduction in fast food sales.)

In addition to the direct effect on energy expenditures and purchase patterns involving energy-consuming appliances, there may also be an indirect effect on general consumption activity. Uncertainty about future price movements may lead to a general conservatism in spending, as consumers engage in precautionary saving and postpone purchases of durable goods. There will also be a decline in spending as the result of a perceived decline in wealth if stock prices fall as a consequence of businesses reducing their earnings expectations. Another indirect effect on spending could occur if interest rates rise, creating a disincentive to make expenditures on more expensive goods, such as cars or appliances. And the shifts in spending patterns described above may create a need for the reallocation of resources across or within sectors of the economy, which in turn may lead to at least a transitional rise in unemployment and a consequent further decline in consumption. However, if there is a strong expectation that a price increase is temporary, then consumers may actually tap into their savings and/or borrow more. A shift to more liquid asset portfolios and increase in the demand for money will cause interest rates to rise, leading in turn to an increase in the general level of prices. An economy could face the somewhat paradoxical outcome of a decline in consumption coupled with rising prices, which of course is exactly what the term “stagflation” was coined to describe.

Using U.S. price and purchase data from February 1970 through July 2006, Kilian (2008) has estimated that a 1% increase in energy prices is followed by a 0.15% decrease in non-energy expenditures over the next twelve months, which is driven mainly by a decline in motor vehicle purchases that have an associated demand elasticity of -0.84. He cites anecdotal evidence that restaurant and lodging purchases, as well as airline ticket sales, are also significantly affected by energy price shocks, but that other durables such as furniture and appliances are not. Spending on entertainment, sports, and other recreational activities are similarly unaffected, he says, while expenditures on public transportation and food for domestic consumption actually increase. Edelstein and Kilian (2007) had examined this same time period to measure specific impacts of energy price shocks on the motor vehicle sector. The effects of energy shocks in different areas of this sector were evaluated through the estimation of impulse response functions over an eighteen-month period, where the “impulse” was an unanticipated 1% increase in energy prices. They found that consumption of motor vehicles and parts would decline by 0.76%, while that of pleasure boats and pleasure aircraft fall by 1.25% and 1.05%, respectively. Recreational vehicle purchases fall even more sharply, peaking at 1.58%, but motorcycle sales and motor vehicle rentals are hardly affected at all. New automobile sales were estimated to fall by 0.71%, but the estimate in this case was only marginally statistically significant. This last result, according to Edelstein and Kilian, suggests that perhaps it is not the overall level of sales in new cars that is specifically affected by energy price shocks, but instead it is a shifting of demand to different types (i.e., more fuel efficient vehicles) that occurs. Although the authors did not have specific sales data by fuel efficiency type to verify this supposition, tangential evidence in the study supports the hypothesis: the impulse response of new domestic automobile sales exhibited a statistically significant decline of about 1%, while new sales of foreign automobiles exhibited an increase in sales over the short-term and a statistically insignificant decline by the end of the eighteen-month period. Similarly, unit light truck sales and unit heavy truck sales fell by 1.05% and 0.86%, respectively. This evidence is consistent with a migration away from fuel-inefficient automobiles and gas-guzzling trucks and SUVs to smaller and/or more fuel-efficient automobiles. As explained below, in the 1970s, such a shift would have favored foreign manufacturers of automobiles since the U.S. auto industry was initially unprepared to meet this change in consumer preferences. Even in recent years, the U.S. auto industry seems to have been more heavily invested in the manufacture of larger vehicles, with 35 to 80% of their production being in trucks. Hence, in both cases, rising energy prices would have contributed to erosion in the demand for domestic vehicles in favor of foreign manufacturers.

Manufacturing Sector Impacts

The manufacturing sector is also affected by energy price shocks through a number of channels. Sales will decline as a result in the drop in consumption. Another direct effect will be through the increased cost of manufacturing inputs: from the higher price of energy itself to those of materials which have energy as a significant input. A rise in the general level of prices will either cause real wages to fall, which will in turn result in a decline of the labor supply, or an increase in labor costs, as consumers demand higher wages to contend with their own higher energy costs. Uncertainty – about both the future of sales and the future of production costs – will induce manufacturers to postpone investment expenditures, particularly expenditures that are irreversible. This phenomenon, in fact, could persist after a sudden fall in energy prices, if it only reinforces the sense of uncertainty about future price movements. In this case, the persistent uncertainty effect could at least partially counteract the positive effects of an energy price drop, leading to asymmetric impacts of energy price changes. If, however, a rise in prices is accompanied by an expectation that it will persist, then manufacturers well tend to shift purchases to more energy-efficient factors of production, similar to the shift in consumer purchasing choices described earlier. Kilian (2008) performed estimates of the energy price elasticity of investment expenditures in the U.S. using quarterly data spanning mid-1970 through the end of 2006, and found that the overall elasticity of nonresidential investment expenditures is quite low (-.016) and statistically insignificant. Only mining structures and equipment exhibited large and statistically significant elasticities, and these were positive (1.39 and 2.13, respectively). Residential investment in structures exhibited nearly unitary elasticity (-1.09), and the estimate was statistically significant, indicating a direct negative impact on housing demand.

Causes and Effects

Kilian has emphasized that the cause of energy price shocks is a critical determinant of both the magnitude and timing of their effect on the economy. In his analysis of oil price hikes, he distinguishes between those that occur due to a sudden restriction of supply, and those which have resulted from an increase in the aggregate global commodity demand. He estimates that a supply shock leads to a sudden but relatively moderate decline in GDP that peaks after about seven quarters from the incidence of the event. A demand shock, on the other hand, actually has the immediate effect of a rise in GDP over the first three quarters, followed by a protracted and more significant decline. He surmises that an unanticipated rise in global oil demand, accompanied by demand for other commodities, translates into a higher demand for U.S. exports. But eventually, the retarding effect of higher oil prices (and other imported commodities) will predominate. Kilian notes that there is a third type of price shock, termed an "oil-market specific shock", which often occurs as the result of a surge in "precautionary oil demand" in response to a perceived threat to supply. To the extent that the threat is accompanied by a real tightening of supply, the result is a simultaneous shift of both the supply and demand curves for oil, with a resulting compounding of the effects of either. And even if the anticipation of a supply shock is not accompanied by an actual tightening of supply, the sharp surge in demand tends to drive prices much higher and faster than in the case of rising demand due to strong global economic growth. As an example, Kilian cites the sharp rise in oil prices that occurred right after the invasion of Kuwait in 1990, which was far in excess of what should have occurred based upon the actual physical reduction in output that occurred at that time. It appears that much of the rise in price actually seemed to have been a result of a precautionary demand surge, as fears arose that Iraq would extend its invasion beyond Kuwait and occupy the Saudi Arabian oil fields. But as soon as the threat of this further invasion dissipated with the arrival in force of U.S. and allied troops, oil prices quickly plummeted. According to Kilian's estimates, an oil-market specific demand shock will result in a persistent and relatively significant decline in GDP that will not reach a maximum until after about three years. Kilian's work provides yet another possible explanation for why the run-up in oil prices during the past ten years did not produce an immediate recession in the U.S. and other economies, as the cause of these was clearly due to strong global economic growth and a concomitant general surge in demand for all industrial commodities. Conversely, each of the energy price shocks in the 1970s almost certainly included an oil-specific demand shock as at least a significant contributing factor to its occurrence.

Bernanke, Gertler, and Watson (1997) contend that the 1973, 1979-1980, and 1990 recessions were actually caused by a tightening of monetary policy in reaction to oil price increases, rather than directly by the increases themselves, but their conclusion has been challenged by other economists, such as Hamilton and Herrera (2004).

International Comparisons: What Factors Have Determined a Country's Susceptibility to Energy Price Shocks?

The magnitude of the economic impact of an energy price shock is dependent on a number of factors. The energy intensity of a nation's economy will be a determinant, as will the degree to which that nation is an importer and/or exporter of the relevant energy commodity. As energy prices increase, oil-importing countries transfer wealth to oil-exporting countries, which results in a decline in the purchasing power of firms and households in oil-importing countries. (This effect is partially – but not completely – offset by an increase in demand for goods and services from them by the oil-exporting countries.) Lutz and Meyer (2009) argue that other factors in international trade will play a role in determining the effects of higher oil and gas prices on countries as well. Using a macroeconomic model to simulate price impacts on the flow of goods and services between 50 countries and OPEC, the authors demonstrated that countries which produce a relatively higher share of investment goods, such as motor vehicles and machinery, will tend to benefit more from the general shift from consumption to investment which occurs in the wake of an energy price shock. (Kilian's work, described earlier, suggests that this phenomenon will be dominated by a shift to more energy-efficient goods, such as smaller cars. Assuming that this is indeed the case, then those countries that devote more production to these goods would have a more pronounced gain from trade.) As demand for these goods increases in the global economy, and nations which produce them benefit from an increase in trade shares, this will tend to at least partially offset the negative impacts from reduced demand in other sectors of their economies. This conclusion is supported in part by an earlier analysis performed by Jimenez-Rodriguez (2008) which compared oil shock impacts on six OECD countries and concluded that Germany, which is a major supplier of investment goods – with a significant share of these to oil-exporting economies (exports account for 53% of GDP in Germany) – was one of the two least affected countries (along with France). Another study, by Gupta (2008), ranks Germany as having one of the lowest oil vulnerability indexes in the world – much lower than Japan's– although both countries have a comparable dependence on oil.

Also, as Huntington (2004) has observed, the impact of a shock will be dependent upon pre-existing economic conditions – particularly how close an economy is to full-employment at the time of the impact. Using annual data from 1970-1998 for 14 major, industrialized economies including the U.S., Huntington analyzed the relationship between oil price movements and GDP in light of the existing GDP gap within each economy and the share of oil consumption relative to GDP within them, and found evidence that those operating closer to full employment tended to exhibit a greater response to significant oil changes. Because the gap between potential and actual GDP has widened in recent decades, this evidence suggests one possible additional explanation for the apparent dampening of the effect of oil price changes upon the economy.

Huang (2008) performed a study to find the determinants of an economy's tolerance and delay of response to the impact of a positive oil price shock. He looked at 21 countries individually over an extended time frame, generally covering in most cases the early 1970s through the end of 2005, and concluded that an economy's threshold of tolerance (i.e., the resilience of an economy, as measured by significant changes in the interest rate, index of industrial production, and stock price) to an oil price shock tends to be greater among countries more advanced in economic development and with a relatively lower ratio of energy use in their industry and transportation sectors. He also found that more advanced economies with a lower ratio of energy use in the industrial sectors also exhibited a greater delay in responding to price shocks.

Has the Economy Become Less Responsive to Price Shocks?

