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Forty Years of Oil Price Fluctuations: Why the Price of Oil May Still Surprise Us

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Abstract: It has been forty years since the oil crisis of 1973/74. This crisis has been one of the defining economic events of the 1970s and has shaped how many economists think about oil price shocks. In recent years, a large literature on the economic determinants of oil price fluctuations has emerged. Drawing on this literature, we first provide an overview of the causes of all major oil price fluctuations between 1973 and 2014. We then discuss why oil price fluctuations remain difficult to predict, despite economists' improved understanding of oil markets. Unexpected oil price fluctuations are commonly referred to as oil price shocks. We document that, in practice, consumers, policymakers, financial market participants and economists may have different oil price expectations, and that, what may be surprising to some, need not be equally surprising to others.

JEL Code: Q43, C53
Key Words: Oil market, oil price shock, heterogeneous price expectations, OPEC, peak oil, unconventional oil.

It has been forty years since the oil crisis in 1973/74, which also coincided with the emergence of a new regime in the global market for crude oil, in which oil prices have been largely free to fluctuate in response to the forces of supply and demand.[1] This crisis arose when the price of imported oil nearly quadrupled over the course of a quarter, forcing substantial adjustments in oil-consuming countries. To make matters worse, some governments in industrialized countries responded by imposing ceilings on the price of domestically produced crude oil and on the price of refined oil products such as gasoline, causing gasoline shortages and long lines at gas stations. In addition, many governments introduced speed limits, banned automobile traffic on Sundays, or limited retail gasoline purchases.[2] Hence, pictures of long lines at gas stations and empty highways have shaped the collective memory of the 1973/74 oil crisis, even though in reality neither phenomenon was an inevitable consequence of the underlying rise in the price of crude oil.

Although sharp oil price increases had occurred at irregular intervals throughout the postwar period, as documented in Hamilton (1983, 1985), none of these increases was comparable in magnitude to the increase in the price of oil in the last quarter of 1973. In fact, prior to 1973 the U.S. price of oil had been regulated by government agencies, resulting in extended periods of constant oil prices, interrupted only by infrequent adjustments, which, as noted by Hamilton tended to coincide with exogenous oil supply disruptions in the Middle East. This policy resulted in occasional sharp spikes in the growth rate of the inflation-adjusted (or real) price of West Texas Intermediate (WTI) crude oil.[3]

The U.S. system of oil price regulation came to an end starting in the early 1970s, when the United States no longer had any spare capacity in domestic oil production to satisfy its

[1] This shift in regimes has been documented in Dvir and Rogoff (2010) and Alquist et al. (2013), among others.
[2] For a review of policies of non-price rationing in oil and gasoline markets see, e.g., Ramey and Vine (2010).
[3] WTI refers to a particular grade of light and sweet crude oil commonly traded in the United States.

growing domestic demand for oil and became increasingly dependent on oil imports from the Middle East, the price of which could not be regulated domestically (see Yergin 1992). When the price of imported crude oil quadrupled in 1973/74, imposing lower ceilings on the price of domestically produced crude oil soon proved impractical. The WTI price rose from $4.31 in September 1973 to $10.11 in January 1974. Although the last vestiges of the regulation of the price of domestic crude oil in the United States persisted until the early 1980s, for all practical purposes, there was a structural break in the time series process governing the WTI price of crude oil in early 1974, with the real price of oil fluctuating in response to supply and demand shocks much like other real industrial commodity prices. It is this modern era of oil markets that our discussion focuses on.

Figure 1 plots the real price of oil (expressed in March 2015 dollars) starting in January 1974. It shows that there have been substantial fluctuations in the real price of oil in recent decades with no obvious long-run trend. The literature has identified a number of potential determinants of oil price fluctuations, including (1) shocks to global crude oil production arising from political events in oil-producing countries, the discovery of new fields and improvements in the technology of extracting crude oil, (2) shocks to the demand for crude oil associated with unexpected changes in the global business cycle, and (3) shocks to the demand for above-ground oil inventories, reflecting shifts in expectations about future shortfalls of supply relative to demand in the global oil market. In this article, we first review the causes of the major oil price fluctuations since 1973/74, episode by episode.

Although economists have made great strides in recent years in understanding the oil price fluctuations in Figure 1 with the benefit of hindsight, some of the variation in the price of oil over the last forty years has been unexpected ex ante. We discuss alternative measures of oil

price expectations employed by central banks, by economists, and by households as well as measures of financial market expectations of the price of oil. Although some oil price expectations measures can be shown to be systematically more accurate than others, all oil price expectations are subject to error. The reason is that, even if we understand the determinants of the price of oil, predicting these determinants can be very difficult in practice. We discuss in the context of concrete examples why it is so difficult to predict the determinants of the price of oil.

The gap between the price of oil that was expected ex ante and its eventual outcome represents an oil price shock. Such surprise changes in the price of oil have been considered important in modelling macroeconomic outcomes in particular. We demonstrate how much the timing and magnitude of oil price shocks may change with the definition of the oil price expectations measure. We make the case that the oil price expectations measure required for understanding economic decisions need not be the most accurate measure in a statistical sense, and we illustrate that the same change in oil prices may be perceived quite differently by households, policymakers, financial markets, and economists, depending on how they form expectations. This insight has potentially important implications for understanding and modelling the transmission of oil price shocks.

Historical Episodes of Major Fluctuations in the Real Price of Oil

The literature on the causes of oil price fluctuations has evolved substantially since the early 1980s. Initially, all major oil price fluctuations were thought to reflect disruptions of the flow of global oil production associated with exogenous political events such as wars and revolutions in OPEC member countries (e.g., Hamilton 2003).[4] Subsequent research has shown that this explanation is only one among many, and not as important as originally thought. In fact, most

[4] OPEC refers to Organization of Petroleum Exporting Countries, which was founded in 1960.

major oil price fluctuations dating back to 1973 are largely explained by shifts in the demand for crude oil (see, e.g., Barsky and Kilian 2002, 2004; Kilian 2009a; Kilian and Murphy 2012, 2014; Bodenstein et al. 2012; Lippi and Nobili 2012; Baumeister and Peersman 2013; Kilian and Hicks 2013; Kilian and Lee 2014).[5] By far the most important determinant of the demand for oil has been shifts in the flow (or consumption) demand for oil associated with the global business cycle. As the global economy expands, so does demand for industrial raw materials including crude oil, putting upward pressure on the price of oil. At times there also have been important shifts in the demand for stocks (or inventories) of crude oil, reflecting changes to oil price expectations. Such purchases are not made because the oil is needed immediately in the production of refined products such as gasoline or heating oil, but to guard against future shortages in the oil market. Historically, inventory demand has been high in times of geopolitical tension in the Middle East, low spare capacity in oil production, and strong expected global economic growth.

The 1973/74 Oil Crisis

At first sight the oil price shock of 1973/74 has the appearance of a negative shock to the supply of crude oil in that the quantity of crude oil produced fell in the last quarter of 1973 and the price of oil increased, consistent with a shift of the supply curve to the left along the demand curve. Indeed, this is the traditional explanation for this oil price increase advanced by Hamilton (2003). It is common to refer to the war between Israel and a coalition of Arab countries that took place between October 6 and 26 of 1973 as the cause of this supply shock. This explanation may conjure up images of burning oil fields, but actually there was no fighting in any of the Arab oil-

[5] In related work, Carter, Rausser and Smith (2011) conclude that similar results hold for commodity prices more generally, noting that commodity price booms over the last four decades have been preceded by unusually high economic growth.

producing countries in 1973, and no oil production facilities were destroyed. Instead this war took place in Israel, Egypt and Syria. None of these countries was a major oil producer or a member of OPEC for that matter. Thus, the disruption of the flow of oil production that took place in the last quarter of 1973 was not caused by the war. Rather Arab OPEC countries deliberately cut their oil production by 5% starting on October 16, 1973, ten days into Arab-Israeli War, while raising the posted price of their oil, followed by the announcement of an additional 25% production cut on November 5, ten days after the war had ended.

