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ANALYSIS

Oil, economic growth and strategic petroleum stocks

Carmine Difiglio [1]

U.S. Department of Energy, 1000 Independence Ave., SW, Washington, DC 20585, USA

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ABSTRACT

An examination of over 40 years of data reveals that oil price shocks are invariably followed by 2–3 years of weak economic growth and weak economic growth is almost always preceded by an oil price shock. This paper reviews why the price-inelastic demand and supply of oil cause oil price shocks and why oil price shocks reduce economic growth through dislocations of labor and capital. This paper also reviews the current state of oil-supply security noting that previous episodes of supply instability appear to have become chronic conditions. While new unconventional oil production technologies have revitalized North American oil production, there are significant barriers to a world-wide uptake of these technologies. Strategic petroleum stocks could provide a large measure of protection to the world economy during an oil supply disruption if they are used promptly and in sufficient volume to prevent large oil-price spikes. Despite the large volume of world-wide emergency reserves, their effectiveness in protecting world economies is not assured. Strategic oil stocks have not been used in sufficient quantity or soon enough to avoid the economic downturns that followed past oil supply outages. In addition, the growth of U.S. oil production has reduced the ability of the U.S. Strategic Petroleum Reserve to protect the economy following a future oil supply disruption. The policy implications of these findings are discussed.

1. Plan of the paper

This paper discusses the vulnerability of the world economy to unplanned oil supply interruptions and how strategic petroleum stocks can lessen or entirely avoid the adverse economic consequences of a serious oil supply outage. The paper is organized into fourteen sections beginning with a discussion of the short-term price elasticity of demand for oil, the initial reason why oil supply outages can cause oil price spikes. After reviewing the literature concerning the price and income elasticities of demand for gasoline and crude oil (Sections 2 and 3), the second problem is discussed: the very small short-term price elasticity of oil supply (Section 4). The inelastic short-term price elasticities of demand and supply imply that relatively small supply outages can produce large oil price spikes (Section 5).

A history of oil pricing from 1970 to the present day (Section 6) is provided as background to an assessment of how each oil price spike since 1970 was followed by an economic downturn (Section 7). Oil price shocks were invariably followed by 2–3 years of weak economic growth and weak economic growth was almost always preceded by an oil price shock. Section 8 investigates the reasons why oil price spikes cause recessions and unemployment in order to confirm that there is a causal relationship between oil price spikes and sharp reductions in GDP growth. Turning towards the future, it's observed that the recent geopolitical disruptions in several oil exporting countries are not likely to be passing problems (Section 9). While increased North American oil production has offset these losses, it is not likely that the new technologies responsible for the rise in U.S. production will bring about inexpensive world oil supplies. Consequently, the world-wide economy is likely to remain vulnerable to future oil outages (Section 10).

Strategic oil reserves have been used in response to past oil supply problems. However, had the reserves been released soon after the initial disruption, in sufficient volumes to offset the supply loss, the subsequent

[1] U.S. Department of Energy: carmine.difiglio@hq.doe.gov. The analysis, data and views expressed in this paper are those of the author and are not endorsed by the U.S. Department of Energy or the United States government.

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economic downturns may have been avoided (Section 12). Today, reduced U.S. oil import dependence raises questions about why the United States should still maintain large strategic stocks. Reduced U.S. oil dependence is also restricting the ability of the United States to release its strategic stocks because of recent midstream and shipping bottlenecks (Section 13). Conclusions and policy implications, especially for U.S. and world-wide stock holding policies, are provided in Section 14.

2. The short-term price elasticity and income elasticity of gasoline demand

If crude oil demand does not slacken very much when oil prices rise, we are more likely to see large increases in oil prices in order to balance the market after an oil supply outage. Since crude oil is an intermediate good, the demand for oil depends on consumers' purchases of petroleum products. Refiners will continue to purchase crude oil when oil prices increase as long as petroleum products can still be sold at a profit. If the demand for petroleum products is inelastic[2], then refiners will not greatly reduce their demand for crude oil as it becomes more expensive. Consequently, it makes more sense to estimate how petroleum product demand responds to changes in price than to estimate how refiners respond to changes in the price of crude petroleum. Gasoline is one of the most important consumer products produced from crude oil and, along with distillate and jet fuel, these fuels constitute the bulk of revenues to petroleum refineries. Kilian [1] noted that an analysis of the economic impacts of energy price shocks benefited from "a direct measure of gasoline prices" as this was "more relevant than a measure of crude oil prices."

Earlier studies found the short-term price elasticity of gasoline to be between −0.1 and −0.3.[3] For example, a survey by Greening, Greene and Difiglio [2] found that the estimated elasticity of demand for travel, with respect to the price of gasoline was between −0.1 and −0.25.[4] An earlier survey by the Dahl and Sterner [3] concluded that the average estimated price elasticity of gasoline demand was −0.26 and that the average income elasticity of gasoline demand was 0.48. Espey's "meta-analysis" [4] considered hundreds of studies of gasoline demand, most of which relied on data from the 1970s and 1980s, and found that the great majority (over 200) estimated the short run price elasticity of gasoline demand to be between 0 and −0.25. Most estimates of the income elasticity of gasoline demand were between 0.26 and 0.50 (short-term) and 0.76 and 1.00 (long-term). Espey also found that the earlier studies estimated higher short-term price elasticities than the later studies but did not find any trend in the estimates of income elasticities. However, Espey did note that income elasticities were higher in studies that included data from developing and other countries outside of the United States suggesting that countries with lower incomes and less saturated auto ownership have a higher income elasticity of gasoline demand. If so, this has implications for future oil demand as developing countries have higher growth rates of GDP than developed countries and helps to explain the rapid growth of oil consumption outside of the OECD.[5]

Studies that analyzed more recent data show a dramatic decrease of the short-term price elasticity of gasoline. Small and Van Dender [6] estimate a short-term price elasticity of gasoline demand of −0.089 using 1966–2001 data but find that it decreases to −0.067 when they only used data for 1997–2001. Hughes, Knittel and Sperling [7] estimate that the price elasticity drops from −0.222 using data for 1975–1980 to −0.034 using data for 2001–2006. They also find that the income elasticity of gasoline demand increases from 0.212 to 0.506 when the later 2001–2006 data is used. Hughes, Knittel and Sperling attribute the declining short term price elasticity of demand to several factors: suburban development has increased average trip distances; distances between homes and non-discretionary destinations have increased; multiple-income households are more dependent on commuting, public transportation use has declined and motor-vehicle fuel efficiency is substantially higher. Another recent study by Lin and Prince [8] included a survey of recent studies concluding that "the short-run gasoline price elasticity shifted down considerably from a range of −0.21 to −0.34 in the late 1970s to −0.034 to −0.077 in the early 2000s." Lin and Price's dynamic model, using U.S. data, focuses on the relationship between price elasticity and gasoline price volatility. They find that price elasticity is somewhat lower during periods with higher volatility (−0.030) than lower volatility (−0.036).

Contrary evidence by Kilian and Murphy [9] needs to be put into perspective. They concluded that "the median short-run price elasticity of gasoline demand is about −0.26," an estimate that is several times larger than the several estimates cited above. Kilian and Murphy derived this estimate using a model in which oil prices were endogenous. They stated: "earlier studies fail to account for price endogeneity and cannot be interpreted as an elasticity in the textbook sense." To address this, Kilian and Murphy embed the elasticity of oil demand with respect to income into their price-elasticity estimate. The simultaneous equation model used by Kilian and Murphy explicitly introduces an income-feedback variable (shipping index) that conveys a macroeconomic impact on oil demand following an oil price shock. As such, Killian and Murphy's relatively high oil price elasticity estimate is not inconsistent with the very low static price elasticity estimates from the other studies cited above so long as we recognize the macroeconomic feedback is not incorporated in the other studies. As noted below, these macroeconomic feedbacks have important impacts on oil prices and economic welfare.