Several economists have noted that the U.S. economy appears to have become less responsive to energy price shocks over time. Edelstein and Kilian (2007) tested this observation by analyzing changes in monthly retail energy prices and the response of aggregate consumer expenditures in several sectors from 1970 through mid-2006. The analysis assessed the aggregate effect of energy price changes by computing changes in purchasing power based upon the prices of gasoline, natural gas, electricity, and heating oil and the respective consumer expenditure share for each of these. (This purchasing power measure essentially represents how much more or less a consumer would have to spend each month to purchase the same amount of energy as had been purchased the previous month.) In the first half of the study period (i.e., through 1987), it was observed that an unanticipated energy price increase of 1.0% would result in an eventual (i.e., after eighteen months) drop in total real consumption of 0.3%. However, in the second half of the study period, the observed drop in consumption was only 0.08%. Similarly, in the first half of the study period, the unanticipated energy price increase produced a rise in unemployment of 1.53%, while in the second half the rise was only 0.36%. As Edelstein and Kilian explain, these changes can't be attributed to a reduced share of energy in the consumption budget, since this share has actually increased, and in any case their method of calculating energy price effects controlled for such changes. Similarly, they argue that the change can't be due to a decline in the variability of purchasing power shocks, since this has actually increased during the study period. A more plausible explanation, they contend, is that the domestic auto industry has changed since the 1970s, when rising oil and gasoline prices caused erosion in the demand for larger American cars in favor of more energy efficient imports. It was only after U.S. auto manufacturers had expanded their product lines to more effectively meet this overseas competition that their vulnerability to the energy price effect was significantly reduced. However, these changes did not prevent a long-term reduction in the U.S market share of domestic automobile manufacturers, and ironically this too may have contributed to a greater resilience to energy price shocks, since this industry, along with other sectors tied to it, now make up a proportionally smaller part of the U.S. economy.

Milani (2009) suggests an interesting additional explanation for the change in responsiveness to energy price shocks. He posits that changes in expectations about the effects of price increases have actually played a role in changing the level of impact of these increases. Pessimism about the consequences of rising energy prices upon output and inflation could actually lead to a self-fulfilling prophecy, he explains, as economic agents shift to less risky investments and engage in behavior that anticipates an economy with rising costs. But if this level of negative expectation is reduced, perhaps because of a perception of a sounder monetary policy, then the result will be an attenuation rather than amplification of the initial economic effects of energy price changes. Milani contends that this shift away from pessimism is exactly what has occurred since the middle 1980s.

Quantifying the Impacts

On GDP

Huntington (2005) compares a number of studies that have attempted to quantify the actual impact of an oil price shock on GDP. He found that estimates for the first-year impact of a $10/barrel increase in crude oil prices ranged from -0.15% to -0.80% with an average estimate of -0.23%, rising in the second year to a range of from -0.24% to -1.61%, with an average estimate of -0.49%. However, these studies all assumed an increase from $30 to $40 a barrel, and might be inapplicable in other ranges. The study also cites a 2005 oil-GDP elasticity estimate developed by Global Insight of -0.011 in the first year, rising to -0.021 in the second, unless the rise which occurred was an actual unanticipated price "shock", in which case the estimates more than doubled to -0.024 and -0.050 in the first and second years, respectively. Other analyses cited in this study, however, report first-year elasticity measurements that are generally much larger, with the highest reported being -0.186. Based on these studies, Huntington estimated the quarterly impacts of both a permanent and a temporary (lasting for one quarter) 1% price shock on GDP. The largest, average, and smallest estimated impacts for these two cases are as follows:

Exhibit 2.1

Inferred Real GDP Response to Permanent 1% Oil Price Shock

Quarter	0	1	2	3	4
Largest	-0.020	-0.035	-0.085	-0.112	-0.186
Average	-0.016	-0.021	-0.042	-0.068	-0.116
Smallest	-0.014	0.004	-0.002	-0.038	-0.073

Exhibit 2.2

Inferred Real GDP Response to "Temporary" 1% Oil Price Shock

Quarter	0	1	2	3	4
Largest	-0.020	-0.035	-0.057	-0.058	-0.074
Average	-0.016	-0.014	-0.021	-0.026	-0.048
Smallest	-0.014	0.004	-0.002	0.001	-0.010

Note: "Temporary" denotes shock lasting only one quarter

An estimate for the U.S. Department of Commerce (Henry and Stokes, 2006) reported that a $20/barrel rise in crude oil prices would result in a GDP drop of from 0.5 - 0.6%.

On Stock Returns

Kilian and Park (2008) analyzed the responses of stock returns to sudden increases in oil prices and found that the effect varied significantly based upon the underlying cause of the price shock and the particular industry. If the price spike was due to a tightening of supply, then the general impact on stock returns was relatively moderate, with the effect peaking at about ten months after the event. If higher oil prices were a consequence of a general growth in global demand for commodities, then the effect on stock prices was positive, peaking at about 7 months after the event and then dissipating within a year. Stock prices were most negatively affected in the wake of an oil-market specific demand shock, which, as described above, often occurs as the result of a spike in precautionary demand brought on by sudden concerns about potential or actual supply disruptions. But even in this case, the stock returns of some industries, such as the obvious ones of petroleum and natural gas, but also gold and silver mining, exhibited a positive appreciation in response to an oil-market specific demand shock. Not surprisingly, returns on the automobile and retail sectors exhibited a significantly negative response to the same type of shock. All of these, however, were found to respond positively – at least for a time – to oil price hikes brought on by a general growth in global demand for commodities. Kilian and Park found the somewhat surprising result that the energy intensity of an industry is not a major determinant of how its stock returns will respond to oil price shocks. Rather, since shocks associated with changes in demand for oil at least seem to have a greater impact on consumer demand for goods and services instead of their supply, it is the stock returns of industries such as retail services, restaurants, and lodging that exhibit the greatest sensitivity. In general, the authors conclude that crude oil price shocks have historically been responsible for about 22% of the variation in historical aggregate stock returns in the U.S.

A similar analysis performed by Park and Ratti (2008) found that oil price shocks only accounted for about 6% of the volatility in stock returns for several European countries. Apergis and Miller (2009) also did an international comparison which included the United States and seven other countries, and attempted to measure both the magnitude and the statistical significance of the three distinct oil shock types described by Kilian and Park. They found the rather intriguing result that statistically significant evidence of causality for oil supply shocks only exists in Australia, for global demand shocks only in France, and for oil-market specific demand shocks in Germany, Italy, the UK, and the United States. There was no evidence of statistically significant oil shock impacts due to any of the three types of causes in Canada or Japan. The time frame of their data spanned 1981 – 2007 – after the energy upheavals of the 1970s – and lends support to the suggestion of other economists, such as Miller and Ratti (2008), who find evidence that the relationship between oil price movements and stock market returns has changed over time. They examined the relationship among six OEC countries during the time period spanning January 1971 through March 2008 and concluded that, while the long-run relationship between stock market and crude oil prices was insignificant when the data for the entire time frame was analyzed together, when instead specific sub-periods were distinguished, then the long-run relationships are statistically significant in some of the countries (including the U.S.) from January 1971 through May 1980 and in all of the countries from February 1988 through September 1999, but that they are insignificant in all of the countries from June 1980 through January 1988 and in most of the countries in September 1999 through May 2008. The authors suggest that the relationship might have broken down in these periods because of other phenomenon which disrupted it, such as the “IT bubble” which peaked in early 2000.

Additional comments on natural gas price volatility

Factors shaping natural gas price movements

Empirical research on the determinants of natural gas prices has focused on the relationship between oil and natural gas prices. Brown and Yücel (2008a) have also shown that seasonality, unseasonal variation in weather, deviations of natural gas in storage from seasonal norms, and disruptions in natural gas production in the Gulf of Mexico exert an independent influence on natural gas prices. In particular, natural gas prices show a pronounced seasonal rise in the winter months, increase in response to colder than normal winter weather due to increased heating demand, increase in response to warmer than normal summer weather due to increased demand to generate electricity, rise when hurricanes disrupt production in the Gulf of Mexico, and rise when natural gas storage is below seasonal norms. Industry experts also observe that industrial activity has a powerful influence on natural gas demand and affects natural gas prices. These price movements show the influence of variations in supply and demand.

More recently, Ramberg and Parsons (2010) have shown that the relationship between oil and natural gas prices has changed since 2005. The change in the relationship predates recognition of the extent to which North American shale gas resources might affect natural gas production, but is generally associated with the rise in natural gas in storage, with rising storage associated with reduced industrial demand for natural gas and the increased availability of natural gas supplies.

Medlock (2010) explains that natural gas demand and supply can be extremely inelastic in the short run, which means that small variations in either the supply or demand would lead to extreme movements in natural gas prices in the absence. These extreme movements as well as seasonal variation in the natural gas price are reduced considerably by natural gas in storage. It follows that when storage is low—shocks to demand or supply can lead to extreme price movements. Such an incident occurred in 2000-01, when there was strong demand for natural gas to generate electric power in California during that states power crisis.

Although Brown and Yücel and Ramberg and Parsons show a relationship between storage and natural gas prices, no empirical research has examined how storage may affect the response of natural gas prices to supply or demand shocks.

Brown and Yücel (2008b) also found that congestion in the natural gas pipeline system can lead to regional shocks in natural gas prices that are independent of those at Henry Hub. They used regional variations in electricity prices to identify regional shocks to natural gas demand.

Although Brown and Yücel did not test the influence of regional storage, one would generally expect that relatively full storage in an end-use region would weaken the regional response to a strong surge in demand.

The Influence of Increased Shale Gas Supplies and Growing Natural Gas Use

Industrial consumers of natural gas, particularly those in the petrochemical industry, have expressed considerable concern about the volatility of natural gas prices. Industrial consumers also have expressed concern about the influence that market-driven and policy-driven shifts toward increased natural gas consumption in the electric power and transportation sectors may have on the overall level of natural gas prices in North America. Brown and Krupnick (2010) have shown that increased shale gas supplies are likely to mean a much more elastic long-term supply curve of natural gas, which would alleviate some concerns about the long-term price effects of a shift toward increased natural gas consumption—whether market or policy driven.

Although Brown and Krupnick do not address the issue, the increased use of natural gas for base-load activities in electric power generation or transportation may result in smaller percentage variation in episodes of demand volatility and reduce demand-driven volatility of natural gas prices. On the other hand, increased natural gas consumption could sharpen price responses to supply shocks, unless the growth of demand results in more elastic short-run demand or is accompanied by increased storage.

The Affects of Natural Gas Price Volatility on Aggregate Economic Activity

Considerable anecdotal evidence suggests that U.S. industrial activity is shaped by natural gas price movements. The importance of natural gas to the industrial sector is underscored by the fact that industrial users remain very concerned about North American natural gas supplies and pricing.