Hamilton (2003) attributes the Arab oil production cuts in October and November entirely to the Arab oil embargo against selected Western countries, which lasted from October 1973 to March 1974, interpreting this oil embargo as an extension of the military conflict by other means rather than an endogenous response to economic conditions. There is, however, an alternative interpretation of the same data that does not rely on the war as an explanation. Barsky and Kilian (2002) draw attention to the fact that in early 1973 the price of crude oil received by Middle Eastern oil producers was effectively fixed as a result of the 1971 Tehran/Tripoli agreements. These five-year agreements set the price of oil received by the host government for each barrel of oil extracted in exchange for assurances that the government would allow foreign oil companies to extract as much oil as they saw fit (see Seymour, 1980, p. 80). When global demand for oil accelerated in 1972/73, reflecting a worldwide economic boom, many Middle Eastern countries were operating close to capacity already and unable to increase oil output; whereas others, notably Saudi Arabia and Kuwait, had the spare capacity to increase their output, and allowed their oil production to be increased, albeit reluctantly. This reluctance can be attributed to the fact that the posted price agreed upon in 1971 might have been reasonable at the time, but was quickly eroded in real terms as a result of a depreciating dollar and rising U.S.

inflation. This development caused increasing Arab opposition to the Tehran/Tripoli agreements that intensified in March of 1973 and culminated in the repudiation of the agreements on October 10, 1973, with oil producers deciding to produce less oil at higher prices.

This reaction makes perfect economic sense even in the absence of any monopoly power by oil producers. Under this interpretation, a substantial fraction of the observed decline in Arab oil output in late 1973 was simply a reversal of an unusual increase in Saudi and Kuwaiti oil production earlier that year in fulfillment of the Tehran/Tripoli agreements. Moreover, the decision to reduce oil production and the objective of raising the oil price was clearly motivated by the cumulative effects of the dollar devaluation, unanticipated U.S. inflation, and high demand for oil fueled by strong economic growth, making this oil price increase endogenous with respect to global macroeconomic conditions.[6]

There is, of course, no reason to expect the price of oil charged by Arab oil producers as of January 1974 to be the equilibrium price necessarily. This price was set on the basis of negotiations among oil producers, not by the market. There is evidence, however, that the negotiated price was in fact close to the equilibrium value. A good indication of the shadow price of crude oil is provided by the steady increase in commonly used indices of non-oil industrial commodity prices between November 1971 and February 1974. In the absence of contractual constraints, one would have expected the price of oil to grow at a similar rate in response to increased global demand. Kilian (2009b) shows that non-oil industrial commodity prices over this period increased by 75% as much as the price of crude oil (with some individual commodity prices quadrupling, not unlike the price of oil), suggesting that at most 25% of the oil price

[6] A detailed analysis in Kilian (2008a) shows that the observed changes in the price of oil and in the quantity of oil produced in the Middle East over the course of the year 1973 is consistent with this interpretation. Notably, only Kuwait and Saudi Arabia reduced their oil output in October 1973 and only to the extent required to return to normal levels of oil production, suggesting that the war was immaterial as a motive for the October production cut.

increase of 1973/74 was caused by exogenous oil supply shocks. This evidence suggests that much of the oil crisis of 1973/74 actually was driven by increased demand for oil rather than reductions in oil supply. This conclusion is also consistent with the predictions of regressions of changes in the price of oil on direct measures of exogenous OPEC oil supply shocks (see Kilian 2008a). These regressions suggest that it is difficult to explain more than 25% of the 1973 oil price increase based on exogenous OPEC supply shocks.

The 1979/80 Oil Crises

The oil crisis of 1973/74 was followed by a second major oil crisis in 1979/80, when the WTI price rose from less than $15 in September 1978 to almost $40 in April 1980. As in 1973/74 governments responded to rising oil prices by rationing gasoline and enforcing price controls, causing the recurrence of long lines at gas stations. The traditional view expressed in Hamilton (2003) has been that this surge in the price of oil was caused by the reduction in Iranian oil production following the Iranian Revolution. As noted in Barsky and Kilian (2002), the timing of events casts doubt on this interpretation. The Iranian Revolution started gradually in late 1978, culminating in the departure of the Shah in January 1979 and the arrival of Ayatollah Khomeini in February 1979. The biggest Iranian production shortfalls occurred in January and February 1979. Iranian oil production resumed in March, but at a reduced pace. Given increased oil production in Saudi Arabia in direct response to the Iranian Revolution, the shortfall of OPEC oil output in January 1979 was 8% relative to September 1978. By April, the shortfall of OPEC output was 0%. The price of oil did not increase substantially before May 1979. Even in April 1979, the WTI oil price was still under $16 (up about one dollar from $14.85 prior to the Iranian Revolution), yet within a year the WTI price would reach a peak level of $40 in April 1980. The same pattern is also found in oil price series not regulated by the government such as the U.S.

refiners' acquisition cost of crude oil imports. It is not clear why the effect of an oil supply shock on the price of oil would be delayed for so long. Thus, the timing of this oil supply shock makes it an unlikely candidate for explaining the 1979 oil price increase.

As stressed in Kilian and Murphy (2014), this does not mean that the Iranian Revolution did not matter for the price of oil, but that it mattered because it affected oil price expectations rather than because it affected the flow of oil production. Empirical oil market models that allow for both oil demand and oil supply shocks to affect the price of oil confirm that oil supply shocks played a minor role for the 1979 oil price increase, but suggest that about one third of the cumulative price increase was associated with increased inventory demand in anticipation of future oil shortages, presumably reflecting geopolitical tensions between the U.S. and Iran and between Iran and its neighbors, but also expectations of high future demand for oil from a booming global economy. This evidence of rising inventory demand starting in May 1979 is also consistent with anecdotal evidence from oil market participants (see, e.g., Yergin 1992). The remaining two thirds of the cumulative oil price increase in 1979 are explained by the cumulative effects of flow demand shocks triggered by an unexpectedly strong global economy, not unlike during the first oil crisis (see, e.g., Kilian 2009a; Kilian and Murphy 2014).

The 1980s and 1990s

Hamilton (2003) also identifies a large exogenous oil supply disruption associated with the outbreak of the Iran-Iraq War which lasted from 1980 until 1988. In late September 1980, Iraq invaded Iran, causing the destruction of Iranian oil facilities and disrupting oil exports from both Iran and Iraq. This event was followed by an increase in the WTI price of oil from $36 in September to $38 in January 1981, which by all accounts must be attributed to this oil supply disruption. This episode is instructive because it represents an example of an oil supply shock

occurring in the absence of major shifts in oil demand. There is little evidence of this shock triggering a large price response, consistent with more formal estimates from structural oil market models.