3. The short-term price elasticity and income elasticity of crude oil demand

Studies of the short term price elasticity of demand for crude petroleum confirm the results obtained for gasoline demand studies. For example, Cooper [10] estimates G7 countries to have a short term elasticity of demand for crude oil from −0.024 to −0.069 and, for all 23 countries studied, the range expands to 0.0 to −0.11. Gately and Huntington [11] estimated a short-run demand elasticity for crude oil of −0.05 for OECD countries and −0.03 for non-OECD countries. They estimated a long-run income elasticity of oil demand of 0.56 for OECD countries and 0.53 for non-OECD countries. Baumeister and Peersman [12] report that the elasticity of demand for crude oil has sharply decreased from 1970 to 2008. They find that "the price elasticity has decreased [in absolute value] from −0.05 to −0.15 during the 1970s and early 1980s to as small as −0.01 to −0.02 since the mid-1980s." One factor that can help explain this change is the movement away from oil-fired generation in the power sector and space heating from 1978 to 1985 observed by Dargay and Gately [13]. Power generation and other stationary uses of oil fuels have greater opportunities for fuel switching than the transport sector where the opportunities for fuel switching are insignificant.

Using different estimation techniques, Krichene [14] found a short-term elasticity of demand for crude oil of −0.005 to −0.02 using data from 1973–1999. For the same period he found a short-term income elasticity crude oil demand of 1.2 to 1.45. Ghouri [15] estimated, for

[2] Inelastic demand means that the price of a commodity or product has a relatively small effect on its demand.

[3] A short term price elasticity of gasoline demand of −0.1 means that an increase in the gasoline price by 10% would reduce the short term demand for gasoline by 1%. The long-run effect would be greater since higher gasoline prices could motivate purchases of more efficient vehicles or taking other actions that would reduce gasoline expenses (e.g., moving to a location that requires less automotive travel).

[4] The surveyed studies in Greening, Greene and Difiglio used data from 1967–1991.

[5] The majority of oil demand has recently shifted from the OECD to the non-OECD. By 2030, China is expected to become the world's largest consumer of petroleum while OECD oil demand is expected to decline [5].

the United States, a long-run income elasticity of oil demand of 0.98 and similar income elasticities for Canada (1.08) and Mexico (0.84). Askari and Krichene [16], estimating the demand for crude oil, found that "short-run price elasticities were very low and insignificant for several time periods between 1970 and 2008. Askari and Krichene's price elasticity estimates ranged from −0.018 for 1986–2001 data to as low as +0.004 (essentially zero) for 2001–2008 data. The estimated price elasticity for 1970–2008 and 1970–1986 was −0.018. Askari and Krichene conclude that:

> "oil demand is highly price inelastic, implying that changes in oil prices have a small effect on the demand for crude oil. Large increase in prices will translate into much larger spending on oil and therefore, *ceteris paribus*, a reduction of spending on non-oil products."

4. The short-term price elasticity of oil supply

In the short run, oil supply can respond to oil price changes in the following ways:

- Higher oil prices (and backwardation of the forward curve) may stimulate the drawdown of oil stocks.
- Saudi Arabia, and a handful of other countries that hold some reserve production capacity, may decide to move reserve capacity into or out of production as oil prices rise or fall.
- If oil prices fall to levels that fail to justify the marginal cost of oil production, those wells would be shut in or fracking operations could be slowed or terminated. Higher oil prices could also stimulate higher tight-oil production more quickly than conventional oil production could increase.

Apart from stock draws or increased Saudi production, oil producers are unable respond to higher oil prices by increasing production to any significant degree. Oil companies can only respond to higher or lower oil prices by increasing or decreasing planned investments in new production capacity. Consequently, the short-term elasticity of oil supply with respect to price is quite small. If high income growth increases the world-wide demand for oil faster than the world-wide growth of supply, oil producers cannot quickly respond to the consequent increases in oil prices as their maximum production generally depends on investments made years earlier. Baumeister and Peersman [17] show that the short term response of oil supply has become quite price-inelastic over time, pointing out that the decreased price elasticity of supply makes inter-temporal comparisons of the economic impacts of oil supply shocks more difficult. As Baumeister and Peersman point out, for a given supply-demand imbalance, the global oil price increase has to be significantly greater now than in the past. This is borne out as we have seen high price increases during periods of high world economic growth (for example, from 2002–2008) or unplanned petroleum supply outages (many examples summarized below).

5. Why the underlying short term price elasticities of oil supply and demand generate oil price spikes

There are significant consequences resulting from the very low price elasticity of demand and supply. Low price elasticities mean that very large price changes are required to significantly increase supply or decrease demand. Consequently a relatively small unplanned oil supply outage can produce an oil price spike. In addition, because of the relatively high income elasticity of oil demand, rapidly rising world economic growth grows oil demand. If rapid economic growth grows oil demand faster than can be accommodated by the growth in oil supply, oil prices can rise significantly. As rising oil expenditures are a large enough component of GDP to adversely affect economic growth, these interactions can produce the following oil price - economic growth – oil production investment cycle:

- Due to:
  - low price elasticities, an unplanned supply outage spikes oil prices, or
  - due to relatively high income elasticities, rapid GDP growth drives oil prices to high levels;
- The resulting high share of GDP spent on oil reverses GDP growth;
- With lower GDP growth, high income elasticity reduces oil demand;
- With lower oil demand, low oil price elasticities sharply lower oil prices; and
- Lower oil prices and reduced GDP growth discourage oil production investment.

World GDP growth and oil prices are periodically engaged in the cycle described above. Kilian [18] notes that oil price shocks do not affect the real price of oil for very long. The above narrative attributes the price drop to reduced economic growth. Kilian finds that the effect of an oil price shock is delayed: "there is some indication that [oil price shocks] lower global economic activity in the third year after the shock" and, consequently, Kilian attributes the rapid reduction in oil prices to an oil supply response. However, as will be discussed below, after every oil price shock, we observe significantly reduced world-wide economic growth in the first, second and third years following the shock. Reduced economic growth, combined with a relatively high income elasticity of oil demand, explains why the price of oil declines so soon after an oil price shock rather than an immediate increase in oil supply.

Oil prices can also stabilize at relatively high levels just short of what would cause a downturn in GDP growth if GDP growth is relatively modest (e.g., the economic conditions that have persisted during the last few years). The relatively high oil prices, during these circumstances, may reflect oil supplies sufficient to keep the oil market in balance with modest world-wide economic growth but oil prices are too high, and oil supplies too inelastic, to support higher economic growth.[6]

6. Oil price history

World oil prices have, from time to time, reached levels that have impaired world economic growth such as the aftermath of the 1973 oil embargo. This "energy crisis" accompanied a major change in the way petroleum was controlled and priced. Prior to 1973, world oil prices were managed by the Texas Railroad Commission and a relatively small number of large oil companies (super-majors) that enjoyed liberal access to most countries' oil resources. They could develop large oil fields in host countries with terms that allowed ample world supply at non-competitive but reasonable prices. The super-majors pursued a strategy of affordable and stable oil prices since the resulting economic growth in the industrialized world increased the demand for oil. By 1973, the Texas Railroad Commission was no longer relevant and reforms in the member-countries of the Organization of Petroleum Exporting Countries (OPEC) ended the super-majors' control of world oil prices. The reforms moved the control of the world's largest oil resources from the international oil companies to the OPEC countries and, given sufficient cohesion, allowed OPEC to control world oil prices.