Nonetheless, no published research has empirically examined the relationship between natural gas prices and aggregate economic activity—even though there is extensive research about the effect of oil price shocks on aggregate economic activity. The absence of such research owes to a couple of simple facts. Because oil prices and natural gas prices have moved together over the long run, and the relationship between oil prices and aggregate economic activity is complex and controversial, it has proved to be extremely difficult to identify how natural gas price shocks affect aggregate economic activity independently of oil price shocks.

In particular, a natural gas price series that has been stripped of the influence of oil prices does not Granger-cause aggregate economic activity. Rather aggregate economic activity Granger causes the natural gas price series that has been stripped of the influence of oil prices.

3. Commodity prices and stock returns

As we discussed in the previous section, there have been numerous studies of the effect of oil price shocks on both aggregate economic activity and on stock market returns. These studies employ time series techniques that are designed to measure the impact of a shock on subsequent changes in economic activity and stock returns.

A major challenge of this line of research is teasing out cause and effect. Do changes in oil prices cause changes in economic activity, or is it the changes in economic activity, or perhaps anticipated changes, that cause oil prices to change. For example, suppose that we observe temporary increases and decreases in aggregate economic growth rates, and that oil prices tend to increase when growth rates increase (due to demand effects). If this is the case, then we are likely to observe decreases in the rate of economic growth following increases in oil prices due simply to the mean reversion in economic growth rates. While the VAR specifications attempt to control for such possibilities, they require strong assumptions.

Examining the relation between oil price changes and stock returns may provide somewhat cleaner tests, since stock returns are forward looking, and at least in theory, measure unexpected changes in expected economic activity. As a result, if one is interested in the effect of oil price changes on future economic activity, one should look at the contemporaneous relation between oil price changes and stock returns rather than the relation between oil price changes and future stock returns. Indeed, evidence of a significant relation between oil prices and stock returns would be evidence of market inefficiency (i.e., perhaps, an under-reaction to oil price information) or perhaps, an unrepresentative sample period.

Since we are unaware of any published studies that closely examine the contemporaneous covariances between oil price changes and stock returns, we estimated the relation between innovations in oil futures prices and stock returns. The advantage of examining innovations in oil futures prices is that these measure unexpected changes in oil prices over relatively long periods of time. Specifically, we examine 1 year futures contracts on NYMEX light-sweet crude oil contract, deliverable as West Texas Intermediate (WTI). The return to holding the 1-year futures contract to maturity is calculated as the purchase price of the expiring prompt month contract at time t, divided by the purchase price of the same calendar futures contract at t-12 (when it was the 1-year generic futures contract). This generates 239 annual returns over a period of 20 years, starting in February 1989.

Annual market returns are calculated over the same time period for the CRSP value weighted U.S. stock index, the Nikkei 225 index in Japan, and the Deutscher Aktien Index or DAX in Germany. Holding period returns are calculated as the closing price in dollars at time t divided by the closing price at time t-12. The excess return is calculated by subtracting the yield on the 1-year local Treasury bond, in realized dollar terms, at time t-12 from the raw return. To estimate the relation between these stock returns and contemporaneous unexpected changes in oil prices, we simply estimate the regression,

$$r_{oil,t} = \square + \square r_{market,t} + \mu$$

The regression results, shown below, indicate that the estimated betas for oil is positive for each stock market index, indicating that increases in oil prices tend to be associated with the anticipation of favorable economic activity. However, the correlation is relatively weak in the U.S. and Germany, but somewhat stronger in Japan.

Exhibit 3.1

Regression results by country

Country	alpha	beta	R^2	N
United States	0.146 *(0.063)*	0.247 *(0.315)*	0.0166	239
Japan	0.182 *(0.059)*	0.419 *(0.198)*	0.0841	239
Germany	0.152 *(0.060)*	0.146 *(0.210)*	0.0127	239

To examine how this correlation structure has changed over time, one can estimate the regression using a rolling 5-year window. Such estimates reveal a marked change in the correlation structure over time. Market betas are significantly negative in all markets over the first five years of the sample, and gradually become positive in later periods. This is especially pronounced in Japan where the 5-year estimation window yields a significantly positive beta over a large fraction of the sample. In each case, we can generate at least two non-overlapping periods which are different in Chow sense, indicating the presence of a structural change in the model. Further analysis suggests that the structural breaks occur around 1999. In the period prior to 1999 the covariances between market returns and oil price changes tend to be negative, but after 1999, the covariances tend to be positive.

One interpretation of this evidence is that the importance of supply and demand shocks has changed over time. When oil price movements are dominated by supply shocks, we expect to see a negative correlation between oil prices and stock returns. However, when oil price movements are dominated by demand shocks we expect to see a positive correlation between oil price movements and stock returns. Perhaps, supply shocks surrounding the first Gulf War dominated the movement of oil prices in the early 1990s – in particular, uncertainty about the political situation in the Middle East made oil prices more expensive, putting a negative drag on economic activity and stock returns. However, in the last 10 years demand shocks have become more important – in particular, in the first half of this decade, increases in demand from Asia, which increased oil prices as well as economic activity throughout the world, and in the latter part of the decade, a financial crisis that decreased the demand for oil and lead to declines in stock prices and economic activity.

4. Deconstructing commodity price volatility

Energy security refers to the notion that economic dislocations are associated with disruptions in energy supply and thus should be avoided. When discussing energy security we often discuss either the level of price or the volatility of price. Neither of these metrics is sufficient when discussing energy security. Rather, unexpected changes in the supply-demand balance (and hence price) are what generate difficulties at the macroeconomic level. Regular variation in price, provided there is a means of mitigating risks through well-functioning forward markets, need not be disruptive. Thus, it is incorrect to argue that prices that are highly variable but in a regular manner are more problematic than prices that are very stable for a period of time then suddenly change. In fact, investment planning is much more difficult in the latter case, and it has been shown in various studies that unexpected changes in price have a much larger negative impact (see, for example, Dixit and Pindyck (1994), Lee et al (1995), Pindyck (1991), Fisher (2000), Abel (1994)).

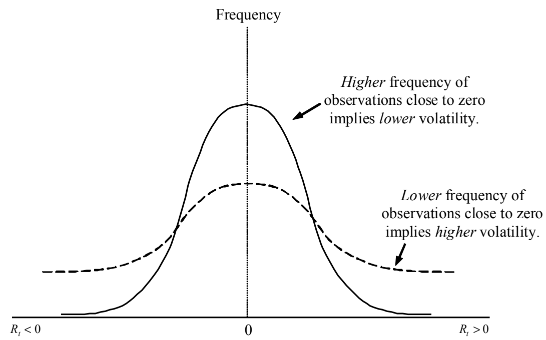
Given the preceding, the focus is often on measures of price volatility. Traditionally, price volatility is estimated by calculating the annualized standard deviation of the periodic (usually daily or weekly) changes in price. Typically, this is done by examining the distribution of the time series of the log return of price, defined as $R_t = \ln P_t - \ln P_{t-1}$. If price changes rapidly over short periods of time, then values of R_t will be large and price is said to have high volatility. On the other hand, if price is not changing very much then R_t will be near zero and price is said to have low volatility. Thus, the volatility of a series can be summarized by examining the density function of R_t (see Exhibit 4.1).

If the probability density function of R_t looks more like the dashed line in Exhibit 4.1, the measure of volatility (the standard deviation of R_t) will typically be higher. It may also be the case that volatility itself is periodic – occurring in clusters – meaning the price series that is characterized by periods of low volatility (realizations of R_t centered on zero) with periods of high volatility interspersed (realization of R_t that are substantially different than zero, either negative or positive). It is generally these periods of high volatility that are of concern, particularly when they are unexpected.[1] Moreover, it is precisely these periods which we seek to avoid, if possible, because they are associated with negative macroeconomic consequences. Increased uncertainty associated with high volatility has been linked to changes in firm behavior, which translates to reduced investment, increased unemployment, and lower output (see, for example, Dixit and Pindyck (1994)).

[1] In these cases a time series estimation known as GARCH (generalized autoregressive conditional heteroskedasticity) is employed for analysis. *Unexpected* shocks are then defined as those price changes that move outside a particular interval (such as one standard deviation), where the interval is conditional on the estimation results.

Exhibit 4.1

Density functions of low and high volatility time series



If high volatility leads to negative outcomes, then one reaction would be to simply set price at a particular level. Of course, the negative consequences of such a policy intervention are well known. In particular, the information carried in price movements would be muted, which can lead to inefficient levels of investment and consumption. As a result, designing policy that addresses price volatility can be difficult at best.

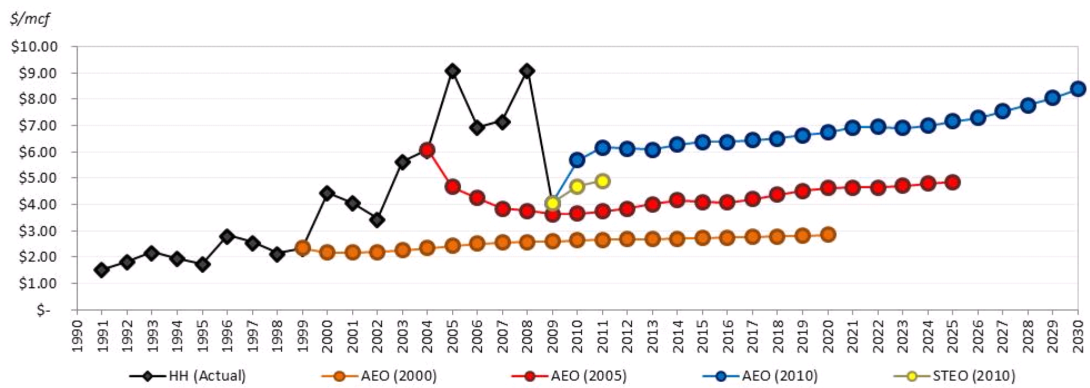
One approach to curb any negative influence of extreme volatility taken by governments has been to develop strategic stockpiles. This practice is common in crude oil markets. The effectiveness of this policy, however, is largely dependent on how governments use these stocks. There is much debate in the US, for example, regarding when it is appropriate to use the Strategic Petroleum Reserve (SPR). Some have argued that the high prices of 2008 could have been somewhat mitigated by releasing supplies from the SPR. Others, however, argue that the high prices were the result of market conditions, not a geopolitical intervention, so governments should remain neutral. In particular, if the oil is released to respond to a market-driven condition, then the government runs the risk of being short of supply in the case of a geopolitical disruption. Since the latter, it is argued, is the principle reason the SPR was established, such market intervention is not a justified use of the SPR. In addition, if government begins to use its stocks to effectively constrain movements in market price, the development of commercial inventories could be discouraged by masking the return that could be earned otherwise. Nevertheless, the questions regarding the development and appropriate use of strategic inventories are far from settled.