The early 1980s in fact saw a systematic decline in the price of oil from its peak in April 1980. One reason was the shift in global monetary policy regimes toward a more contractionary stance led by Paul Volcker's decision to raise U.S. interest rates. The resulting global recession lowered the demand for oil and hence the price of oil. This decline was further amplified by efforts to reduce the use of oil in industrialized countries. In addition, declining prospects of future economic growth in conjunction with higher interest rates made it less attractive to hold stocks of oil, causing a sell-off of the oil inventories accumulated in 1979. Finally, one of the legacies of the first oil crisis had been that numerous non-OPEC countries including Mexico, Norway, and the United Kingdom responded to persistently high oil prices by becoming oil producers themselves or by expanding their existing oil production. Given the considerable lag between exploration and production, it was only in the early 1980s, that this supply response to earlier oil price increases became quantitatively important. OPEC's market share fell from 53% in 1973 to 43% in 1980 and 28% in 1985. The increase in non-OPEC oil production put further downward pressure on the price of oil.

OPEC attempted to counteract this price decline. Indeed, this is the first time in its history (and the only time) that OPEC took a proactive role in trying to influence the price of oil (also see Almoguera et al. 2011).[7] When OPEC agreements to jointly restrict oil production in an effort to prop up the price of oil proved ineffective, with many OPEC members cheating on

[7] The literature has not been kind to the view that OPEC since 1973 has acted as a cartel that sets the price of oil or that controls the price of oil by coordinating oil production among OPEC members. For example, Alhajji and Huettner (2000) stress that OPEC does not fit the theory of cartels. Smith (2005) finds that there is no conclusive

OPEC agreements, as predicted by the economic theory of cartels (see, e.g., Green and Porter 1984), Saudi Arabia decided to stabilize the price oil on its own by reducing Saudi oil production.[8] As Figure 1 shows, this approach did not succeed. The price of oil continued to fall in the early 1980s, albeit at a slower pace. The resulting losses in Saudi oil revenue proved so large that by the end of 1985 Saudi Arabia was forced to reverse its policy of restricting oil production. The result was a sharp fall in the price of oil in 1986, caused not only by the resumption of Saudi oil production, but more importantly by a reduction in inventory demand for oil, given that OPEC had shown itself to be unable to sustain a higher price of oil (see, e.g., Kilian and Murphy 2014).

Given the abundance of crude oil supplies in the world relative to oil demand, the ongoing Iran-Iraq War had little effect on the price of oil in the 1980s, notwithstanding considerable damage to oil shipping in the Persian Gulf with as many as 30 attacks on oil tankers in a given month. It took the invasion of Kuwait in August of 1990 (followed by the Persian Gulf War which was directed at ejecting Saddam Hussein from Kuwait) to generate a sharp increase in the price of oil. The disruption in Iraqi and Kuwaiti oil production associated with this war played an important role in causing this spike in the price of oil, but an equally important determinant was higher demand for oil inventories in anticipation of a possible attack on Saudi oil fields (see Kilian and Murphy 2014). Only in late 1990, when the coalition led by the United States had moved enough troops to Saudi Arabia to forestall an invasion of Saudi Arabia, these fears subsided and the price of oil fell sharply along with inventory demand. Without this expectational element it would be difficult to explain the quick return to lower oil prices in 1991, given that oil production from Kuwait and Iraq was slow to recover (see Kilian 2008a).

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evidence of OPEC acting as a cartel. Cairns and Calfucura (2012) conclude that OPEC has never been a functioning cartel. For further discussion also see Almoguera et al. (2011), and Colgan (2014).

[8] For a detailed discussion of how these policies were implemented see Skeet (1988).

In the late 1990s, the price of oil weakened further. By December 1998 the WTI price of oil reached an all-time low in recent history of $11, when only two years earlier oil had been trading at $25. This slide was largely associated with reduced demand for crude oil, arguably caused by the Asian Financial Crisis of mid-1997 which in turn triggered economic crises in other countries including Russia, Brazil, and Argentina. The recovery in the price of oil starting in 1999 reflected a combination of factors including higher demand for oil from a recovering global economy, some cuts in oil production, and increased inventory demand in anticipation of tightening oil markets (see Kilian and Murphy 2014).

This recovery was followed by two major exogenous oil supply disruptions in late 2002 and early 2003 that in combination rivalled the magnitude of the oil supply disruptions of the 1970s (see Kilian 2008a). One was a sharp drop in Venezuelan oil production caused by civil unrest in Venezuela; the other was the disruption of oil production associated with the 2003 Iraq War. The production shortfalls in Iraq and Venezuela were largely offset by increased oil production elsewhere, however. Moreover, compared with 1990, there was less concern that this war would affect oil fields in Saudi Arabia, especially after the U.S.-led ground offensive proved successful with missile attacks being the main threat at the beginning of the war. As a result, there was only a modest shift in inventory demand. Indeed, this oil supply shock episode is remarkable mainly because the price of oil proved resilient to geopolitical events. The price of oil only briefly spiked, adding an extra $6 approximately to the price of oil.

From the Great Surge of 2003-08 to the Global Financial Crisis

The most remarkable surge in the price of oil since 1979 occurred between mid-2003 and mid-2008 with the WTI price climbing from $28 to $134. There is widespread agreement that this price surge was not caused by oil supply disruptions, but by a series of individually small

increases in the demand for crude oil over the course of several years. Kilian (2008b), Hamilton (2009), and Kilian and Hicks (2013), among others, have made the case that these demand shifts were associated with an unexpected expansion of the global economy driven by strong additional demand for oil from emerging Asia in particular. Because oil producers were unable to satisfy this additional demand, the price of oil had to increase. This view is consistent with estimates from empirical models of the global oil market, which attribute the bulk of the cumulative increase in the price of oil to flow demand shocks (see Kilian 2009a; Baumeister and Peersman 2013; Kilian and Murphy 2014). Only in the first months of 2008 is there any evidence of increased inventory demand (see Kilian and Lee 2014).

An alternative view among some observers has been that this surge in the price of oil in the physical market is unprecedented and can only be explained as the result of speculative positions taken by financial traders in the oil futures market. This literature has been reviewed in depth in Fattouh et al. (2013). There is no persuasive evidence in support of this financial speculation hypothesis, which in fact is at odds with estimates of standard economic models of markets for storable commodities (see, e.g., Alquist and Kilian 2010; Kilian and Murphy 2014; Knittel and Pindyck 2015).

The financial crisis of 2008 illustrates the powerful effects of a sharp drop in the demand for industrial commodities on the price of these commodities. As orders for industrial commodities worldwide were sharply curtailed in the second half of 2008 in anticipation of a major global recession, if not depression, the demand for commodities such as crude oil plummeted, causing a fall in the price of oil from $134 in June 2008 to $39 in February 2009. It is noteworthy that shifts in the demand for industrial commodities such as crude oil may have much larger amplitude than the corresponding changes in global real GDP because global real

GDP consists to a large extent of consumption, which remained much more stable during the crisis. When it became clear in 2009 that the collapse of the global financial system was not imminent, the demand for oil recovered to levels prevailing in 2007, and the WTI price of oil stabilized near $100.

There have been a number of smaller demand and supply shocks in the oil market between 2010 and early 2014. For example, events such as the Libyan uprising in 2011 were associated with an increase in the price of oil. Kilian and Lee (2014) estimate that the Libyan crisis caused an oil price increase of somewhere between $3 and $13, depending on the model specification. Likewise, tensions with Iran in 2012 account for an increase of between $0 and $9. An additional development since 2011 has been a widening of the spread between the WTI and Brent prices, with WTI oil trading at a discount, reflecting a local glut of light sweet crude oil in the central United States driven by increased U.S. shale oil production (see Kilian 2014a). As a result, the WTI price of crude oil is no longer representative for the price of oil in global markets, and it has become common to use the price of Brent crude oil as a proxy for the world price in recent years.