OPEC's control of oil prices was short-lived. The rapid price hikes associated with the 1973 embargo and the 1979 Iranian revolution stimulated new supplies, especially from the North Sea and Alaska. High

[6] Due to an inability for oil production to keep up with the supply needed to support robust world-wide economic growth. For example, see Kopits [19] and Tverberg [20].

oil prices also stymied demand as consumers turned to more efficient automobiles. By 1981, oil prices began a steady decline. Saudi Arabia tried to maintain higher prices by cutting production until, by 1985, its output had fallen to 3 million barrels per day (mmb/d), 70 percent lower than it had been in 1980. In 1986, Saudi Arabia adopted netback pricing[7] to regain market share. Oil prices collapsed to $12 per barrel[8]. By 1988, the OPEC pricing regime was replaced by commodity market pricing, a system that remains in place today and for the foreseeable future. The London InterContinental Exchange (ICE) established a contract for Brent, a mixture of high quality North Sea crudes[9]. The price trajectory of Brent since 1987 is shown in Fig. 1. Additionally, the New York Mercantile Exchange (NYMEX) established a contract for West Texas Intermediate (WTI), a high-quality crude similar to Brent.

Today, only a small percentage of the world's crude petroleum is WTI, Brent or other traded "marker" crudes. Nonetheless, these marker crudes affect the contract price of other types of crude oil since most crude oil contracts are indexed to one or more marker crudes. This new pricing regime did not entirely eliminate OPEC's price setting role. A few OPEC countries maintain spare oil production capacity. Saudi Arabia, by far, keeps the largest production capacity in reserve. Saudi Arabia can increase or decrease its oil production in response to world market conditions. If Saudi Arabia believes that prices are too high, it can put spare capacity into production, putting downward pressure on market prices. Conversely, if Saudi Arabia believes that prices are too low, it can reduce production (increasing spare capacity) putting upward pressure on market prices. Most other oil producing countries and all private oil companies are price takers. They only respond to higher or lower oil prices by increasing or decreasing planned investments in new production capacity. Whether or not these investments are made has little impact on current oil supplies or prices, but may have a large impact on future oil supplies and prices.

The new pricing regime produced relatively stable, inflation adjusted, oil prices until 1999 (except for a sharp increase in 1990 due to the Gulf War). In 1999, oil prices began a sharp upward trend culminating in an extremely sharp $40/b rise from January 2007 to June 2008. With record high oil prices, U.S. demand finally slackened and, soon after, failing financial institutions precipitated a world-wide banking crisis. Oil prices plummeted, reversing in one year the gains made since 2005.

Since 2008, there have been two rapid increases in oil prices. In early 2011, the Libyan civil war removed 1.5 mmb/d of light-sweet crude from the market. Oil prices spiked again in 2012 due to increased supply outages in Iran, Nigeria, Sudan and Yemen. The 2012 run-up was followed by a significant price slide due to a deteriorating economic outlook in the Eurozone and uncertainty whether the EU and the European Central Bank would take the necessary actions to prevent an unraveling of the euro.

7. Oil prices and GDP growth

Fig. 2 shows oil prices and annual changes in world-GDP. Each spike in oil prices was followed by a sharp drop in world GDP growth. The price rise from the 1973 oil embargo preceded a 4% drop in world GDP growth. Within two years, world growth slid from over 6% to 1%. The oil-supply outage resulting from the 1979 Iranian revolution doubled oil prices. Growth slid from 4% to 2% and, later, to below 1%.

The spike in oil prices resulting from the 1990 Gulf War led to a drop in world GDP growth from over 3% in 1990 to 1% in 1991. GDP growth did not return to 3% until 1994. The price spike from 1999–2000 was followed by a drop in world GDP growth from over 4% in 2000 to 2% in 2001. The world economy appeared to survive the long price rise from 2002 to 2007 until 2008, when the world suffered the worst financial crisis since the 1930s. World GDP growth dropped from over 4% in 2007 to less than 2% in 2008 and then plummeted to −2% in 2009. While the 2008 recession followed a liquidity freeze, high oil prices were a partial cause of the financial crisis. Excessive construction lending had been made in locations that were dependent on low automobile commuting costs. Rapidly rising oil prices then reduced the market value of real-estate on the outskirts of cities causing a significant rise in underwater mortgages. Sexton, Wu and Zilberman [21] analyzed the role of rising gasoline prices on the real estate crisis of 2007–2008. They found that housing prices first dropped in the suburbs and that the foreclosure rate increased with the distance away from the urban center. With rising gasoline expenses and no home equity, many lower income households defaulted. Sexton, Wu and Zilberman's model showed why these foreclosures spread throughout the entire overvalued housing market. Rapidly increasing oil prices did not just affect the housing market. They also reduced automobile sales and economic activity in vacation and entertainment-focused regions. All of these consequences resulted from reduced household income after paying unavoidable fuel expenses. [10] With reduced spending, important economic sectors contracted causing dislocations of labor and capital. The world-wide real estate bubble enabled the economy to tolerate rising oil prices for a number of years. However, by 2007–2008, the strain of exponentially rising oil prices on disposable income, employment and mortgage defaults contributed to the worst world-wide economic contraction in 75 years.

8. Why oil price spikes cause recessions and unemployment

During the last 40 years, each oil spike has been followed by a sharp drop in world economic growth. There has been only one sharp annual reduction in world economic growth that was not preceded by an oil price spike.[11] Otherwise, world GDP growth has remained above 3%, apart from the 1st, 2nd or 3rd years following an oil price spike. Unless these episodes linking oil price spikes to poor world-wide economic growth are coincidences, or result from mismanagement of the economy by monetary authorities, there must be a mechanism through which these oil price spikes cause such economic harm. This mechanism has been well-researched with many authors focusing on the multiplier effects that cascade through the economy. Reduced spending on other goods and services has multiplier effects that grow over time. Edelstein and Kilian [22] found that the reduction of spending resulting from an oil price shock accelerates in later time periods. For example, Edelstein and Kilian found that a shock causing a 1% spending reduction produces a 2.2% reduction one-year later. As the economy adjusts to a new pattern of expenditures, transitional effects force the economy to operate below the potential output until full adjustments are made. These adjustments include inter-sectoral and inter-regional relocations of labor that are displaced by reduced spending in the economic sectors that they had previously worked.

[7] The netback price is based on a formula that subtracts from the price of petroleum products the value added of refining and transport. While having certain attractive features, it failed to be a practical method of pricing for oil.

[8] Nominal dollars during the first half of 1986 or $22/b in constant dollars indexed to 2012.

[9] The selection of Brent and WTI as marker crudes reflected several factors: 1) the desirability of Brent and WTI to most refiners; 2) the sources of Brent (UK and Norway) and WTI (United States) relative to the world's financial capitals, London and New York; 3) the supply of Brent and WTI would not be controlled by national governments or OPEC; and 4) Brent and WTI were produced in sufficient volumes to be an important component of world oil supply.

[10] Fuel expenses are "unavoidable" in the sense that the elasticity of oil demand with respect to price is low. Consumers believe that they have little choice except to consume travel and other energy services even when fuel prices are high.

[11] There was a sharp decline in growth from 1997 to 1998 (3.7% to 2.4%).