Price Volatility versus Forecast Error

Short term fluctuations in price are often not the focus of utilities, regulators and project developers. Rather, the concern centers on the accuracy of price expectations. Sometimes, although inaccurate, this is discussed as “long term volatility.” Exhibit 4.2 illustrates how much forecasts of the price of natural gas have varied in the recent past and provides an indication as to why there is often such consternation about this metric.

Exhibit 4.2

EIA AEO 20 Year Outlooks from Selected Years for Natural Gas



As seen in Exhibit 4.2, the forecast path of natural gas prices has varied substantially in the last decade. Of course, the EIA conducts scenario analysis around these forecasts to demonstrate key sensitivities, but the variation is undeniable. More to the point, in an environment where expectations about future market prices fluctuate so dramatically, long-term investment planning decisions are made difficult at best.

Volatility in the expected price path can be caused by a number of different factors. These include, but are not limited to, changes in policy and regulation, structural changes in supply-demand conditions, and dramatic changes in the prices of other energy commodities. Over the last decade, each of these issues has affected the prices of oil and natural gas to varying degrees, perhaps the most notable one being the emergence of shale gas and its impact on the long term view of natural gas prices.

Technological developments also play a fundamental role. In fact, the emergence of shale gas has been characterized by many as a technology play. Geologists have long known about the resource potential, but technological and economic hurdles made it unattainable. While many have accepted the scale of the shale resource, the developments with regard to shale gas are still being internalized and there is still uncertainty with regard to the actual cost of full development. Thus, there will likely be continued revisions to the long term view.

Extrapolating the shale gas lesson to oil, one must recognize that technological innovations that enable lower cost recovery of oil resources in unconventional formations sometime in the not too distant future. Most of the natural gas industry did not see the shale phenomenon until it was upon us, so it is legitimate to ask if something similar might occur with oil. Of course, this is not meant to be prophetic in any way, it is simply meant to highlight a critical source of uncertainty.

A Framework for Analysis: A Stock-Flow Model for understanding pricing dynamics in a market for a storable commodity

In general, what does all this mean for price formation? To begin, it is fairly well-established that inventories tend to reduce volatility. We can more formally see this through developing an appreciation of the mechanism by which price is determined in a market for a storable energy commodity. Models with this goal in mind have been used to explore such things as the influence of futures markets on spot prices (see Kawai (1983) and Jacks (2007) for example). In what follows, we will present the basic framework using a simple graphical representation in order to demonstrate concept. This will then allow us to understand factors that influence price volatility, such as price elasticity.

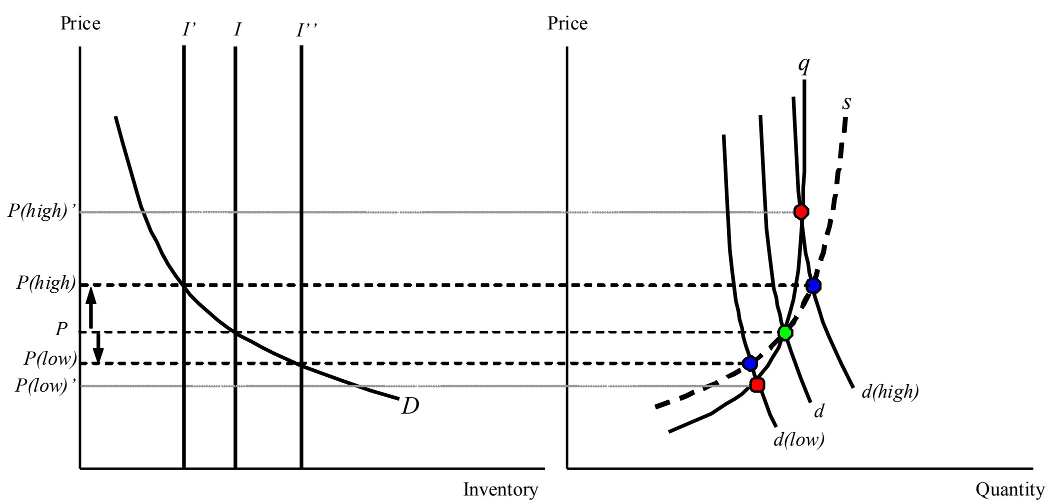
To begin, let there be two markets – an inventory (or “stock”) market and a “flow” market – in which price is simultaneously determined. The stock market represents the market in which inventories are valued against the demand for future supply. This provides the vehicle through which the expected future price and current price are linked. (In markets with an actively traded futures market, the "stock" market provides the link to realizations of the forward curve at any moment in time and the spot price.) So, expectations can influence price by altering the demand for inventories (or perceived value of supply in the future).

The "flow" market represents the current delivered supply and end-use demand of natural gas. Thus, it is simply the market clearing price that arises as a result of daily trade in the physical commodity. This is the standard partial equilibrium representation of market supply and demand that we are used to seeing when a product is not storable. Importantly, the "stock" market and "flow" market must clear at the same price.

In order to understand how this fits together, let's consider the graphical representation of the natural gas market depicted in Exhibit 4.3. The level of inventory in the stock market is fixed at any point on time and denoted as *I*. The demand for inventory is given as *D*, and is downward sloping to reflect the notion that as the spot price, *P*, falls, the profitability of holding inventories to be sold in some later period rises. This is the classic "buy low – sell high" paradigm, and it holds particularly well if demand in the flow market changes on a regular basis.

Exhibit 4.3

A graphical representation of the "stock-flow" model



The demand and supply curves in the flow market are d and s, respectively. Inventories either expand or shrink depending on the position of the demand curve in the flow market relative to production, where production capability is denoted by q. Note that in a market without storage, $q=s$, and our picture simplifies to the very simple partial equilibrium framework most of us recall from introductory economics. Now, let demand in the "flow" market change on a seasonal basis, such that in the winter the demand for natural gas increases from $d \rightarrow d(high)$ but decreases to $d(low)$ in other months. Absent an ability to augment production with supplies from inventory, price would increase to $P(high)'$. However, inventories provide an ability to augment production, and thereby dampen price volatility, when demand increases. Specifically, when price rises inventory is drawn down, so that $I \rightarrow I'$, and production in the flow market is augmented by the withdrawal from inventory. Accordingly, actual supply to the "flow" market is given as $s=q+\Delta I$ where q is current production and ΔI is the change in inventory. Notice, since we can use inventory to enhance production in the flow market, price only rises to $P(high)$, which is much lower than $P(high)'$. If we allow for imports and exports, then the equation defining supply to the flow market becomes $s=q+\Delta I+m$ where m is defined as net imports. Notice this means that, ceteris paribus, the flexibility of supply is greater when both inventories and import/export capabilities are present.

In periods where storage is very high, the ability to enhance supply to the flow market is only constrained by the speed at which inventories can be drawn down. On the other hand, if the initial storage level is low, then $s \rightarrow q$ and price will generally begin and rise to a higher level when demand increases. As noted above, if inventories are non-existent, then $s=q$ and we have much larger price swings from low to high demand periods.

By analogy, when demand falls toward *d(low)* we see that price will decline. This will encourage injections into inventory thus taking production out of the flow market. As a result, price does not decline as much as it would if there was no storage capability. The end result is that, in general, storage acts to buffer price movements in response to stimuli to demand and supply. Moreover, the size of injections and withdrawals are important because they act to flatten the supply curve in the flow market.[2]

Another important aspect of the stock-flow model pertains to expectations. In particular, the position of the curve depicting demand for inventories, given as D, in the stock market is largely dependent on expectations about future market conditions. For example, if there is concern that future supplies might become scarce, then the demand for inventories will increase. This will tend to drive price up today. To the extent this happens, it should create an excess supply condition in the flow market, thereby resulting in injections to storage which keeps price from rising wildly. However, if adequate injections to storage do not occur, perhaps due to constraints on production or very inelastic demand and supply, then price will continue to rise until inventories can be filled. Note this also means that the forward curve should move into steeper contango, which although not pictured here, is the implicit link between inventories, the futures market and spot price. In particular, to the extent that the spread between current spot price and the price on the forward curve is what determines storage injection and withdrawal, then the demand for inventories curve, D, will be a function of the shape of the forward curve.

Elasticity and Price Volatility in the Stock-Flow Model

The model presented above facilitates a discussion of various factors that influence price volatility, some of which have been mentioned already. With regard to elasticity, we see the following.

- Elasticity of supply – a higher elasticity of supply means that a given change in price will result in a large increase in supply, so that the supply curve is relatively flat. Thus, changes in demand, either in the short run or long run, will not result in large changes in price. Increased elasticity of supply can be achieved in multiple ways. One means is through an increase in productive capability (see Exhibit 4.4). Another is through enhancement of the ability to augment production with inventory injections/withdrawals (see Exhibit 4.5). This latter case can also occur through the ability to import/export supplies from an external source. Notice in each of the cases the supply response is determined by the ability to increase production in response to a price increase as well as the ability to bring supplies to market from inventories and/or foreign sources. Although not immediately apparent in the figures below, it can also be shown that the marginal effect of increased supply responsiveness on price volatility is diminishing.

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[2] Note this does not necessarily mean increased storage capacity is desirable. A flatter supply curve will render seasonal movements in price smaller. This, in turn, would at some point render storage capacity commercially unviable. This follows because the incentive to store is related to the profitability of buying in a low demand period and selling in a high demand period. As prices in the two periods move closer to one another, the incentive to inject into storage is diminished. This results in lower utilization of storage capacity (when capacity is sufficiently large), which in turn renders that capacity unprofitable. This point is, in fact, often raised with regard to government stockpiles being a disincentive for commercial stocks.

- Elasticity of demand – a higher elasticity of demand means that a given change in price will result in a larger change in demand. Notice, this tells us changes in supply, perhaps due to disruptions or outages, will result in smaller changes in price than would otherwise occur.