Following a long period or relative stability, between June 2014 and January 2015, the Brent price of oil fell from $112 to $47, providing yet another example of a sharp decline in the price of oil, not unlike those in 1986 and 2008. Baumeister and Kilian (2015a) provide the first quantitative analysis of the $49 drop in the Brent price between June and December 2014. They conclude that about $11 of this decline was associated with a decline in global real economic activity that was predictable as of June 2014 and reflected in other industrial commodity prices as well. An additional decline in the Brent price of $16 was predictable as of June 2014 on the basis of shocks to actual and expected oil production that took place prior to July 2014. These

shocks likely reflected the unexpected growth of U.S. shale oil production, but also increased oil production in other countries including Canada and Russia. The remaining decline of $22 in the Brent price is explained by two shocks taking place in the second half of 2014. One is a $9 decline explained by a shock to the storage demand for oil in July 2014; a further $13 decline is explained by an unexpected weakening of the global economy in December 2014.

How to Measure Oil Price Expectations

Although economists have made great strides in recent years in understanding historical oil price fluctuations with the benefit of hindsight, as illustrated in the preceding section, some of the variation in the price of oil over the last forty years has been unexpected ex ante. The extent to which oil price fluctuations are unexpected depends on how expectations are formed. Below we introduce four alternative measures of oil price expectations that may be viewed as representative for the oil price expectations of economists, policymakers, financial market participants, and consumers, respectively.

Economists' Oil Price Expectations

One common approach to constructing oil price expectations is to relate the price of oil to its own past values as well as past values of other key determinants of the price of oil suggested by economic theory (see, e.g., Alquist et al. 2013). This is the central idea underlying vector autoregressive (VAR) models of the global oil market (see, e.g., Kilian 2008b, 2009a; Baumeister and Peersman 2013). In our empirical analysis we employ a VAR model specification in the tradition of Kilian and Murphy (2014) that includes the real price of oil, global crude oil production, global real economic activity, and changes in global crude oil stocks. We refer to the implied expectation of the price of oil as the economists' expectation.

Policymakers' Oil Price Expectations

Of course, oil price expectations based on regression models need not be representative for the views held by financial market participants or by firms and households in the economy. One possibility is that financial market participants have more information than can be captured by econometric models. It is equally possible for financial market participants to ignore, misinterpret, or miss information captured by model-based oil price predictions, especially if that information is costly to obtain. A natural source of information about the market expectation of the price of oil is the price of oil futures contracts. Futures contracts are financial instruments that allow traders to lock in today a price at which to buy or sell a fixed quantity of crude oil at a predetermined date in the future. The most common approach to inferring the expected price of oil for immediate delivery in the physical market (also known as the spot price) has been to treat the price of the oil futures contract of maturity h as the h-period market expectation of the nominal price of crude oil. This is, for example, how the International Monetary Fund forms oil price expectations, and this has been common practice at many central banks in the world, as discussed in Alquist et al. (2013), which is why we refer to this approach as the policymakers' oil price expectation. If today's price of a futures contract expiring a year from now is $50, for example, then the expectation of the spot price of oil one year from now is $50.

Financial Market Oil Price Expectations

The use of futures prices as measures of market expectations, however, is valid only if the risk premium, defined as the compensation arbitrageurs receive for assuming the price risk faced by hedgers in the oil futures market, is negligible. This assumption is questionable. Hamilton and Wu (2014) document that there is a large horizon-specific time-varying risk premium in the oil futures market. This risk premium varies with the hedging demands of oil producers and refiners

and the willingness of financial investors to take the other side of hedging contracts. The oil price expectation may be recovered by subtracting the Hamilton-Wu estimates of the risk premium from the oil futures price for a given horizon. This specification has been shown to produce the most reliable oil price expectations measure overall in a comparison of alternative risk premium estimates (see Baumeister and Kilian 2014a). We refer to the latter expectation as the financial market expectation of the price of oil.

The policymaker's expectation based on the oil futures price and the financial market expectation proposed in Baumeister and Kilian (2014a) differ not only quantitatively, but also qualitatively. For expository purposes our discussion focuses on expectations of the WTI price of crude oil; analogous results could also be constructed for the Brent price. We consider horizons of up to six months. The sample period starts in January 1988 and extends to the end of 2014. Figure 2 treats the current oil futures price with a maturity of h months as the expectation for the spot price of oil in h months. In contrast, Figure 3 plots the corresponding financial market expectation of the price of oil obtained by subtracting from the current WTI futures price of maturity h the risk premium estimate for horizon h implied by the term structure model of Hamilton and Wu (2014).

Figures 2 and 3 illustrate that adjusting the futures price for the risk premium may matter a lot in measuring oil price expectations. For example, at the peak of the oil price in mid-2008 and in the subsequent months the term structure of futures prices in Figure 2 slopes upwards, seemingly implying expectations of rising oil prices, whereas the risk-adjusted futures prices in Figure 3 indicates expectations of sharply falling oil prices. Only after the spot price of oil fell below about $85 in late 2008 in Figure 3, participants in the futures market expected the price of oil to recover. Similar patterns can also be found around the smaller oil price peaks of 2011 and

2012.

Another important difference is that during the long surge in the spot price between 2003 and early 2008, the futures curve in Figure 2 mostly suggests expectations of falling WTI oil prices, whereas the risk-adjusted futures curve in Figure 3 often indicates much more plausible expectations of rising oil prices. Only when the spot price surpassed about $100, the risk-adjusted futures price became more bearish than the unadjusted futures price. Finally, following the invasion of Kuwait in 1990, the unadjusted futures curve in Figure 2 suggests expectations of much more rapidly falling oil prices than the risk-adjusted futures curve in Figure 3.

Consumers' Oil Price Expectations

Yet another approach to measuring oil price expectations is to focus more directly on the expectations of firms or households. There are no survey data on the oil price expectations of U.S. households or U.S. manufacturing firms (or of oil companies, for that matter); but recent research by Anderson et al. (2011) has shown that households in the *Michigan Survey of Consumers* typically form expectations about the real (or inflation-adjusted) price of gasoline according to a simple no-change model such that the nominal gasoline price is expected to grow at the rate of inflation. Given that the price of gasoline is primarily determined by the price of crude oil, a reasonable conclusion is that consumers forecast the real and nominal prices of crude oil along much the same lines, allowing us to proxy consumer expectations about the nominal price of oil based on the current price of oil and an inflation forecast. Because the inflation expectations data in the *Michigan Survey of Consumers* is limited to selected horizons, in practice, we rely on the fixed coefficient gap model inflation forecast proposed in Faust and Wright (2013). Given that the inflation component in oil price forecasts is small at short horizons, as shown in Alquist et al. (2013), the difference is likely to be negligible.

The use of such simple prediction rules makes perfect economic sense when consumers do not have access to more sophisticated oil price forecasts. After all, consumers cannot be expected to have the time and resources to become experts in oil price forecasting or to make sense of the range of competing oil price forecasts produced by experts. Indeed, a good case can be made that in thinking about and in modelling households' purchase decisions, it is households' own oil price expectations that matter even if those expectations are not as accurate as some alternative model-based forms of oil price expectations. We refer to this simple rule of thumb as the consumer oil price expectation.

What Is an Oil Price Shock?

The unanticipated or surprise component of a change in the price of oil is referred to as an oil price shock. By comparing oil price expectations to subsequent outcomes, we may obtain a direct measure of the magnitude of the oil price shock. Clearly, whether an oil price shock occurred, and how large this shock was, depends on which measure of the oil price expectations we use. This question has not received much attention to date. Below we compare (1) the oil price shocks perceived by financial markets, based on the oil price expectations shown in Figure 3, (2) the oil price shocks perceived by policymakers, as shown in Figure 2, (3) oil price shocks perceived by consumers employing a simple rule of thumb for predicting oil prices, and (4) oil price shocks as measured by economists employing oil market VAR models. For expository purposes, we again focus on the nominal WTI price of oil.