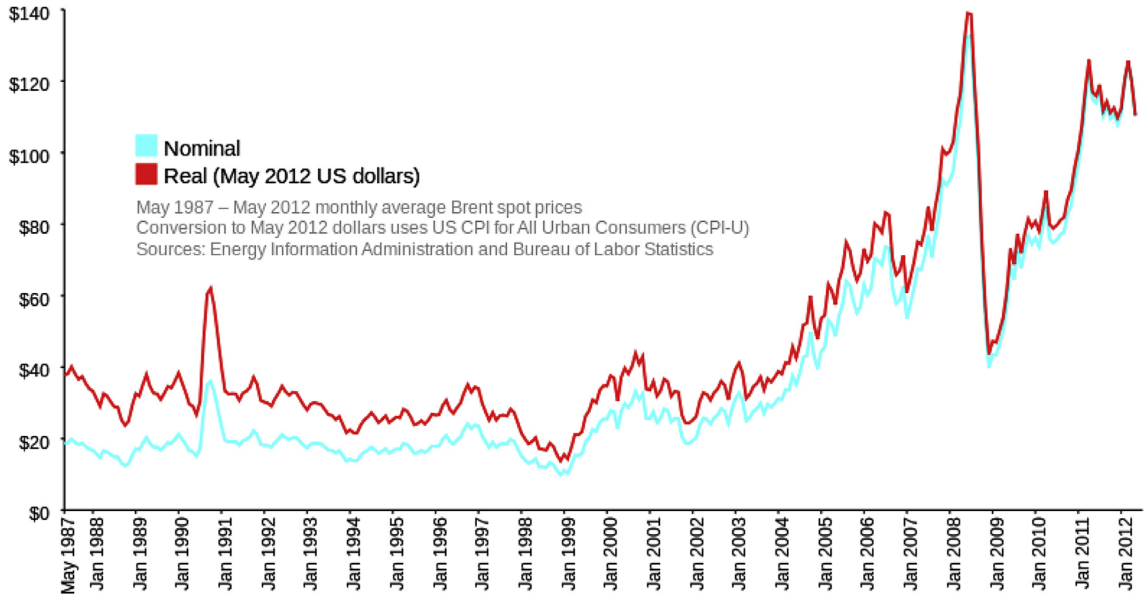

Fig. 1. Real and nominal world oil prices.

A major mechanism through which oil price shocks affect the economy involves the motor vehicle industry. Oil price spikes reduce spending on motor vehicles out of proportion to their effect on disposable income. The economic harm from decreased automotive sales cascades throughout the economy. Tracing impulses with a 1949–2012 statistical model, Santini and Poyer [23] showed that real expenditures on motor vehicles declined immediately following a gasoline price shock, but well before subsequent declines in employment. Santini and Poyer [24] also showed for 1967 to 2008 that declines in U.S. motor vehicle output clearly preceded declines in the rest of GDP in each of the recessions during that time interval. While automobile production is typically associated with the United States, Japan, Germany and South Korea (they are the 2nd to 5th largest automobile manufacturers), automobile production is widely distributed. The largest current producer is China and, after South Korea, there are 11 countries that produce at least 1 million motor vehicles per year. The economic ripple of reduced automobile purchases also extends to countries that produce few or no automobiles via reduction of their exports to the auto-producing countries that have reduced spending and output.

The economic harm caused by oil price increases is not linear. Hamilton [25] showed that oil price changes do not matter unless they set a new high relative to the previous 3-years. This supports the view that economic dislocations are the vector that spread economic harm beyond the share of GDP lost though higher oil prices. Mork [26] showed that *reductions* in oil prices can cause economic harm supporting the view that major sectoral dislocations caused by abrupt oil price *changes* are a key mechanism for economic harm. This could explain why the rapid decrease in oil prices during the 1980s did little to promote economic growth. This asymmetry might alternatively suggest that it is the monetary response to oil price changes that affects the economy: Monetary responses to higher and lower oil prices may be asymmetric or may have asymmetric effects. However, before addressing this question, it is necessary to review whether monetary policy itself has been an important factor in causing economic disruptions after an oil price shock.

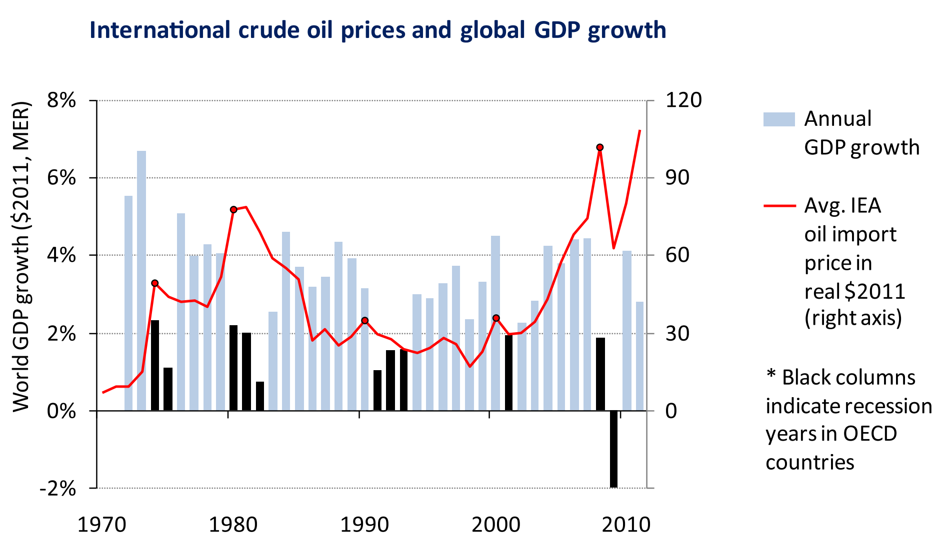

Fig. 2. International crude oil prices and global GDP growth. Source: IEA, *World Energy Outlook 2011*.

Well before the recent monetary accommodation from 2001—2008 (and beyond) Bernake, Getler and Watson [27] suggested that that contractionary monetary policies exaggerated the adverse effects of past oil-price shocks and, with improved monetary policies, oil price increases need not have serious economic consequences. Hamilton [28], however, found that the 2007—2009 recession followed earlier oil price-GDP patterns despite expansionary monetary policies during the uninterrupted rise of annual oil prices from 2001—2007, noting plunging U.S. automobile sales and 1.2% lower real GDP growth in 2007. However, the importance of constructive monetary policy should not be discounted. Wu and Ni [29] conclude, using symmetric and asymmetric models, "monetary policies still matter, after accounting for the oil prices, the energetic variable." Askari and Krichene [16], whose work on oil demand elasticities was cited above, conclude that

> "Aggressive monetary policies would stimulate oil demand, however [because of low short term elasticities] would be met with rigid oil supply and would turn disruptive to economic growth if there was little excess capacity in oil output. We argue that a measure of stability in oil markets cannot be achieved unless monetary policy is restrained and real interest rates become significantly positive. Monetary tightening during 1979—1982 might imply that monetary policy has to be restrained for a long period and with high interest rates in order to bring stability back to oil markets."

This monetary policy prescription can be compared to contrary advice by Bernake, Getler and Watson [27]. Askari and Krichene emphasize that there is reduced disposable income available to spend on non-oil commodities because of the oil price shock and that loose monetary policies will not increase oil supplies.

Returning to the question of whether monetary policy explains the observed asymmetric effect of oil price changes, Federer [30] concludes that "the monetary channel cannot explain the asymmetry puzzle" and "sectoral shocks and uncertainty channels offer a partial solution to the asymmetry puzzle." Balke, Brown and Yucel [31] acknowledge that increased oil prices introduce financial stress and that "factors other than monetary policy would appear to contribute to asymmetry on the real side" while acknowledging the influence of asymmetric Fed policy and the role of interest rates. Davis and Haltiwanger [32] note that "employment growth declines sharply following a large oil price increase but changes little following a large oil price decrease." Hamilton [33] concludes "empirically, oil price increases appear to hurt aggregate economic activity while price declines do not appear to help" and attributes this disparity to the "costs of sectoral realignments after relative price changes."