Exhibit 4.4

The effect of increased responsiveness of production capability

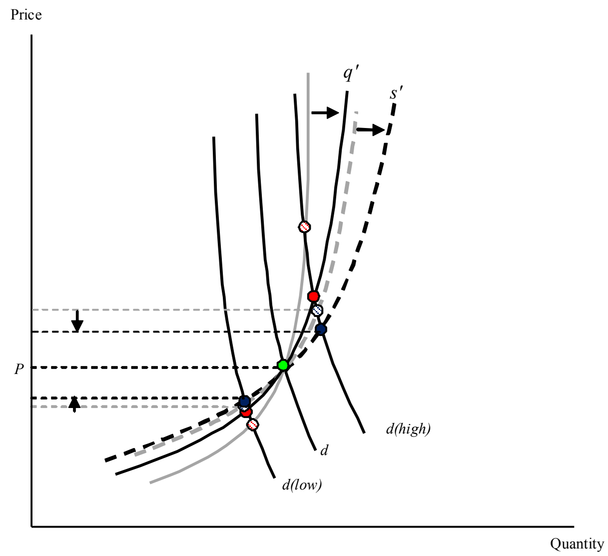
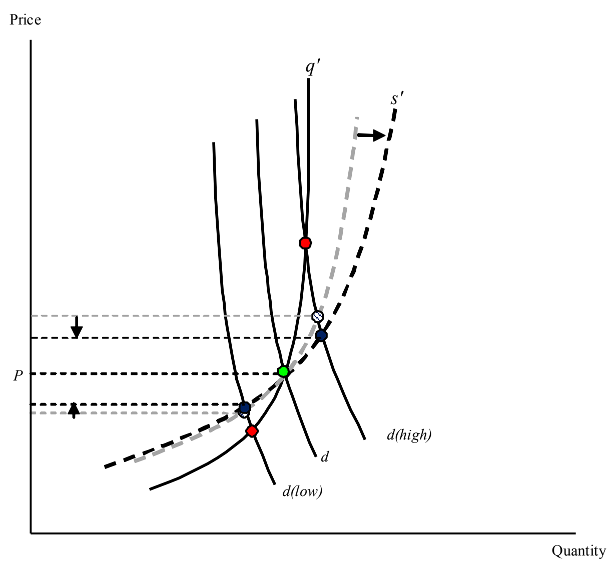


Exhibit 4.5

The effect of increased responsiveness of inventories and/or net imports



Commentary - Impact of Shale Gas and Market Liberalization

Perhaps the most intriguing development in global energy markets in the last decade or so is the emergence of shale gas. The application of innovative new techniques involving the use of horizontal drilling with hydraulic fracturing has resulted in the rapid growth in production of natural gas from shale. Moreover, the production potential that has been identified since the emergence of the Barnett shale in Northeast Texas – which is now the largest single producing natural gas play in North America – has dramatically altered expectations for global LNG trade. Fewer than 10 years ago, most predictions were for a dramatic increase in LNG imports to North America and Europe, but shale production in North America has turned this thinking upside down.

To understand the shear speed with which shale potential has emerged, we need only look at assessments of recoverable resource over the past several years. As recently as 2003, the National Petroleum Council examined the long term North American natural gas market using an assessment of 38 tcf of shale gas, and in 2005 the Energy Information Administration was using an estimate of 140 tcf in its forecasting efforts. In 2008, Navigant Consulting, Inc. estimated a range of between 348 tcf and 892 tcf of technically recoverable resource, which puts the median at about 620 tcf. In 2009, the Potential Gas Committee put its estimate at just over 680 tcf, and in 2010 Advanced Resources International reported an estimate of over 1000 tcf. Note that although each assessment is from an independent source, the estimates are increasing over time.

The emergence of shale gas has in North America is yielding enormous liquidity benefits. Specifically, the global supply curve more elastic (or flatter). This has rendered international gas prices lower and less volatile. Prices are lower because supply is relatively abundant. Volatility is lower because a flat supply curve means no production constraint is present, and generally, as discussed above, constraints are necessary for volatility to arise.

Shale production growth may also provide a secondary benefit. The ability to adjust drilling activities and production may provide a virtual storage service. In particular, as developers are able to stimulate production through hydraulic fracturing such that high flows are timed to coincide with seasonal increases in demand, then the shale reservoir becomes a de facto form of storage, or a "just-in-time" source of production. To the extent this eventuates, it should dampen the price volatility associated with temporary market tightness that results due to seasonal increases in demand, which follows from the discussion of the stock-flow model above.

In general, the increase in shale gas production has led to a dramatic increase in physical liquidity because it has enhanced the diversity of potential supplies in the natural gas market. A key vehicle to achieving diversity in supply sources and overall market flexibility brings us to a more general point. Namely, liberalization of gas markets should be promoted. As a matter of policy, promoting flexibility within markets is an important step to ensuring secure delivery of energy supplies.[3] This runs counter to the arguments of many large consumers and large producers who support the use of bilateral long-term contracts to promote energy security. However, such arrangements allow for substantial dislocations if circumstances emerge that disrupt delivery, particularly when there is no accessible alternative source of supply. Competitive, liberalized markets operating through well-functioning, transparent exchanges allow the risk associated with dealing with any single counterparty to be mitigated. They do so by letting consumers and producers rapidly find new trading partners if there is a problem with an existing agreement. Such markets also allow any arbitrage opportunities that may arise to be quickly eliminated. This is, in fact, a general benefit of market liquidity. Moreover, large numbers of market participants are encouraged when there are ample opportunities for each to gain by inclusion. By contrast, a market that is limited to bilateral contracts that exclude opportunity for additional participants does not provide the benefits that liquidity brings.

[3] This is not meant to promote a lack of oversight. Rather, a well-functioning market is one in which the appropriate oversight and regulatory mechanisms are in place to allow smooth operation without fear of manipulation by any participant.

In general, the natural gas market in Europe has been dominated by long term contractual relationships that allowed a national operator to control the distribution of gas from producer to consumer and allowed little, if any, room for competitive threat from an third party supplier. Incumbent suppliers, such as Russia, stood to benefit from this arrangement because by locking up markets long term, they faced little competitive threat to building a position of dominance within the European market. On the one hand, this arrangement is desirable from the standpoint that it brings the benefits of certainty, and therefore may facilitate relatively easier expansion of long haul facilities such as pipelines. On the other hand, the lack of competition associated with the structure of the market tends to raise the average price paid for natural gas.

Liberalization in natural gas markets usually means that capacity rights and transportation services are marketed separately (often called 'unbundling' of transportation services). A chief benefit of this arrangement is that it should stimulate production at the margin by removing any constraints for potential producers to access a market, i.e. – it provides physical liquidity. This, in fact, has occurred very successfully in North America, with most recent evidence in the recent expansion of shale gas production in the US, which arguably would not have occurred at its current pace had the market not been liberalized. The ability to secure capacity rights on pipelines and trade natural gas at various liquid 'hubs' has allowed producers to receive a guarantee of competitive pricing. By effectively removing volume risk, liberalization has facilitated the timely expansion of domestic supplies, in many cases from small producers, needed to meet demand growth. Moreover, this has occurred without the use of long term contracts.

Liberalization of the natural gas market has also provided many benefits associated with energy security. Market participants can buy and sell rights to transportation and storage capacity and nominate gas from multiple sources. The ability to trade pipeline capacity effectively guarantees that the consumer who places the highest value on natural gas at any particular point in time will receive it. The ability to nominate supplies from multiple sources provides a diversification benefit. In particular, it prevents any one party from extracting exorbitant rents by allowing demands to be met in multiple ways.

Finally, liberalization has also yielded benefits in the North American natural gas storage market. In general, the ability to trade storage capacity allows one to move commodity temporally, which can mitigate the effects of short term price pressures created by unexpected and sudden increases in demand or reductions in supply. More specifically, the adoption of market-based pricing for storage services, as opposed to pricing based on a regulated rate of return, has led to an increase in the amount of investment in both storage capacity and the ability the cycle storage more quickly. The former allows a greater amount of supply to be sold forward or held for times of excess demand. The latter allows storage to be withdrawn and re-filled more quickly, thus allowing greater ability to meet near term variations in demand without compromising the ability to do so in the future.

Importantly, promoting liberalization is counterintuitive to many. In particular, if we are concerned primarily with the delivery of supply, then locking those volumes up in long term contractual arrangements may seem to be the correct thing to do. However, history with the North American market has taught us this is not a correct thesis. Moreover, for European consumers, long term contracts with Russia yielded no benefit during the Russia-Ukraine pricing disputes in the winters of 2005-2006 and 2008-2009. In fact, a liberalized market may have facilitated a better reaction to the cut-off of supplies precisely because it would have allowed for a greater number of supply options.

One last comment pertains to the development of strategic stocks. In particular, such a move could have negative unintended consequences. As discussed above, a government inventory discourages the development and use of commercial inventories. This puts the responsibility of responding to regular changes in price induced by changes in demand on the government rather than in the market. In addition, market participants could be exposed to an additional source of uncertainty – namely, when and how will the government use its inventories. While this can be specified in legal doctrine, in practice strategic stocks are designed to be used for unforeseen emergency situations. But, defining “unforeseen emergency situations” can be difficult, especially since by supposition, they are unforeseen. This typically leaves latitude in the response mechanism, which can differ across administrations, and would invariably inject uncertainty – and volatility – into the market.

5. The impacts of commodity price changes on producers and consumers of oil & natural gas

Impacts of commodity price changes on energy consumption by energy companies and individuals

Recent research has shown that changes in commodity prices affect the energy consumption behaviors of both energy companies and individual consumers of energy. While changes in commodity prices may result in some immediate demand response, the magnitude and longevity of the response will be influenced by the type of consumer, the type of price change and the availability and adoptability of substitutes. Depending on these variables, businesses and consumers may be driven to explore new technologies that do not rely upon oil or natural gas for energy.

As the theory of supply and demand predicts, increases in energy prices result in decreased demand for energy products. In the study, "The Economic Effects of Energy Price Shocks", Kilian presents an analysis of historical data supporting this inverse relationship between energy prices and energy consumption (Exhibit 5.1).[4] While an elasticity coefficient of -0.45 indicates that total energy consumption in the U.S. is relatively inelastic in reaction to commodity price changes, the negative relationship is pronounced, and Kilian finds that the elasticity is statistically significant at the 5% level.

Exhibit 5.1

One-Year Energy Price Elasticities: U.S. Consumer Expenditures (1970 – 2006)

	Elasticity
Total energy consumption	**-0.45**
Electricity	-0.15
Gasoline	**-0.48**
Heating Oil and Coal	**-1.47**
Natural Gas	-0.33

Source: Reproduced from Kilian, "The Economic Effects of Energy Price Shocks", Table 2

Note: Full sample estimates based on the purchasing power loss associated with a change in weighted retail energy prices. The elasticities have been computed based on the average share of energy in the sample period. All results are based on estimates in Edelstein and Kilian (2007a). Boldface indicates statistical significance at the 5% level.

In evaluating the effects of price changes on consumption, it is useful to decompose the commodities into specific products that can be measured separately because the price elasticities of different energy products may vary widely. In a study of petroleum consumption, H.G. Huntington asserts, "The long-run relationship between consumption, prices and income may be hidden or disguised if dissimilar products are aggregated together."[5] Exhibit 5.1 addresses this issue by providing detail on demand elasticities of specific energy products. While the aggregate energy consumption elasticity is -0.45, the elasticities of the disaggregated energy consumption components range from -0.15 to -1.47. This supports Huntington's assertion that aggregating products for an evaluation can be misleading.