Figure 4 shows all four measures of oil price shocks of interest for five specific episodes, starting in 1988.II, namely the invasion of Kuwait in 1990, the Asian Crisis of 1997, the 2001/02 oil price slump, the financial crisis in 2008, and the 2014/15 oil price decline. In each of these episodes, the oil price shocks implied by the VAR model are smaller on average than those

implied by any of the other three expectations measure, but the differences are most pronounced in the last two episodes. For example, following the global financial crisis, in the last quarter of 2008, the consumer oil price shock was -79%, and the policymaker oil price shock was -77%, compared with only -73% based on financial market expectations, suggesting that financial markets were able to anticipate the oil price decline in the fourth quarter somewhat more accurately than consumers and policymakers. Even more striking is the fact that the VAR oil market model predicted a much larger decline in oil prices than financial markets did, reducing the oil price shock in the fourth quarter to only -45%.

Similarly, neither consumers nor policymakers or financial markets anticipated the 2014/15 oil price drop, which was reflected in large negative oil price shocks of between -7% and -9% in the third quarter of 2014, between -26% and -28% in the fourth quarter of 2014, and between -22% and -26% in the first quarter of 2015. Again, this decline was predicted to a considerable extent by the VAR model, which implies much smaller model-based oil price shocks of -2% for 2014.III, of -10% for 2014.IV, and of -18% for 2015.I.

Figure 4 illustrates that it can make a difference whether we take the consumer's perspective, the policymaker's perspective, the financial market perspective, or the economist's perspective in measuring oil price shocks. The extent of the differences differs by episode. Overall, oil price shocks are largest from the consumer's perspective, somewhat smaller from the financial market perspective and smallest when viewed through the lens of the VAR model of the oil market. In fact, policymakers' oil price expectations often are close to consumers' expectations. This finding is interesting because it suggests that heterogeneity in oil price expectations and hence in oil price shocks across economic agents may matter for the transmission of oil price shocks, a possibility that has not been considered in existing research.

Figure 4 also illustrates another important point, which is that that it does not take large positive oil price shocks to generate a sustained increase in the price of oil. The most persistent surge in the price of oil in modern history occurred between 2003 and mid-2008, as illustrated in Figure 1, yet none of the positive oil price shocks between 2003.II and 2008.I exceeded one standard deviation of the oil price shock series.

Why Is It So Difficult to Anticipate Oil Price Fluctuations?

Although it may seem that economists, policymakers, or financial market participants should be able to form accurate expectations about the future price of oil, if they actually understand the determinants of past oil price fluctuations, Figure 4 illustrates that this is not necessarily the case. The reason is that the price of oil will only be as predictable as its determinants, even if economic models of the global oil market are approximately correct. Unless we can foresee the future evolution of these determinants, surprise changes in the price of oil driven by unexpected shifts in oil demand or oil supply will be inevitable. This problem arises whether we formally model the key determinants of the price of oil, as in oil market VAR models, or whether we rely on an intuitive understanding of oil markets as financial market participants are prone to.

The Role of Unexpected Demand Shifts Associated with the Global Business Cycle

Economic models of oil markets imply that the price of oil all else equal depends on the state of the global economy. This fact does not make forming oil price expectations any easier, however, because in practice these expectations can be only as accurate as our predictions of the evolution of the global business cycle. The problem is that changes in global real economic activity can be predicted at best at short horizons and even then only imprecisely. For example, empirical studies have documented that the predictive accuracy of vector autoregressive models of the global oil market improves during times of persistent and hence predictable economic

expansions or contractions, but is greatly reduced during normal times (see Baumeister and Kilian 2012, 2015b).

Just how difficult the task of forecasting the state of the global economy is, is illustrated by the oil market data since 2003. It is now widely accepted that the surge in the price of oil starting in 2003 was caused primarily by increased demand for crude oil from emerging Asia and notably China, as these countries industrialized on a large scale, yet Kilian and Hicks (2013) document that professional real GDP forecasters systematically underestimated the extent of Chinese growth time and again for a period lasting five years. This example shows that not only econometric models, but also professional forecasters have limited ability to predict the state of the global economy. One of the difficulties in assessing the prospects for the Chinese economy even today is that we do not know to what extent Chinese growth after 2003 reflected a permanent structural transformation of the economy and to what extent it was fueled by expansionary macroeconomic policies that are not sustainable. Another challenge is the lack of reliable and timely data for the Chinese economy.

The Role of Unexpected Shifts in Global Oil Production

Another key determinant of the price of oil is global oil production. There will always be oil supply disruptions due to political events in oil-producing countries that are largely unpredictable. A case in point is the disruption of oil production caused by the Libyan uprising in 2011 and the subsequent civil war in Libya. Similarly, the task of predicting Iraqi oil production is complicated by the activities of ISIS and by sectarian violence, neither of which are easily predictable.

It is not just unexpected disruptions of oil production we need to be concerned with, however. An even more important task is to gauge the response of global oil production to surges

in the price of oil driven by increased demand for crude oil. For example, the unprecedented 1973/74 oil price increase was followed by an equally unprecedented search for new oil fields, which resulted in substantial increases in non-OPEC oil production in the early 1980s. It was by no means clear in the 1970s how successful this search for more oil would be and how long it would take to succeed. Hence, it is not unreasonable to view the oil production increases of the early 1980s as unexpected oil supply increases or oil supply shocks from the point of view of oil market participants.

A very similar situation arose as the result of the demand-driven oil price surge between 2003 and mid-2008. Indeed, there was no shortage of skeptics who doubted the ability of oil producers to satisfy increased demand even in the long run. A case in point was proponents of the peak oil hypothesis who insisted that global oil production had permanently peaked by 2007 or that the peak was imminent, as discussed earlier.[9] For example, an IMF study by Benes et al. (2015), using data up to 2009, predicted a near doubling of the price of oil over the coming decade based on the view that geological constraints would win out over technological improvements in conserving oil use and in oil extraction.

There is little doubt that the peak oil hypothesis, taken literally, cannot be right because it ignores the fact that at higher oil price levels more oil production will be forthcoming, as more expensive extraction technologies become profitable. For example, deep sea oil drilling becomes profitable only at sufficiently high oil prices. Yet, this hypothesis also contains a grain of truth in that as of 2008 no one would have known for sure whether future oil production would be sufficient to meet demand at current prices. Even granting that such a supply response did occur

[9] The peak oil hypothesis originates with Hubbard (1956) and postulates a bell-shaped curve intended to describe the rate at which crude oil is extracted over time. Once the peak of this curve has been reached, the rate of oil production will decline permanently. This curve may be estimated from past oil production data. For an economic perspective on the peak oil debate see Holland (2008, 2013).

following the 1973/74 oil price surge with a delay of five years or more, the obvious question in 2008, as in any similar situation, was whether this time would be different. Nothing in past experience guaranteed as of 2008 that the oil supply response would be adequate going forward or that it would occur in a timely manner. For example, the rapid growth of U.S. shale oil production after 2008, which was facilitated in important part by technological innovations in oil drilling, was a surprise to many analysts.