There is evidence that economies have become more resilient against the adverse effects of oil price increases (Rasmussen and Roitman [34], Baumeister, Peersman and Van Robays [35]). Nonetheless, it goes too far to wonder "whether [oil prices] are really that bad?" (Rasmussen and Roitman [35]). The decreased elasticity of demand for oil, combined with evolving conditions in the world oil market, can more than offset improved economic resiliency to a given oil price increase. As shown in Fig. 2: 1) oil price shocks are invariably followed by 2—3 years of weak economic growth; and 2) weak economic growth is almost always preceded by an oil price shock. Looking forward, there is little reason to be complacent about the economic damage that could be caused by future oil price spikes considering increased instability of Middle East and North Africa (MENA) oil exporting countries and increased non-OPEC oil production costs[12].

9. Looking forward

The world oil market has been subject to unplanned supply outages since its inception. However, since 2011, supply outages have increased considerably from prior years. They also reflect causes that are likely to be chronic conditions, as opposed to one-off events. During 2010, oil supply outages averaged less than 1 mmb/d; since 2011, they have averaged $\sim$ 3 mmb/d. These outages have been caused by a variety of problems including tribal grievances with the central government, sectarian conflict and piracy. The security situation has caused private industry to withdraw personnel from regions not deemed to be safe. In addition to loss of trained personnel, insurgent attacks on infrastructure, political disputes concerning sovereignty and disagreements about the validity of oil-related contracts are not likely to be passing problems. While these may be necessary side effects as countries replace autocratic rule with democratic governments, they nonetheless pose a great risk for future oil supplies. The International Energy Agency (IEA) recently warned that relatively stable oil prices should not conceal "an abundance of risk" as "much of the Middle East and North Africa remains in turmoil." "The current stalemate between the West and Iran" is "unsustainable" and "sooner or later, something has to give." The political situation in the MENA region reflects a "precarious balance" that does not bode well for "clear, stable and predictable oil policies, let alone supplies" [36].

The oil-economy problem would be reduced if future oil prices trended significantly lower as a result of new discoveries and oil-production technologies. However, there are reasons to believe that we cannot count on abundant cheap oil as a way out of our oil-economy problem. First of all, there is a large uncertainty about future oil supplies. As pointed out by Brant, Plevkin and Farrell [37], "data [for conventional oil supplies] are unavailable for political or economic reasons, reserves reporting practices are poor, and some regions are not yet thoroughly explored."[13]

The remaining conventional oil that can be produced at a relatively low marginal cost is likely to be in MENA OPEC countries (Khatib [39]). Despite this, OPEC production capacity has grown relatively little for the last 30 years. For example, OPEC production capacity has risen by only 1 mmb/d, 2000—2013, while world-wide liquids consumption has increased by 15 mmb/d over the same time period [40]. Over that time, growing oil demand has been met by additions to non-OPEC capacity. A number of disappointing non-OPEC supply developments helped drive the sharp rise in oil prices from 2002 and 2008. During that period, the cost of oil and gas drilling equipment and support activities increased by 260% [41]. More recently, the growth of Canadian oil sands and U.S. tight oil production has kept the world oil market in balance. Without increased oil production in the United States and Canada, non-OPEC production would have been in decline in recent years.

Sufficiently high oil prices are needed to sustain the growth on non-OPEC oil. The IEA estimates that the cost of oil sands and tight oil production ranges from \$45/b to over \$100/b [42]. As production moves from the most productive plays to less promising plays, costs will tend to move to the upper end of the IEA range. For example, Global Energy Securities estimates that the price of oil needed to generate an attractive internal rate of return increases from \$67/b in Eagle Ford to

[12] As marginal suppliers of oil, non-OPEC producers have more to do with setting long-term international oil prices than does, for example, Saudi Arabia though increased or decreased production from its spare production capacity. As long as OPEC production capacity remains relatively flat, the growth in world-wide oil demand must be met with increased non-OPEC production. Since increasing non-OPEC production means tapping more expensive-to-produce oil reserves, unless international oil prices are sufficiently high, there will not be sufficient growth in non-OPEC production to meet growing world-wide demand.

[13] Brant, Plevin and Farrell develop a nonlinear optimization model to estimate the transition to oil substitutes such as gas-to-liquids, coal-to-liquids, bitumen and kerogen. They relax the "perfect foresight" assumption used in most optimization models of this type (to estimate producers' investments) and find that the transition to alternatives "could be more chaotic." They appropriately quote Pindyck's observation that "producers may not optimize at all [or] that, to the extent that they do optimize, their time horizons may be very limited" (Pindyck [38]).

$84/b in Monterey/Santos [43]. While current oil prices are relatively high,[14] they are not that much higher than what's needed to motivate the large investments needed to grow non-OPEC oil production.[15]

Tverberg [20] considers three scenarios of oil supply growth and their impact on OECD economic growth concluding "we are reaching limits on the amount of oil that the world can extract at a price OECD countries can afford to pay without serious recession." Hallock, *et al* [44] confirm Tverberg's findings using global and national data. Hallock modeled the future growth of conventional oil[16] and concluded that "proclamations of large future increases of conventional oil…are not supported by empirical data" and "if there are to be to be significantly larger quantities of conventional oil produced, then higher oil prices, or technological innovation will have to have a much larger effect in the future than they have had in the last 11 years."

Robelius [45] projects that the production of oil from giant oil fields will peak from 2008 to 2018 (worst and best case scenarios respectively). As defined by Robelius, a giant filed contains 500 mmb of recoverable oil. Only 1% of oil fields are giants but they provided 60% of 2005 production and 65% of total recoverable oil reserves. Large increases of production from other sources will be needed to offset the lost production from giants after they peak. While there are ample sources of petroleum available to make up the loss, the investment required to tap these sources will be motivated by higher, not lower, world oil prices.

10. Will tight oil flood the world oil market?

The U.S. Energy Information Administration's *2014 Annual Energy Outlook Early Release* has again projected higher levels of U.S. tight oil production. The reference case has domestic overall oil production growing through 2020, when total production reaches 9.6 mmb/d. Tight oil production increases to 4.8 mmb/d by 2020, but declines after 2021 [46].[17]

Recent projections of high U.S. tight oil production reflect massive resource estimates and the explosive production growth in North Dakota and Texas that have proven past expectations to be too conservative. Applying the straight line to past production growth, however, could provide a false picture of what can reasonably be expected. Three U.S. plays are responsible for rocketing U.S. production: Bakken, Eagle Ford and the Permian. In comparison, Niobrara and Anadarko have only achieved modest production growth while the prospects for development in the Monterey are poor. Like any major oil field development, initial high production growth does not foretell sustained indefinite growth. For tight oil, the rapidity of change can be even greater. Consider that two-thirds of tight-oil drilling activity is needed to maintain constant tight oil production due to the high decline rates associated with hydraulic fracturing. Inevitably well productivity must also decline as production expands. Despite high Bakken production growth, for example, well productivity there has already declined by 15 percent since 2009Q4 to 2012Q4 (Bernstein & Co. [47]). Likewise, drilling costs cannot continue to decline. Of the 18% well cost deflation since 2011, Bernstein & Co. distinguishes between cyclical deflation, about 15%, and secular deflation, about 3% [47]. This suggests that drilling costs are more likely to rise in the future than decline.