The disaggregated data in Exhibit 5.1 reveals that the consumption of natural gas is quite inelastic. A study by the California Energy Commission observes that the price elasticity of natural gas differs depending on the consumer.[6] Individual and small business consumers who depend on natural gas for winter heating needs cannot quickly shift their demand away to a

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[4] Kilian, p. [x].

[5] Huntington (2010), p.[x].

[6] California Energy Commission, p. 5.

substitute for natural gas.[7] As such, their demand is more stable than that of industrial consumers that may "consider fuel switching where possible or even shutting down operations" during periods of natural gas price volatility.[8]

Relative to natural gas, heating oil and coal are quite elastic to price swings. Kilian predicts that this may be due to the fact that heating oil can be purchased at favorable prices and stored so that consumers can tap into heating oil reserves as prices climb.[9] For other forms of energy that are not as easily stored, the demand remains relatively consistent through short-term price fluctuations.

Gasoline is inelastic but still presents a negative relationship between price and demand that is statically significant at the 5% level. Huntington notes that in 2002 the elasticity of demand for gasoline had declined relative to the elasticity in prior decades suggesting a potential change in consumer behavior and/or wealth.[10] As the population's inflation-adjusted wealth grew faster than inflation-adjusted commodity prices over the period leading up to 2002, the real price of energy consumption felt less significant; therefore, consumers did not change their behaviors in response to short-term fluctuations in gasoline prices.

When consumers perceive a long-term change in commodity prices, they may alter their consumption patterns due to what Kilian calls the "Operating cost effect."[11] The Operating cost effect is the decline in the use of energy-driven goods and technologies in conjunction with increasing energy prices due to the increased cost of operating energy-driven goods. To the extent that an increase in prices is perceived to be long-term, consumers may stop using the existing energy dependent goods and begin investing in more energy efficient technologies.

Huntington also distinguishes between short-term and long-term gasoline prices, noting, "The [consumer demand] response is stronger and more permanent when oil prices reach beyond levels that were previously experienced."[12] In 2007 and 2008 when commodity prices hit record highs, consumers began taking actions to alter their energy consumption patterns. Because these commodity prices were historically high and sustained, they encouraged a shift from traditional technologies that use commodity-based power generation to technologies that use renewable or "green" energy sources.[13] Examples of new technologies explored in the face of high commodity prices include fuel efficient or alternative-powered automobiles, renewable energy sources such as solar, wind and hydropower, fuel cells and more.

Impacts of commodity price changes on capital investment decisions by oil & natural gas companies

Several authors have studied the effects of commodity prices and commodity price fluctuations on investment by companies in the oil and gas industry.

Kilian examines the effects of commodity price changes on non-residential investment. This study specifically isolates variables related to investment for mining activities, which are defined as "mining for crude oil, coal and natural gas," to observe how changing commodity prices affect the investment decisions made by oil, gas and mining companies.[14] The data collected on investment in mining activities span the period from 1970 – 2006. The results of Kilian's analysis show that of the various subcomponents of the analysis, "only the response of [investment in]

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[7] California Energy Commission, p. 5.
[8] California Energy Commission, p. 6.
[9] Kilian, p. 12.
[10] Huntington, H.G.
[11] Kilian, p. 11.
[12] Huntington, H.G.
[13] Huntington, H.G.
[14] Kilian, p.18.

mining structures and mining and oil field machinery is large and statistically significant" as investment in mining has an elasticity of 1.39 and investment in mining and oil field machinery has an elasticity of 2.13.[15]

Ringlund et al. studied the effects of short-term and long-term crude oil price changes on oilrig activity. The authors assert that an increase in commodity price which is expected to be short-lived will not influence investment decision-makers to take on new field development projects because it is costly to develop an oilfield and the investment is spread over a long period of time. The study does find "a clear positive relationship between oilrig activity in non-OPEC regions and crude oil prices in the long-run" in North America.[16] When price increases are expected to be long-term, the long-term elasticity observed is 1.28, and the authors find "about half of the long-run response is obtained after five months."[17] Based on these data and the data on other countries studied, drilling activity in the U.S. reacts relatively quickly to long-term commodity price changes. The authors suggest that this short reaction time may be due to the flexible rig market, limited regulations in the U.S. and the fact that oil drilling in the U.S. is a mature industry so any new drilling activity is done at the margin and will be highly sensitive to commodity prices.[18]

Mohn and Misund look at how option value arising from the ability to make fixed investments in times of commodity price uncertainty impact investment decision-making by oil and gas companies. One such option examined is the option to defer investment. According to Mohn and Misund, "Any increase in uncertainty around future profitability will enhance the value of this waiting option, implying a negative investment response to increased uncertainty."[19] In other words, commodity price uncertainty and fixed investment by oil and gas companies is inversely related due to the positive relationship between this waiting option and uncertainty.[20] Another option that is factored into investment decisions is the future development option or strategic option to further develop an asset.[21] Making a fixed investment will provide the investor exposure to the future development option, and a positive relationship exists between this option and commodity price uncertainty.[22] However, gaining exposure to the future development option requires making a fixed investment and, thus, sacrificing the waiting option.[23] Therefore, in making an investment decision, the values of these two options are netted against one another to derive the compound option value.[24] The study finds a negative relationship between short-term price changes and investment at a rate of 1:-1 and a positive relationship between long-term price changes and investment at a rate of 1:4.1.[25] Based on these findings, Mohn and Misund conclude that in the current context, the value of the future development option outweighs the value of the waiting option due to "increasingly scarce oil and gas resources."[26]

Publicly available data on historical commodity prices and historical capital expenditures may be cut in various ways to better understand the response of capital investment by companies to commodity price changes. Exhibits 5.2 and 5.3 summarize raw data obtained from J.S. Herold data service in an effort to better understand what relationships, if any, exist between commodity

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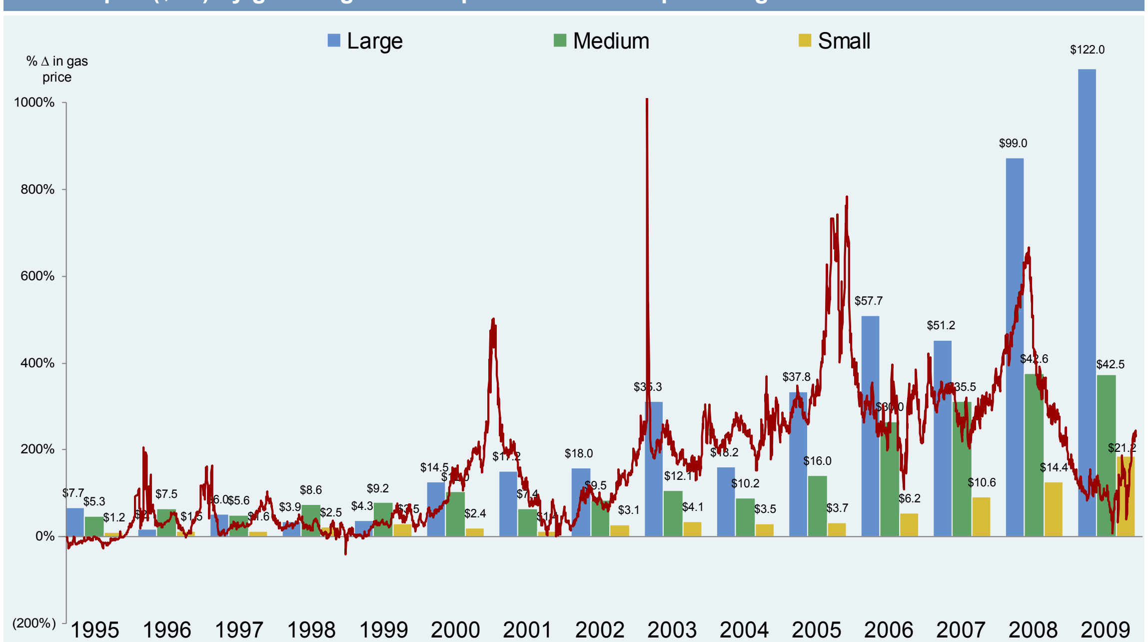
[15] Kilian, p.18.
[16] Ringlund, et. al, p. 373.
[17] Ringlund, et. al, p. 381.
[18] Ringlund, et. al, p. 382.
[19] Mohn and Misund, p. 241.
[20] Mohn and Misund, p. 241.
[21] Mohn and Misund, p. 246.
[22] Mohn and Misund, p. 246.
[23] Mohn and Misund, p. 246.
[24] Mohn and Misund, p. 246.
[25] Mohn and Misund, p. 245.
[26] Mohn and Misund, p. 246.

price changes and capital investment decisions by companies in the oil and gas industry. In these exhibits, companies are grouped by size based on their production output during each year shown. This distinction is made to examine whether smaller companies are more responsive to commodity price changes given that they have less financial flexibility and possibly more operational flexibility larger companies. Data from companies that are more heavily weighted towards gas based on reserves are examined Exhibit 5.2, and Exhibit 5.3 examines data for companies that are primarily oil-weighted based on reserves. Capital expenditure encompasses acquisition capital and finding and developing capital.

Exhibit 5.2 reflects the percentage change in nominal natural gas prices from 1/1/1995 and the nominal dollar amount of capital expenditures in billions by gas-weighted companies aggregated by company size. Between 1995 and 2004, the percentage increase in gas prices had two significant peaks on 12/29/2000 and 2/25/2003. These peaks were accompanied by periods of increased spending by gas-weighted companies; however, in 2004 when there was no peak, capital expenditures fell from 2003 levels suggesting that gas-weighted companies may have anticipated lower future prices. From 2004 through 2008, higher prices were observed and sustained over the period, and the peaks observed in 2005 and 2008 were high and lasted longer than previous peaks. During this period, capital spending by all sizes of gas-weighted companies grew considerably reaching $99bn, $43bn and $14bn for large, medium and small companies, respectively. Interestingly, when gas prices fell to nearly 1/1/1995 levels in 2009, capital spending **increased** further at large and small companies and remained **constant** at medium companies. These results may be explained or influenced by a number of variables including: (1) the discovery of shale gas and implementation of horizontal drilling which has increased the supply of gas and decreased the break-even price making projects economic at lower commodity prices; (2) the recent availability of low-cost funding for drilling opportunities; (3) the increased inflow of foreign investment which supports drilling projects; and (4) the possibility of a change in the natural gas price paradigm stemming from the high sustained gas prices over the 5-year period from 2003 – 2008.