Looking back at this episode, we now know with the benefit of hindsight that the market for oil worked once again. As in the 1970s, it took about five years from the peak in the price of oil for the market to experience substantial increases in oil production on a global scale. This does not mean that increased scarcity will not become a reality in the long run. In this regard, Hamilton (2013) documented that historically higher oil production usually reflected the development of oil fields in new locations rather than increased efficiency in oil production. The current U.S. shale oil boom, which is driven by improved technology for horizontal drilling and fracking, is a counterexample. This boom is unlikely to last forever, however, even granting that efficiency in shale oil production gains may extend the length of the boom (see Kilian 2014a).

The real question thus is whether demand for oil will diminish when the price of oil ultimately rises, as firms and consumers substitute alternative fuels for oil products in the transportation sector, for example. If they do, the peak oil hypothesis will become irrelevant. Indeed, no one today is concerned about the world running out of coal, yet the "Coal Question" raised by Jevons (1866) is eerily reminiscent of the peak oil hypothesis of 2007. Jevons stressed that British coal reserves were finite and would be exhausted by the 1960s, if coal consumption were to grow at the same rate as the population. His predictions proved inaccurate because coal, which at the time was the primary fuel, was replaced by oil starting in the 1920s and by other

fuels in the 1970s. The question is whether in the very long run renewable energies will do the same to oil products.

The Role of Unexpected Shifts in Inventory Demand

A third difficulty in forming oil price expectations is unanticipated changes in perceptions about the future scarcity of oil that affect future demand for oil inventories. Such perceptions may evolve rapidly, for example, in response to geopolitical or economic crises. Thus, expectations of the price of oil that are perfectly reasonable ex ante may easily be rendered obsolete by unforeseen political or economic events. In fact, oil prices may change merely in response to a shift in uncertainty, reflecting precautionary demand (see, e.g., Adelman 1993; Pindyck 2004; Kilian 2009a; Alquist and Kilian 2010).

Obviously, predicting the exact timing of specific political crises and their impact on oil markets is next to impossible, even if political analysts have no trouble identifying geopolitical hotspots. The Arab Spring is a case in point. Likewise, the timing of economic crises is difficult to anticipate. An example is the financial crisis of 2008. Moreover, predicting political crises alone is not sufficient to ensure that oil price expectations are accurate. It is important to keep in mind that oil inventory demand depends on the shortfall of expected supply compared with expected demand rather than just one side of the market. Historical evidence suggests that in practice shifts in inventory demand tend to arise only when geopolitical turmoil coincides with expectations of strong demand for crude oil and tight oil supplies. Geopolitical tensions alone, in contrast, will not have an effect on the price of oil, as long as oil supplies are plentiful relative to expected demand (see, e.g., Mabro 1998). For example, as noted earlier, persistent attacks on oil tankers in the Persian Gulf during the 1980s – at the rate of as many as 30 attacks per month – had no apparent effect on the price of oil. Thus, most oil price predictions simply ignore the

possibility of future political or economic crises, except to the extent that they are already priced in at the time the prediction is made. Because crises are rare, this strategy usually works, but occasionally it may result in spectacular predictive failures.

Conclusion

Although our understanding of historical oil price fluctuations has greatly improved, oil prices keep surprising economists, policymakers, consumers and financial market participants. Our analysis focused on the question of how large this surprise or shock component of oil price fluctuations is. We illustrated that the timing and magnitude of oil price shocks depends on the measure of oil price expectations. The reason that economists care about oil price shocks is that these shocks affect economic decisions. One channel of transmission is the loss of discretionary income that is associated with unexpectedly higher oil prices (and hence higher gasoline prices). Consumers who are forced to commute to and from work, for example, often have little choice, but to pay higher gasoline prices, which reduces the amount of discretionary income available for other purchases. Another channel is that oil price shocks affect expectations about the future path of the price of oil. Such expectations enter into net present value (NPV) calculations of future investment projects, the cash flow of which depends on the price of oil. For example, an automobile manufacturer's decision of whether to build new production facilities for an SUV is directly affected by the price of oil, as is a household's decision which car to buy. What matters for NPV calculations is not the magnitude of the oil price surprise in the current period, but the revision to the expected path of the future price of oil which enters the cash flow. In addition, oil price shocks also affect the cash flow of earlier investment decisions by manufacturing firms. In general, ongoing projects remain profitable as long as the price exceeds the marginal cost, which depends on the current price of oil. It is even possible for higher oil prices to cause ongoing

projects to be abandoned (much like a consumer may choose to scrap a gas-guzzling car in response to higher gasoline prices). A more comprehensive review of the transmission of oil price shocks that also takes account of the joint determination of the price of oil and the state of the economy is provided in Barsky and Kilian (2004) and Kilian (2008b, 2014b), for example.

These basic transmission mechanisms have been linked to a wide range of macroeconomic outcomes including inflation, output, employment, and wages (see, e.g., Kilian 2008, 2014). They also have implications for the debate about climate change and for environmental policies. Of particular interest is the question of how the effects of oil price shocks vary across industries, plants, and households, how long these effects last, and how they may have changed over time. One important insight of the recent literature has been that these questions cannot be answered without taking account of the underlying causes of the oil price shock. Our analysis suggests another important direction for future research. Macroeconomic models of the transmission of oil price shocks to date have not allowed for heterogeneous oil price expectations across economic agents. Given the differences in the implied oil price shocks associated with alternative measures of oil price expectations that we documented, such distinctions may be of first-order importance for applied work.

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References

Adelman, Morris A. (1993), *The Economics of Petroleum Supply*, Cambridge, MA: MIT Press.

Alhajji, A.F. and David Huettner (2000), "OPEC and other Commodity Cartels: A Comparison," *Energy Policy*, 28, 1151-1164.

Almoguera, Pedro A., Christopher C. Douglas, and Ana María Herrera (2011), "Testing for the Cartel in OPEC: Noncooperative Collusion or just Noncooperative?" *Oxford Review of Economic Policy*, 27(1), 144-168.

Alquist, Ron, and Lutz Kilian (2010), "What Do We Learn from the Price of Crude Oil Futures?" *Journal of Applied Econometrics* 25(4), 539-573.

Alquist, Ron, Kilian, Lutz, and Robert J. Vigfusson (2013), "Forecasting the Price of Oil," in: Elliott, Graham, and Allan Timmermann (eds.), *Handbook of Economic Forecasting*, 2, Amsterdam: North-Holland, 2013, 427-507.

Anderson, Soren T., Kellogg, Ryan, Sallee, James M., and Richard T. Curtin (2011), "Forecasting Gasoline Prices Using Consumer Surveys" *American Economic Review Papers and Proceedings***,** 101(3), 110-114.

Barsky, Robert B., and Lutz Kilian (2002), "Do We Really Know that Oil Caused the Great Stagflation? A Monetary Alternative," *NBER Macroeconomics Annual*, 16, 137-183.

Barsky, Robert B., and Lutz Kilian (2004), "Oil and the Macroeconomy since the 1970s," *Journal of Economic Perspectives*, 18(4), Fall, 115-134.

Baumeister, Christiane, and Gert Peersman (2013), "The Role of Time-Varying Price Elasticities in Accounting for Volatility Changes in the Crude Oil Market," *Journal of Applied Econometrics*, 28(7), 1087-1109.

Baumeister, Christiane, and Lutz Kilian (2012), "Real-Time Forecasts of the Real Price of Oil,"

Journal of Business and Economic Statistics, 30(2), 326-336.

Baumeister, Christiane, and Lutz Kilian (2014a), "A General Approach to Recovering Market Expectations from Futures Prices with an Application to Crude Oil," unpublished manuscript, University of Michigan, http://www-personal.umich.edu/~lkilian/bk4_081915withappendix.pdf.