A recent study funded by Advanced Resources International (ARI) and the Energy Information Administration found that only one country, Russia, has technically recoverable tight-oil resources larger than those of the United States [48]. China has slightly more than half of the U.S. resource base, followed in declining order by Argentina, Libya, Australia, Venezuela, Mexico, Pakistan and Canada (at about one-sixth the U.S. resource base). Many of these countries can be excluded as likely tight-oil producers, including Russia, Argentina, Libya, Venezuela and Pakistan, unless their current political and economic regimes undergo fundamental change. ARI's top-10 tight-oil countries include several major oil producing countries (Russia, Libya, Venezuela and Mexico) that could more easily expand conventional oil production, something they would likely do if they didn't have above-ground problems.[18]

As valuable as the ARI estimates are, they provide no information on tight oil production costs in the countries estimated to have significant tight oil resources. There has been very little exploration of tight-oil plays around the world apart from some exploration in Argentina and China (Vaca Muerta and Chinese Jurassic plays respectively). Much more exploration will be needed before an assessment can be made of the geological factors that ultimately govern production cost and feasibility. These include: oil source quality; extent and homogeneity; pay-zone thickness; existence of permeable beds and maturity. However, even a favorable outcome on geology may be insufficient to ensure tight oil production outside of North America. Above-ground constraints may turn out to be the most significant reason the U.S. experience is not replicated elsewhere, at least for many years. These include: political risk; land access; regulatory processes; availability of an E&P service industry; supply chain; water availability and water management. It is difficult to overestimate the importance of two factors that have enabled the development of tight oil and shale gas in the United States: private ownership of mineral rights and huge service sector/logistical resources. Without land access and an E&P industry, especially in countries with a high political risk, significant tight oil production outside of North America is unlikely even if geology proves to be favorable. Maugeri [49] also considers these factors to be important:

> "…there are other factors that will make the global replication of a U.S. shale boom difficult, including an absence of private mineral rights in most countries, as well as the absences of the U.S. independent companies whose guerilla-style operational mindset has proven essential to the exploitation of shale formations that (unlike conventional oil and gas fields) required companies to move on a micro-scale, on multiple micro-objectives, and flexibility, leverage short-term opportunities."

In addition, Maugeri observes that shale oil development depends on low population density and will be more difficult to pursue in more densely populated areas such as the Monterey play in California and face "an insurmountable environmental hurdle in Europe and other parts of the world that have a high population density and no tradition of intensive drilling." Maugeri also emphasizes that U.S. shale oil production could suddenly decline with lower world oil prices:

> "…because shale development occurs on a per-well basis and not an a field basis, as in conventional oil activity, and critically depends on short-term oil prices given that peak productions is achieved during

[14] Since 2011, average oil prices have been significantly higher in real terms than in the last 50 years apart from the 2007—08 oil price spike.

[15] Increased investment is needed just to offset decline rates especially from the largest "super-giant" oil fields. Investment has to surpass this "break-even" level to meet growing demand.

[16] Using "Uppsala-Campbell" definition that requires a gravity higher than 17.5 degrees.

[17] In one year, the EIA increased its projected 2020 tight oil production by 70%. The estimated 2020 tight oil production was 2.8 mmb/d in the *2013 AEO* and grew to 4.8 mmb/d in the *2014 AEO Early Release*.

[18] The above-ground problems vary among these countries but include political instability; risky business environment; limited or no participation by international oil companies; limited competence and/or resources of the national oil company; and insufficient security. Recent reforms in Mexico could reverse the structural decline in Mexican oil production, especially on previously untapped onshore resources. However, the turnaround in Mexican production will take years and will require that domestic content or other requirements don't create large inefficiencies.

the first weeks of a well's activity and the bulk of production is obtained during the first and second year of production." [49]

11. Using strategic oil stocks to protect the world-wide economy against future oil supply disruptions

Strategic oil stocks are the main defense governments have to protect their economies from oil price shocks. Under normal circumstances, government stocks do not increase the short-term elasticity of oil supply since their release depends on government actions that are only taken in response to a serious oil supply interruption. Depending on the volume of internationally held reserves and the rate at which these reserves can be made available to the market, world-wide emergency reserves have the potential to offset lost oil supplies as a result of unplanned supply outages in major oil exporting countries. Ideally, the prompt release of emergency reserves would prevent an economically damaging oil-price spike until exports are restored or alternative sources of supply are secured.

The world economy is less vulnerable to the economic consequences of an unplanned oil supply outage when oil prices are relatively low or OPEC spare capacity is relatively high. Unfortunately, OPEC spare capacity tends to grow when oil prices are falling and declines when oil prices are rising (see Fig. 3). While this relationship is not surprising given the reasons why Saudi Arabia maintains reserve production capacity, nonetheless, it implies that just when the world economy's exposure to the economic damages of an oil supply interruption is greatest, because oil prices are already high, OPEC spare capacity is likely to be low. It is under these circumstances that a strategic petroleum stock release would be most necessary to reduce or prevent an economically-damaging oil price spike.

The IEA treaty requires its Member-countries to hold enough petroleum or petroleum products to replace 90-days worth of their imports. After a declaration of a petroleum supply emergency, an IEA collective action would compel Member countries to release agreed-upon amounts of petroleum or petroleum products from their strategic reserves. The IEA estimated in 2010 that its Member countries could release as much as ~10 mmb/d during the first month following a disruption. This would fall to ~5 mmb/d in the 5th month following a disruption [50]. Information on emergency reserves held by countries outside the IEA is sparse. China may hold as much as 200 million barrels but reliable information is lacking.

As will be discussed below, it is not always easy to determine whether an unplanned oil-supply outage constitutes an oil emergency of sufficient magnitude to justify the release of strategic stocks. In assessing the potential severity of an oil supply outage, primary consideration has to be given to the actual or expected changes to the price of oil for, after all, the price of oil is the vector by which oil supply disruptions cause economic harm. If a strategic reserve can keep the price of oil from spiking, it can avoid the economic harm that would otherwise be caused by the disruption. However, the dividing line between the normal ups and downs of the oil market and a petroleum supply emergency that would repeat past episodes of economic harm is not always easy to draw. If strategic stocks are used in the absence of clearly defined emergency circumstances, they could discourage commercial stock holding and decrease net emergency stocks.

12. Lessons learned from past emergency releases from the U.S. strategic petroleum reserve (SPR)

The U.S. Strategic Petroleum Reserve (SPR) is the largest stockpile of government-owned emergency crude oil in the world. The SPR has a capacity of 727 million barrels and, as of May, 2014, the SPR held 693 million barrels of crude oil. The SPR is comprised of four storage facilities connected to three crude distribution systems: Seaway, Texoma and Capline. The maximum drawdown rate has been estimated to be as high as 4.4 mmb/d with marine capabilities of about 2.5 mmb/d. However, as will be discussed below, changes to the U.S. midstream and commercial activities in the Gulf of Mexico have significantly lowered the maximum drawdown rate of the SPR.