Exhibit 5.2

Total capex ($bn) by gas-weighted companies vs. % ∆ in price of gas



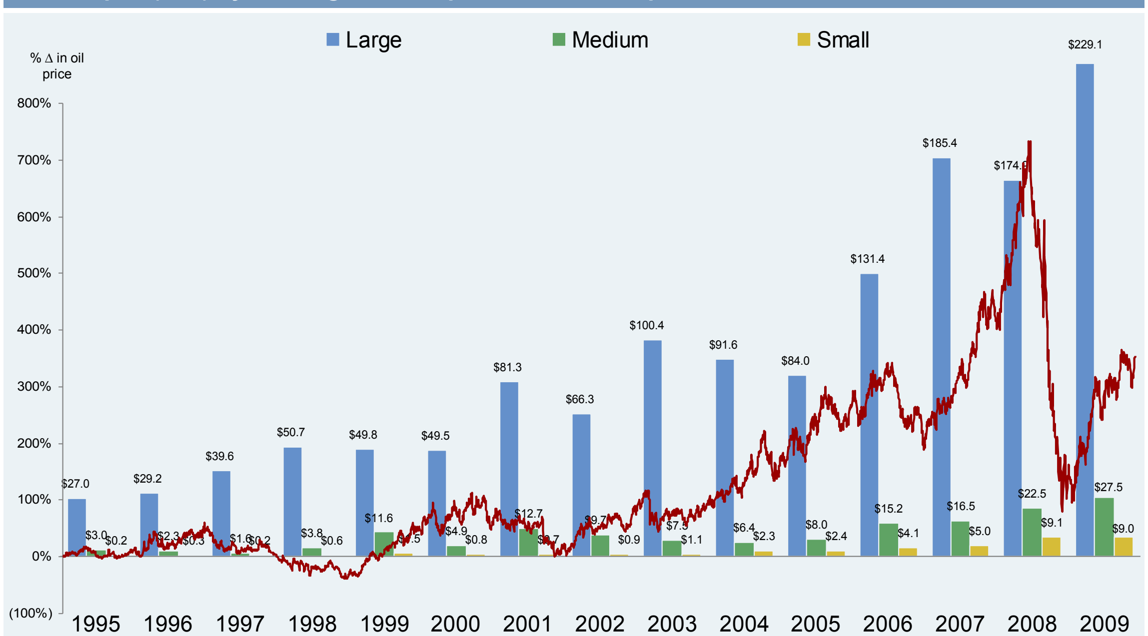
Note: Historical gas prices based on Henry Hub; companies included if reserves are greater than 50% gas; large companies have 100+ Mmboe production; Medium companies have more than 10 Mmboe and up to 100 Mmboe; Small companies have less than 10 Mmboe.

Source: J.S. Herold, Bloomberg

Exhibit 5.3 reflects the percentage change in nominal oil prices from 1/1/1995 and the nominal dollar amount of capital expenditures in billions by oil-weighted companies aggregated by company size. From 1995 – 2003, the price of oil was consistently observed within 100% of the 1/1/1995 base; however, over the same period, the capital expenditures rose to as much as ~3.7x the 1995 level for large companies, ~4.2x the 1995 level for medium companies and ~5.5x the 1995 level for small companies. Thus, observed nominal capital expenditures grew at a faster rate than observed nominal oil prices. From 2004 through 2008, higher prices were observed and sustained until mid-2008 when prices began falling, reaching pre-2004 levels by the end of 2008. During this period, capital spending by large oil-weighted companies fell only slightly and capital spending by medium and large companies grew substantially. In 2009, oil prices recovered to levels considered high relative to the 1995 – 2003 period but less than half of early 2008 levels; yet, capital spending by large and medium oil-weighted companies increased to record highs, and capital spending by small oil-weighted companies remained stable. A couple of variables are likely to have driven these results: (1) the availability of low-cost funding for drilling opportunities; and (2) the possibility of a change in the oil price paradigm stemming from the high sustained oil prices over the 5-year period from 2004 – 2009.

Exhibit 5.3

Total capex ($bn) by oil-weighted companies vs. % ∆ in price of oil



Note: Historical oil prices based on WTI at Cushing; companies included if reserves are 50%+ oil; large companies have 100+ Mmboe production; Medium companies have more than 10 Mmboe and up to 100 Mmboe; Small companies have less than 10 Mmboe.

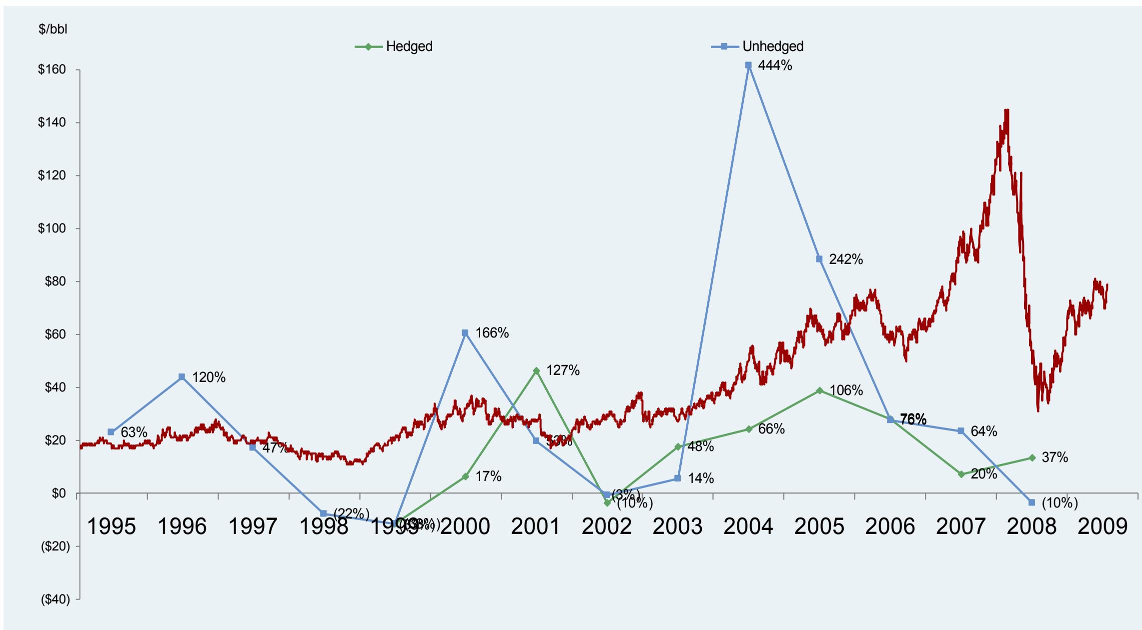
Source: J.S. Herold, Bloomberg

An additional factor that may influence company spending decisions during periods of increased commodity price volatility is the practice of hedging. Companies that run hedging programs typically secure their hedges 6-18 months in advance. As such, these companies are better protected in the short- and medium-term against commodity price fluctuations. Because hedged companies have better visibility of their future cash flows, they may be less likely than unhedged companies to significantly alter their capital spending programs due to changing commodity prices. Unhedged companies may be better able to capture upside in rising commodity price environments and may also decrease their capital spending plans if commodity prices, and thus cash flows, drop significantly in the near-term. Although the datasets available on historical hedging programs are limited, we attempt to address the influence of hedging in Exhibits 5.4 and 5.5.

Exhibit 5.4 provides an overview of year-over-year changes in finding and developing capital spending by companies for which J.S. Herold reports data on annual average oil price. The companies are further classified as "hedged" or "unhedged" as follows: a company with more than one year of oil hedging data in J.S. Herold is classified as hedged, and a company with one year or less of oil hedging data in J.S. Herold is classified as unhedged. For consecutive years in which a hedged company reported oil hedging data, we recorded the finding and developing capital expenditures and calculated the year-over-year percentage changes. Then, we calculated an average of year-over-year percentage changes found for all hedged companies in each year. By calculating an average change across companies, we control for the different number of observations between years. We performed the same exercise to obtain year-over-year percentage changes in finding and developing capex for unhedged oil companies. For Exhibit 5.4, the maximum number of hedged observations in any year is 5, and the maximum number of unhedged observations in any year is 12.

Exhibit 5.4

Hedged vs. unhedged companies: price of oil vs. % ∆ in finding and developing capex



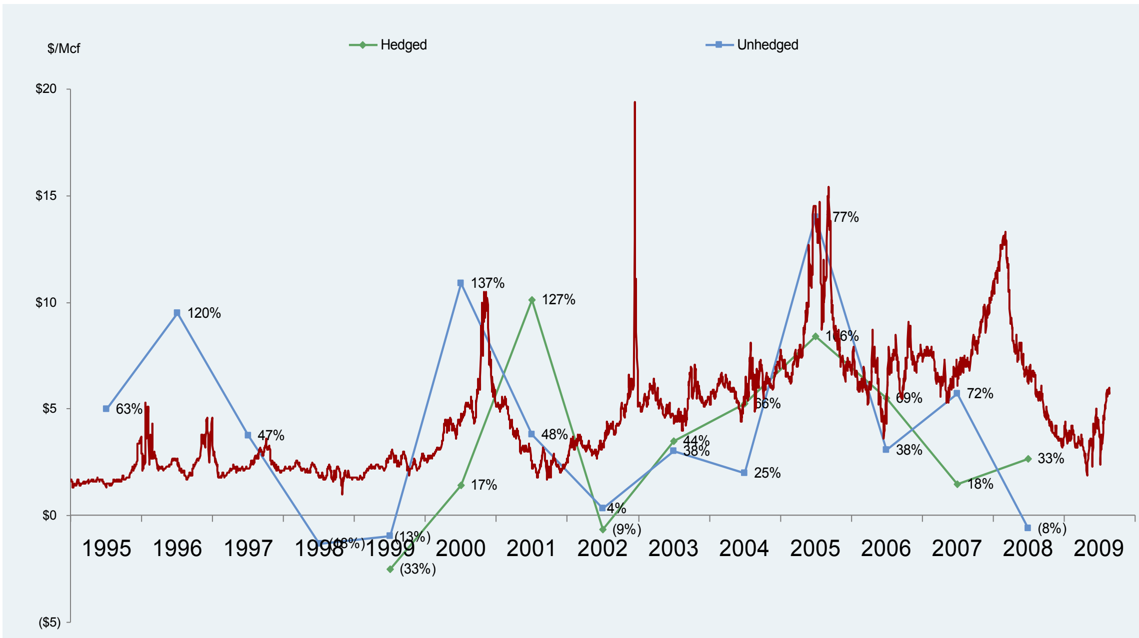
Note: Historical oil prices based on WTI at Cushing

Source: J.S. Herold, Bloomberg

Exhibit 5.5 provides an overview of year-over-year changes in finding and developing capital spending by companies for which J.S. Herold reports data on annual average gas price. Similar to the methodology used in the previous exhibit, the companies are further classified as "hedged" or "unhedged" as follows: a company with more than one year of gas hedging data in J.S. Herold is classified as hedged, and a company with one year or less of gas hedging data in J.S. Herold is classified as unhedged. For consecutive years in which a hedged company reported gas hedging data, we recorded the finding and developing capital expenditures and calculated the year-over-year percentage changes. Then, we calculated an average of year-over-year percentage changes found for all hedged companies in each year. By calculating an average change across companies, we control for the different number of observations between years. We performed the same exercise to obtain year-over-year percentage changes in finding and developing capex for unhedged gas companies. For Exhibit 5.5, the maximum number of hedged observations in any year is 7, and the maximum number of unhedged observations in any year is 14.