Baumeister, Christiane, and Lutz Kilian (2014b), "What Central Bankers Need to Know about Forecasting Oil Prices," *International Economic Review*, 55(3), 869-889.

Baumeister, Christiane, and Lutz Kilian (2015a), "Understanding the Decline in the Price of Oil since June 2014," forthcoming: *Journal of the Association of Environmental and Resource Economists*.

Baumeister, Christiane, and Lutz Kilian (2015b), "Forecasting the Real Price of Oil in a Changing World: A Forecast Combination Approach," *Journal of Business and Economic Statistics*, 33, 338-351.

Benes, Jaromir, Chauvet, Marcelle, Kamenik, Ondra, Kumhof, Michael, Laxton, Douglas, Murula, Susanna, and Jack Selody (2015), "The Future of Oil: Geology versus Technology," *International Journal of Forecasting*, 31(1), 207-221.

Bodenstein, Martin, Guerrieri, Luca, and Lutz Kilian (2012), "Monetary Policy Responses to Oil Price Fluctuations," *IMF Economic Review*, 60(4), 470-504.

Cairns, Robert D., and Enrique Calfucura (2012), "OPEC: Market Failure or Power Failure?" *Energy Policy*, 50, 570-580.

Carter, Colin A., Rausser, Gordon C., and Aaron D. Smith (2011), "Commodity Booms and Busts," *Annual Review of Resource Economics*, 3, 87-118.

Colgan, Jeff D. (2014), "The Emperor Has No Clothes: The Limits of OPEC in the Global Oil

Market," *International Organization*, 68(3), 599-632.

Dvir, Eyal, and Kenneth S. Rogoff (2010), "Three Epochs of Oil," unpublished manuscript, Boston College, http://scholar.harvard.edu/files/rogoff/files/three_epochs_of_oil.pdf.

Faust, Jon, and Jonathan H. Wright (2013), "Forecasting Inflation," in: Elliott, Graham, and Allan Timmermann (eds.), *Handbook of Economic Forecasting*, 2, Amsterdam: North-Holland, 2-56.

Fattouh, Bassam, Kilian, Lutz, and Lavan Mahadeva (2013), "The Role of Speculation in Oil Markets: What Have We Learned So Far?" *Energy Journal*, 34(3), 7-33.

Green, Edward J., and Robert H. Porter (1984), "Noncooperative Collusion under Imperfect Price Information," *Econometrica*, 52(1), 87-100.

Hamilton, James D. (1983), "Oil and the Macroeconomy since World War II," *Journal of Political Economy*, 91(2), 228-248.

Hamilton, James D. (1985), "Historical Causes of Postwar Oil Shocks and Recessions," *Energy Journal*, 6(1), 97-116.

Hamilton, James D. (2003), "What is an Oil Shock?" *Journal of Econometrics*, 113(2), 363–398.

Hamilton, James D. (2009), "Causes and Consequences of the Oil Shock of 2007-08," *Brookings Papers on Economic Activity*, 1, Spring, 215-261.

Hamilton, James D. (2013), "Oil Prices, Exhaustible Resources and Economic Growth," in: Fouquet, Roger (ed.), *Handbook of Energy and Climate Change*, Edward Elgar Publishing, Cheltenham, UK, 29-57.

Hamilton, James D., and J. Cynthia Wu (2014), "Risk Premia in Crude Oil Futures Prices," *Journal of International Money and Finance*, 42, 9-37.

Holland, Stephen P. (2008), "Modeling Peak Oil," *Energy Journal*, 29(2), 61-80.

Holland, Stephen P. (2013), "The Economics of Peak Oil," in: Shogren, Jason F. (ed.), *Encyclopedia of Energy, Natural Resource, and Environmental Economics*, Vol. 1, Amsterdam: Elsevier, 146-150.

Hubbert, M. King (1956). "Nuclear Energy and the Fossil Fuels," *American Petroleum Institute Drilling and Production Practice, Proceedings of Spring Meeting*, San Antonio, 7-25.

Jevons, William S. (1886), *The Coal Question*, London: Macmillan and Co.

Kilian, Lutz (2008a), "Exogenous Oil Supply Shocks: How Big Are They and How Much Do They Matter for the U.S. Economy?" *Review of Economics and Statistics*, 90(2), 216-240.

Kilian, Lutz (2008b), "The Economic Effects of Energy Price Shocks," *Journal of Economic Literature*, 46(4), 871-909.

Kilian, Lutz (2009a), "Not All Oil Price Shocks Are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market," *American Economic Review*, 99(3), 1053-1069.

Kilian, Lutz (2009b), "Comment on 'Causes and Consequences of the Oil Shock of 2007-08' by James D. Hamilton," *Brookings Papers on Economic Activity*, 1, Spring, 267-278.

Kilian, Lutz (2014a), "The Impact of the Shale Oil Revolution on U.S. Oil and Gasoline Prices," CEPR Working Paper No. 10304.

Kilian, Lutz (2014b), "Oil Price Shocks: Causes and Consequences," *Annual Review of Resource Economics*, 6, 133-154.

Kilian, Lutz, and Bruce Hicks (2013), "Did Unexpectedly Strong Economic Growth Cause the Oil Price Shock of 2003-2008?" *Journal of Forecasting*, 32(5), 385-394.

Kilian, Lutz, and Daniel P. Murphy (2012), "Why Agnostic Sign Restrictions Are Not Enough: Understanding the Dynamics of Oil Market VAR Models," *Journal of the European*

Economic Association, 10(5), 1166-1188.

Kilian, Lutz, and Daniel P. Murphy (2014), "The Role of Inventories and Speculative Trading in the Global Market for Crude Oil," *Journal of Applied Econometrics*, 29(3), 454-478.

Kilian, Lutz, and Thomas K. Lee (2014), "Quantifying the Speculative Component in the Real Price of Oil: The Role of Global Oil Inventories," *Journal of International Money and Finance*, 42, 71-87.

Knittel, Christopher R., and Robert S. Pindyck (2015), "The Simple Economics of Commodity Price Speculation," forthcoming: *American Economic Journal: Macroeconomics*.

Lippi, Francesco, and Andrea Nobili (2012), "Oil and the Macroeconomy: A Quantitative Structural Analysis," *Journal of the European Economic Association*, 10(5), 1059-1083.

Mabro, Robert (1998), "OPEC Behavior 1960-1998: A Review of the Literature," *Journal of Energy Literature*, 4(1), 3-27.

Pindyck, Robert S. (2004), "Volatility and Commodity Price Dynamics," *Journal of Futures Markets*, 24(11), 1029-1047.

Ramey, Valerie A., and Daniel J. Vine (2010), "Oil, Automobiles, and the U.S. Economy: How Much Have Things Really Changed?" *NBER Macroeconomics Annual*, 25, 333-368.