Decisions to withdraw crude oil from the SPR are made by the U.S. President under the authorities of the Energy Policy and Conservation Act (Pub. L. No. 94-163, 1975). There have been three emergency releases of the SPR[19]:

1) On 16 January 1991, during the 1990/91 Gulf War, President George H.W. Bush ordered the first-ever emergency drawdown of the SPR resulting in the sale of 17.3 million barrels of crude. The Iraqi invasion of Kuwait occurred on 2 August 1990 curtailing 7% of world oil production. By mid-October, oil prices had doubled. Within days of the Iraqi invasion of Kuwait, the United States responded by sending U.S. military forces to Saudi Arabia and the Persian Gulf. Operation Desert Storm commenced on 17 January 1991, one day after the emergency oil stock release was announced. The Gulf War was concluded on 28 February with the liberation of Kuwait and the retreat of Iraq occupation forces. In retrospect, the Gulf War release would have been much more effective if it had been announced in early August, 1990, in sufficient volume, to prevent or substantially reduce the doubling of oil prices that occurred within two months. It is conceivable that an earlier release would have mitigated or prevented the recession of 1991. However, in August 1990, it wasn't clear how long the oil market would remain disrupted or whether Saudi Arabian production might be affected. Contemporary objections to an August release of the SPR were: 1) SPR reserves should not be depleted lest they be needed for a longer and larger supply outage; and 2) other OPEC countries should increase production to help replace lost Kuwaiti supplies (Taylor and Van Doren [51]).
2) In 2005, President George W. Bush ordered a release of 11 million barrels of crude from the SPR after Hurricanes Katrina and Rita caused significant damage to the oil production facilities, terminals, pipelines, and refineries along the U.S. Gulf Coast. The release of crude oil replaced supplies lost from crude oil production in the Gulf of Mexico. However, if the SPR system contained petroleum products, in addition to crude oil, it is likely that the subsequent increase of petroleum product prices would have been much smaller as these hurricanes disabled 50% of the refining capacity in the Gulf Coast region, a problem not alleviated by crude oil supplies from the SPR.
3) On June 23, 2011, the IEA agreed to release a total of 60 million barrels of petroleum as a result of protests and civil war that erupted February 15, 2011 (the beginning of the "Arab Spring"). [20] Libya had provided about 1.5 mmb/d of light-sweet crude oil to the world market. Despite the small loss of global oil production (less than 2% of global oil supplies) and 4 mmb/d of spare production capacity [52], Brent prices increased by ~$20/barrel by April 2011 [53]. The June 23 release was timed to help mitigate the negative economic impacts that could result from elevated oil prices as refineries were returning from seasonal maintenance. Brent crude prices fell by $7/barrel on the day the IEA/SPR release was announced. The severe backwardation of Brent was reversed causing Brent and WTI prices to align (in contango). This

[19] These and other SPR releases are discussed in http://energy.gov/fe/services/petroleum-reserves/strategic-petroleum-reserve/releasing-oil-spr

[20] The U.S. share was 30 mm barrels which were successfully sold and dispersed within two months. The European sales achieved less than one-third of their target, often because emergency stock programs that relied on industry mandates failed to put oil into the market when the respective stock-holding requirements on industry were relaxed (Patron and Goldwyn [54]).

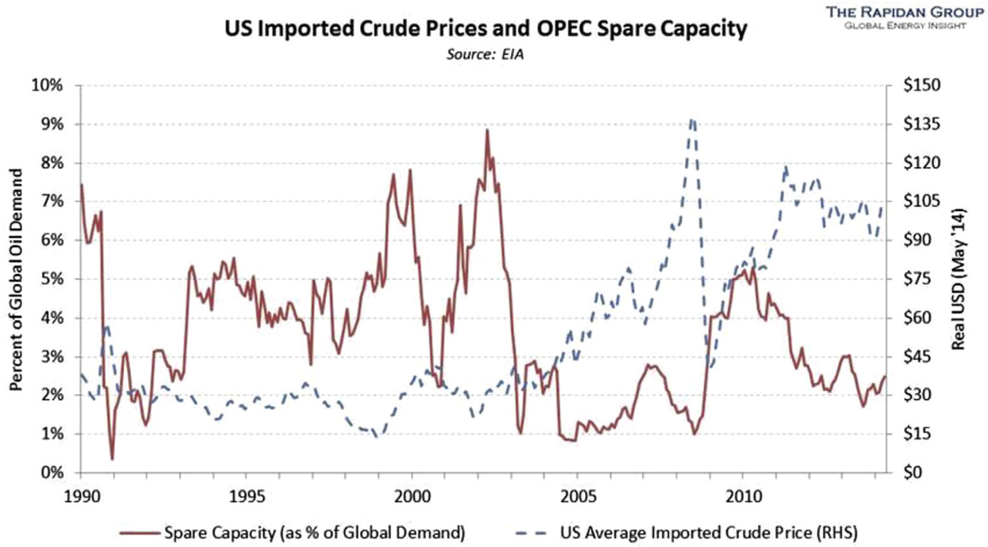

Fig. 3. US Imported Crude Prices and OPEC Spare Capacity. Source: The Rapidan Group; EIA data.

relief was short lived as tightness returned to the Brent market by August. Nonetheless, independent analysts concluded that the release calmed the market preventing a more damaging oil price spike.[21] As with the 1990/1991 Gulf War release, in retrospect, it can be questioned whether the Libyan Collective Action would have been more effective had it been announced in late February 2011 since peak oil prices were reached in April, two months before the IEA/SPR release. However, in February, it wasn't clear whether a loss of 1.5 million barrels/day of exports, even exports of light sweet crude that were important to European refineries, was a serious enough disruption to warrant a stock release. There were also concerns that a stock release would deter an increase of Saudi Arabian production or give markets the impression that surplus production capacity could not replace lost Libyan supplies (Clayton [55]).

The 1991 and 2011 SPR releases illustrate the difficulty in deciding whether and when to release the SPR. They demonstrate four important issues that can delay a quick response to a supply outage: 1) whether the supply disruption is of sufficient magnitude to justify the use of the SPR; 2) whether the SPR should be held in reserve lest the disruption becomes more severe; 3) whether the release of strategic stocks would discourage employment of OPEC spare production capacity; and 4) the time that is required to achieve a consensus by IEA Member countries to undertake a coordinated drawdown. Even critics of the SPR recognize that the potential benefits of the SPR have not been realized because "it has not been used frequently, robustly and quickly enough during the *early* stages of oil price shocks (Taylor and Van Doren [51])." Taylor and Van Doren believe that "there is little reason to believe that the program's dynamics will change in the future." They conclude that the oil in the SPR should be sold and the program shut down. However, the cost-effectiveness of the SPR program could be improved by reforming the decision-making process so SPR stocks would be used quickly enough, in sufficient quantity, to prevent or mitigate future oil-price spikes. Clayton [55] also recognizes that even though the SPR may not be effective in lowering oil prices (they "may have only a modest effect of prices and broader market forces can overwhelm them") it may "be more effective at preventing harmful price spikes." Consequently, tardy use of emergency stocks should be avoided. Also, as Clayton concludes, the threat of an oil stock release must be credible and "mixed signals from energy officials about a possible future release, as in July 2011, can make oil prices even more volatile" (Clayton [55]). Avoiding "mixed signals," or announcing a stock release before prices have spiked, requires that difficult decisions be made before a supply disruption has played out. There has to be a quick consensus on how much the disruption is likely to raise oil prices. Even then, there are "blurry lines," as noted by Jaffe and Soligo [56] before oil prices are high enough to justify a strategic stock release. Nonetheless, as Patron and Goldwyn [54] point out,

> "In many cases, the United States has failed to deploy the reserve despite circumstances that would justify a release. These missed opportunities result in price run-ups that may have been avoidable and uncertainty as to when the U.S. government would release stocks in future crises."

13. Implications of reduced U.S. oil import dependence

It is beyond the scope of this paper to estimate the optimal size of the SPR or world-wide strategic stocks. It is also beyond the scope of this paper to consider different processes for releasing emergency oil reserves. Consequently, the implications of reduced U.S. oil import dependence are discussed in the context of an SPR that is approximately the same size as it is today and is governed by current U.S. law and IEA treaty obligations.[22] Nonetheless, the significant reduction of U.S. oil imports, resulting from declining domestic gasoline consumption and rising domestic oil production, require that we ask: What is the

[21] John Kemp, Reuters, September 19, 2011 and additional assessments by experts at the Baker Institute at Rice University; Ed Morse, head of commodities research at Citigroup; and Olivier Jakob of Petromatrix in Geneva.