Exhibit 5.5

Hedged vs. unhedged companies: price of gas vs. % Δ in finding and developing capex



Note: Historical gas prices based on Henry Hub

Source: J.S. Herold, Bloomberg

The data in Exhibits 5.4 and 5.5 show that while the average hedged company still experiences some changes in finding and developing capex over time, the highs and lows are somewhat more contained than those of unhedged companies. While this hedge analysis provides some insight, the analysis is limited by the very low number of observations available and the fact that finding and developing capital expenditures are not reported by commodity type and thus cannot be analyzed based on the type of commodity hedge in question.

Utility Use of Hedging Instruments and Long-Term Natural Gas Contracts

In the presence of natural gas price volatility, one might expect local distribution companies and electric power generators to either use hedging instruments or long-term contracts to reduce price volatility. In fact, during the era in which wellhead prices for natural gas and pipelines were regulated, long-term contracts between natural gas producers, pipelines and the natural gas utilities, electric utilities and big industrial users was the norm. The contracts allowed the producers and pipelines to lock in expected margins, and allowed the customers to lock in secure supplies.

This contract system mostly disappeared after the Federal Energy Regulatory Commission shifted the pipelines toward contract carriage. Even though Ellig and High (1992) suggested that competitive long-term contracting could lead to market efficiency, few long-term contracts have been signed between natural gas producers, pipeline companies and the utilities. Utilities do hedge to some extent, but not much of their consumption and not much beyond a year. Electric power generators who serve restructured electric markets generally engage in longer-term natural gas supply contracts.

The lack of long-term contracts and limited hedging seems to owe to asymmetric loss functions on the part of state regulatory commissioners. In conversations with commissioners about the use of long-term contracts or hedging strategies by the utilities they regulate, the commissioners' typically express opinion that they favor the use of these long-term instruments if the utilities are able to lock prices that will remain below those prevailing in the spot market—even as market prices fluctuate. The commissioners are happy to explain to their constituents any hedging strategies or long-term contracts that have locked in below market prices for natural gas, but they are loathe to explain to their constituents any hedging strategies or long-term contracts that have locked in above market prices for natural gas. Of course, the natural gas producers have little interest in such lopsided contracts.

6. The Relationship between natural gas and oil prices

A small but coherent body of academic research shows that U.S. natural gas prices were related from the early 1990s through sometime in the mid- to late 2000s. Recent contributions include Villars and Joutz (2006), Brown and Yücel (2008), and Hartley, Medlock and Rosthal (2008). In general, these studies show that movements in crude oil prices lead those of natural gas in an error-correction process. That is, a process in which crude oil prices move first on international markets and then U.S. natural gas prices adjust to reestablish their historical relationship with crude oil prices. This empirical work also shows that international crude oil prices are not influenced by movements in U.S. natural gas prices.

Brown and Yücel further show that econometric models do a better job of explaining the relationship between crude oil and natural gas prices than industry rules of thumb. The primary reason is that the models allow for a lagged adjustment process, a more complicated relationship and the influence of additional variables.

Within the energy industry, the explanation frequently given for the historical relationship between crude oil prices was the ability for electric utilities and industrial energy users to switch between natural gas and petroleum products. Since the mid-2000s, natural gas prices have been well below what can be explained by industry rules of thumb or simple econometric models. This development has led many analysts to argue that everyone that can switch from petroleum products to natural gas has done so. Hence, U.S. natural gas prices are free to fall well below those implied by any historical parity with international crude oil prices and are likely to remain depressed relative to such historical measures.

Is Substitution at an End?

The facts on the ground tend to support the view that U.S. natural gas prices could remain well below that implied by a historical relationship with crude oil prices. The U.S. electric power sector shows much less use of petroleum products than it did in the past, with most producers switching to natural gas either for environmental or price reasons. Petroleum products are used mostly in transportation, while natural gas is used broadly throughout much of the economy except transportation.

In contrast with this perspective, empirical testing of recent price movements still finds that movements in world oil prices lead those of natural gas prices (though the relationship stands up better in first differences than as an error-correction process). In industry parlance, this continuing relationship might be described as the energy price complex moving together. For some analysts, this continued co-movement suggests that substitution possibilities continue to affect U.S. natural gas pricing. Hartley, Medlock and Rosthal show that the of substitution between natural gas and petroleum products remains an important factor shaping natural gas prices in some areas of the United States. Huntington (2007) further shows that there can be substantial substitution between natural gas and petroleum products in the industrial sector if one looks at the long-term planning process rather than interfuel substitution within a specific plant.

The global petrochemical industry may also help link U.S. natural gas and international crude oil prices. The U.S. petrochemicals industry relies heavily on natural gas as a feedstock, while much of its international competition relies on naphtha, which is a petroleum derivative. Furthermore, there is considerable evidence that the output of the U.S. petrochemical industry is sensitive to the differential between U.S. natural gas prices and world oil prices, although there is little formal research on the subject.

Other Short-Term Natural Gas Price Dynamics

Several market factors other than a lack of potential substitution may be contributing to the current weakness of natural gas prices. The massive development of shale gas resources in the latter half of the 2000s was largely a surprise. Most firms working in natural gas development were aware that they were sitting on considerable resources, but it was only when the Navigant (2008) study was released that anyone realized just how much natural gas could be forthcoming. At the same time, the U.S. recession sharply reduced industrial output and industrial natural gas demand. Together these two developments generated prices of natural gas that are too low to support a high level of exploration and development activity.

Longer-Term Developments

When considering the relationship between natural gas and oil prices, longer-term views tend be dominated by current market realities and the apparent lack of substitution opportunities. For instance, the EIA's Annual Energy Outlook 2010 projects U.S. natural gas prices will remain well below historical parity with crude oil prices through 2035. At the same time, the outlook shows natural gas failing to displace the use of petroleum products in the residential, commercial and industrial sectors even though its price is expected to remain low relative to those for crude oil through the foreseeable future. Such an outlook takes the perspective that U.S. natural gas resources are sufficiently abundant that everyone who can switch from petroleum products to natural gas has done so or will have done so by the time that the forecast period is reached.

The EIA projection shows limited use of natural gas in the transportation sector—either directly or indirectly. Direct use might include the more extensive deployment of vehicles using compressed natural gas or liquefied natural gas or the use of natural gas to create liquid fuels. Indirect use might include more extensive use of natural gas to generate electricity and the use of that electricity to recharge electric or hybrid-electric vehicles. The more extensive development and deployment of any these technologies could easily restore a strong linkage between oil and natural gas prices. Certainly, at the differential between natural gas and petroleum prices projected by the EIA, gas-to-liquids seems to be an attractive option.

The direct or indirect use of natural gas in the transportation sector could sustain a link between natural gas and crude oil prices—although the switching would occur in the planning process rather than within a single vehicle or plant. Similarly, the substitution between natural gas and petroleum products in industrial sector planning process could help link natural gas and crude oil prices over the longer-term. These longer-term issues related to the planning for fuel use need additional study before reliable projections can be made that fuel-switching will not continue to link U.S. natural gas and international crude oil prices over the foreseeable future.

Implications of Climate Policy

The implementation of climate policy is likely to alter the mix of fuels used in the United States (Weyant 2009). Because carbon dioxide is regarded as a principal contributor to global warming, climate policy is likely to favor lower carbon energy sources over higher carbon ones, which could benefit natural gas relative to oil and oil relative to coal.

Whether climate policy leads to an increase or decrease in natural gas use will depend on the elasticity of natural gas supply and the relative attractiveness of non-carbon energy sources under the policy (Brown and Krupnick 2010). In any case, climate policy is likely to favor natural gas over oil, which would increase the price of natural gas relative to oil (Brown, Gabriel and Egging 2010). In most projections, increased natural gas prices would narrow the gap between natural gas and crude oil prices.

A narrowing of the projected gap between natural gas and crude oil prices should not be confused with a tighter link between oil and natural gas price, however. Any such link depends upon the potential for substitution—through fuel switching within a plant, between plants or in the planning process. The implementation of climate policy will tighten the relationship between natural gas and oil prices only if it increases the potential substitution between these two fuels. At this point in time, there is no reason to expect climate policy to affect the potential for interfuel substitution.

7. Conclusion and future considerations

Our findings on the effects of commodity price fluctuations on consumer spending, investment decisions, and stock prices, among other macroeconomic indicators, support the argument that securing reliable sources of energy at stable prices should be a goal of future energy policies. Further, as described herein, liberalized energy supply market in the United States will ensure a more liquid supply of energy and will help to minimize severe price fluctuations.

As our scope in this paper was primarily limited to oil and natural gas, we did not compile an in depth analysis on liquefied natural gas (LNG), but this is one additional energy supply to consider in future research. Since 2000, the capacity to import liquefied natural gas (LNG) into the United Sates has expanded dramatically. During this period, 2 terminals were re-commissioned and expanded (Cove Point in Maryland and Elba Island in Georgia) and 9 others have been constructed. This has increased LNG import capacity from just over 2 billion cubic feet per day (bcf/d) in 2000 to just over 17.4 bcf/d currently, and import capacity could reach 20 bcf/d by 2012. Tremendous growth in LNG import capability has also been observed in Europe. Asia already has a large LNG footprint, with Japan and South Korea being the two largest LNG consumers globally, and the Asian footprint is set to expand, largely due to the emergence of China in the global economy.

This expanded capability to deliver LNG to multiple markets is removing the traditional paradigm – one in which the Asian, European and North American natural gas markets were largely disconnected from one another. In fact, growth in LNG has led to a growing interconnectedness between these previously regionally disconnected markets. This has, in turn, raised energy security concerns. In particular, might the US natural gas market be more exposed to a cutoff of Russian supplies to Europe? One might think so if the event resulted in more LNG flowing to Europe as it is diverted from other destinations. This effectively transmits (by displacement) the supply reduction from Russia as supplies bound to other markets are disrupted. Future policies should anticipate this and other potential and/or unexpected evolutions of global energy supply and demand.

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