[22] Nonetheless it is worth noting that some authors have concluded that the current SPR is far too large to be cost-effective and its oil should be sold off (e.g., Taylor and Van Doren, [51]). Others find that the SPR is too small. For example, Edmunds and Singh [57] suggest that the size of the SPR be significantly increased to give the United States more leverage in the international oil market. Blumstein and Komor [58] suggest, in order to make the use of the SPR more predictable, and to make an SPR release less likely to "heighten tensions in an already tense situation," that the SPR be operated by a chartered corporation that could release SPR reserves without a declaration of an oil supply emergency by the U.S. President.

purpose of a large SPR while U.S. oil imports are declining so rapidly?[23] U.S. IEA stock holding obligations are also falling, in line with our declining oil imports, since the IEA treaty requires that each Member-country hold 90 days of its petroleum imports.

The growth of U.S. and Canadian oil production has also affected the physical ability of the SPR to distribute oil during a supply emergency. Midcontinent refiners are no longer relying on crude petroleum imports shipped from the U.S. Gulf Coast. Instead, oil is flowing by pipeline, rail and barge *to* the U.S. Gulf Coast rather than *from* the Gulf Coast. East Coast refining capacity has also declined by 40% from a September 2005 high of 1.7 mmb/d to less than 1 mmb/d by November 2013 [59]. These changes affect the use of the SPR in two ways: 1) since many U.S. refineries have replaced crude oil that had been provided by foreign tankers with domestic or Canadian crude oil, the number of refineries that would need to secure SPR oil in the event of an international petroleum supply emergency has declined; and 2) the pipelines that the SPR formerly used to provide SPR oil to domestic refineries have been repurposed. Of major significance has been the reversal of the Seaway and Capline pipelines which had formerly been relied on to move SPR crude north but now move midcontinent and Canadian crude south. Flow was also reversed on the Ho-Ho pipeline in order to provide Bakken and Eagle Ford crude oil to U.S. Gulf Coast refineries. In addition, the surge in U.S. product exports has increased product tanker traffic in the Gulf Coast complicating the logistics of loading SPR oil onto barges or tankers. As a result of these developments, the Department of Energy conducted an SPR test sale in March-April, 2014 to help evaluate the capability of the SPR to expeditiously release emergency oil reserves.[24]

As the United States moves towards "energy independence," the *raison d'etre* of the SPR would have to shift from replacing lost U.S. oil imports to U.S. refineries, after an international disruption, to reducing the international price of oil, regardless of which refineries process the oil that would be released from the SPR.[25] As discussed above, oil price spikes cause inter-sectoral and inter-regional disruptions of labor and capital and, as a result, reduce U.S. GDP growth. These disruptions to labor and capital markets are caused by higher petroleum product prices and are not affected by the level of U.S. oil imports. However, if we import less oil, there is a smaller wealth transfer to oil exporting countries as a result of an oil price spike. With higher domestic oil production, more of the money spent on fuels by U.S. consumers stays in the U.S. economy. As higher U.S. oil company profits are recycled through the U.S. economy, through increased upstream oil production, investments and dividends, economic gains are realized. Nonetheless, the initial economic dislocations caused by the oil price spike are not avoided. While higher U.S. oil company revenues may facilitate inter-sectoral and inter-regional relocations of labor and capital, it still takes time for the adjustments to occur. We will still experience lower economic growth during the first to third year after an oil price shock. Since oil prices sharply decline after the fall-off in world GDP growth, the increase in U.S. oil company revenues after an oil price shock may be short-lived, ending well before they have a significant effect on labor and capital market realignment. Consequently, the time required to return to normal-GDP growth after an oil price shock may not be greatly affected by lower U.S. oil imports.

The specter of an energy-independent United States holding the largest emergency petroleum stockpile makes clear, as pointed out by William Hogan, that:

> "despite the combined force of common sense and computer studies, oil-importing governments have not succeeded in building a reserve of oil that matches the apparent threat of insecure supplies. In part this reflects a lack of commitment to the objective, and governments have spent an inordinate amount of effort in trying to convince others to do their stockpiling for them" (Hogan [60]).

If the United States is to accept the burden of maintaining the world's largest emergency reserve, despite declining reliance on oil imports, in order to protect the world economy (and, of course, its own economy) in the event of an oil supply disruption, there should be corresponding efforts by other countries to build emergency stocks, especially the emerging Asian economies that are largely responsible for the growth of world oil demand. As world oil consumption shifts from the OECD to emerging economies[26], oil-importing countries that are now outside the treaty obligations of the IEA should establish emergency oil reserves as their economies are also vulnerable to the economic consequences of a world-wide oil-supply interruption.

14. Conclusions and policy implications

Oil price shocks are invariably followed by 2–3 years of weak economic growth and weak economic growth is almost always preceded by an oil price shock. If we look forward, there is little reason to be complacent about the economic damage that could be caused by future oil price spikes considering the increased instability of Middle Eastern and North African oil suppliers. The investments needed for non-OPEC oil production to keep up with the growth in worldwide demand are challenging and do not appear to be feasible in a low-price environment.

Oil price spikes will remain a threat to world economic growth. Strategic oil reserves can protect the world-wide economy, if sufficiently large releases are promptly announced, by preventing the oil price spikes that would otherwise occur as a result of unplanned supply outages. Governments should streamline procedures for a coordinated release of emergency stocks and recognize the important economic benefits to be had by a prompt and sufficient stock release that would eliminate or substantially reduce oil price shocks. Because of increased U.S. oil production, the repurposing of midstream assets that the SPR had previously relied on and increased U.S. refineries' processing of domestic petroleum, the capability of the SPR to respond to a serious petroleum supply emergency needs to be reassessed.[27] As U.S. oil imports continue to decline, in order to avoid a spike of international oil prices after a serious supply disruption, it may be necessary to increase the capacity of the SPR to deliver oil to the U.S. Gulf Coast, increase tanker loading capacity and sell SPR oil directly to foreign refineries. As the United States is unable to use its SPR to protect its economy without providing similar benefits to the rest of the world, and since global oil consumption is only growing outside of the OECD, the emerging economies, especially in Asia, should develop larger strategic oil stocks. This would not only increase the volume of oil available to respond to an oil supply emergency but aim toward a fair sharing of the oil stocks burden in recognition of their collective world-wide economic benefit.

[23] The EIA 2014 *Annual Energy Outlook* projects that the net percentage of U.S. oil and liquids imports, relative to U.S. consumption, will drop to 25% by 2016 (Reference Case). Their High Oil and Gas Resource Case projects a much sharper decline of U.S. oil imports with net imports steadily declining to zero before 2040.

[24] http://www.spr.doe.gov/doeec/TestSale14/Notice_of_Sale.pdf

[25] U.S. law restricts the export of SPR reserves and most domestically-produced crude oil (Energy Policy and Conservation Act; Pub. L. No. 94-163, 1975). SPR oil may be sold to a foreign refinery if the products produced from that oil are to be returned to the United States. However, U.S. law also provides the President of the United States authority to permit sales of domestically-produced crude oil or SPR reserves to foreign refineries (without re-import requirements) if the President determines that such sales would be in the national interest.

[26] The majority of oil demand has recently shifted from the OECD to the non-OECD. By 2030, China is expected to become the world's largest consumer of petroleum while OECD oil demand is expected to decline [5].

[27] A reassessment has begun with the SPR test sale of March-April, 2014 to help determine the SPR's current distribution capabilities.

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