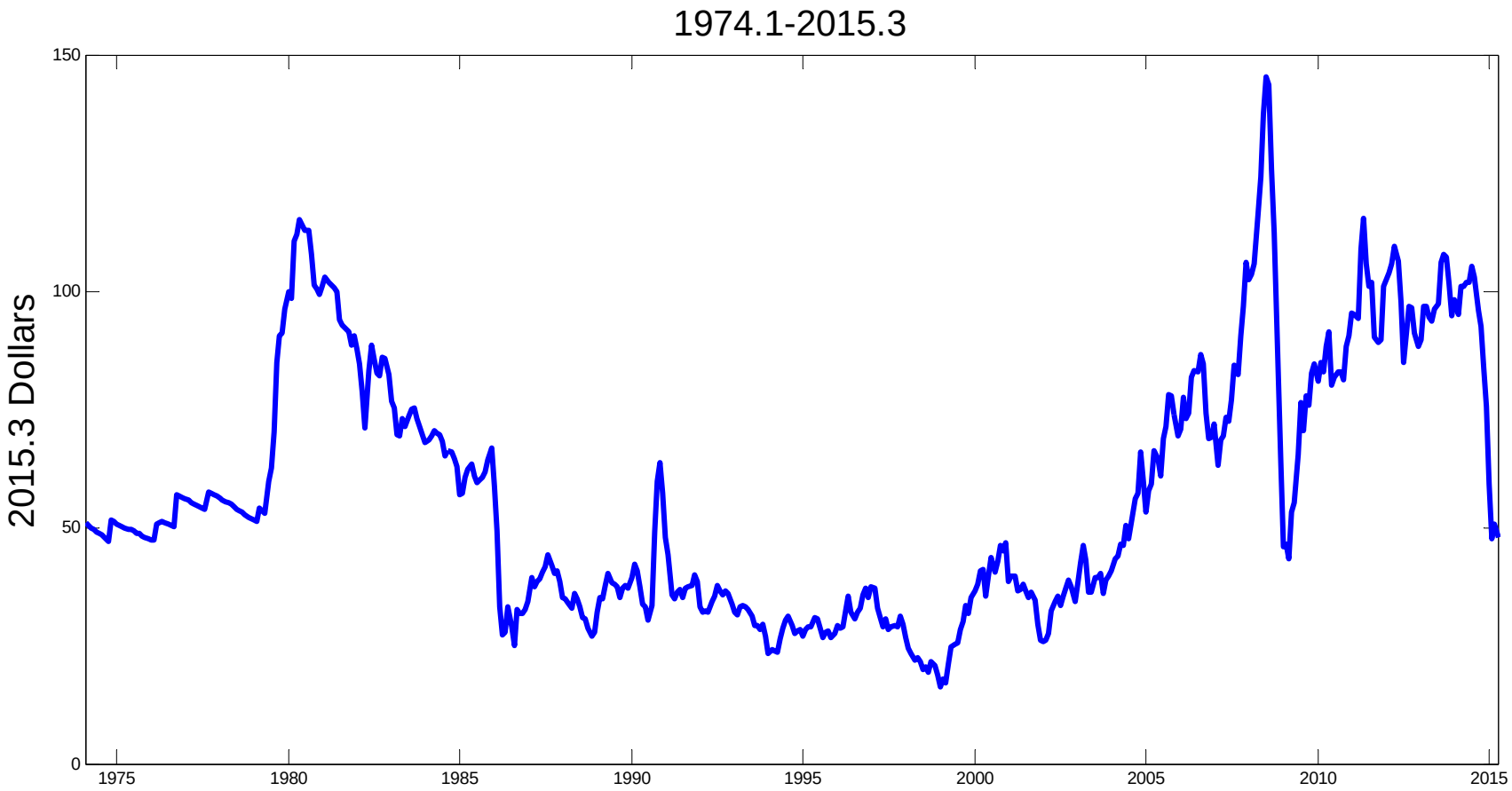
Seymour, Ian (1980), *OPEC: Instrument of Change*, London: MacMillan.

Skeet, I. (1988), *OPEC: Twenty-Five Years of Prices and Politics*, New York: Cambridge University Press.

Smith, James (2005), "Inscrutable OPEC? Behavioral Tests of the Cartel Hypothesis," *Energy Journal*, 26(1), 51-82.

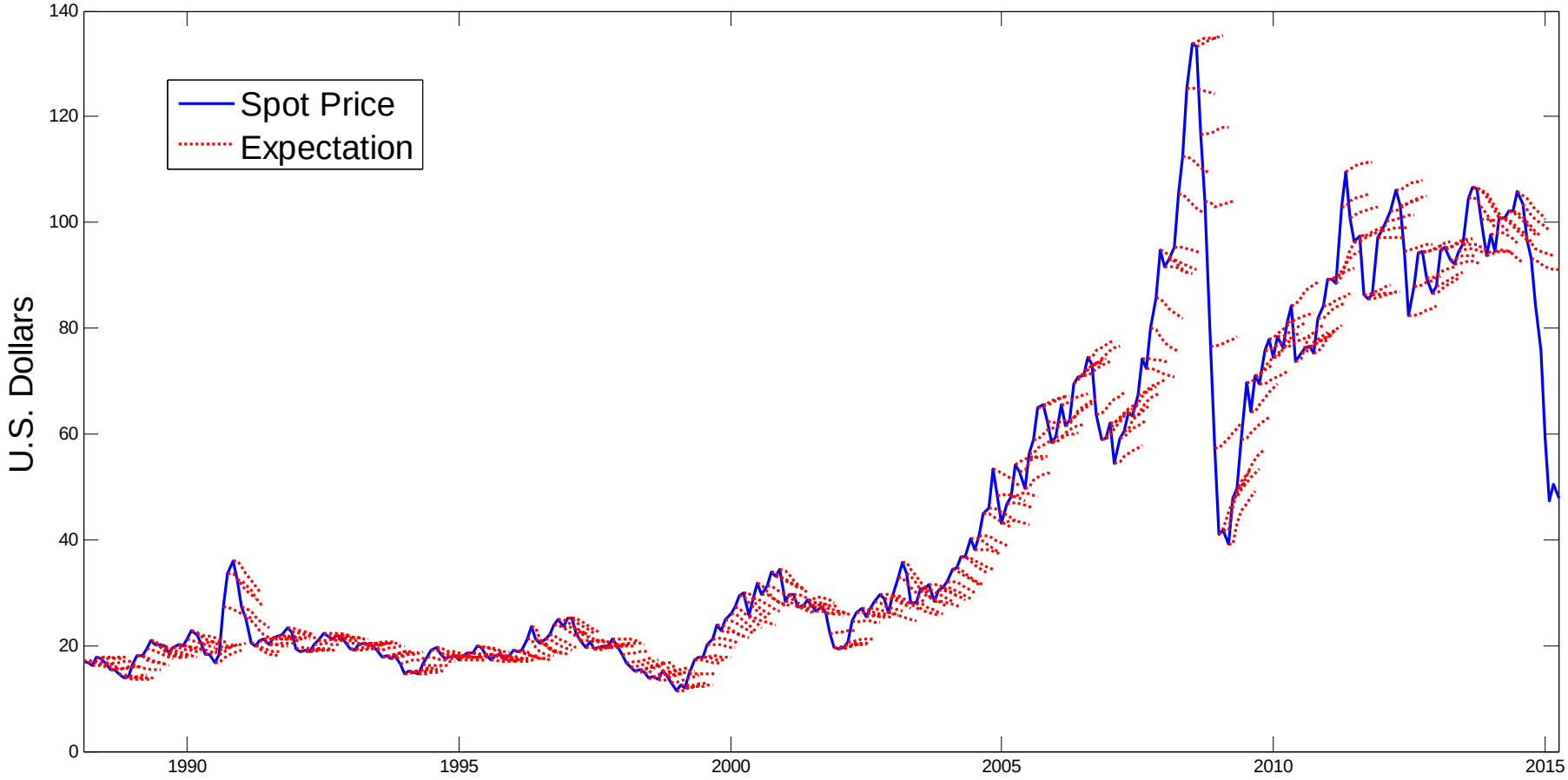
Yergin, Daniel (1992), *The Prize. The Epic Quest for Oil, Money, and Power*. New York: Simon and Schuster.

Figure 1: Inflation-Adjusted Price of WTI Crude Oil



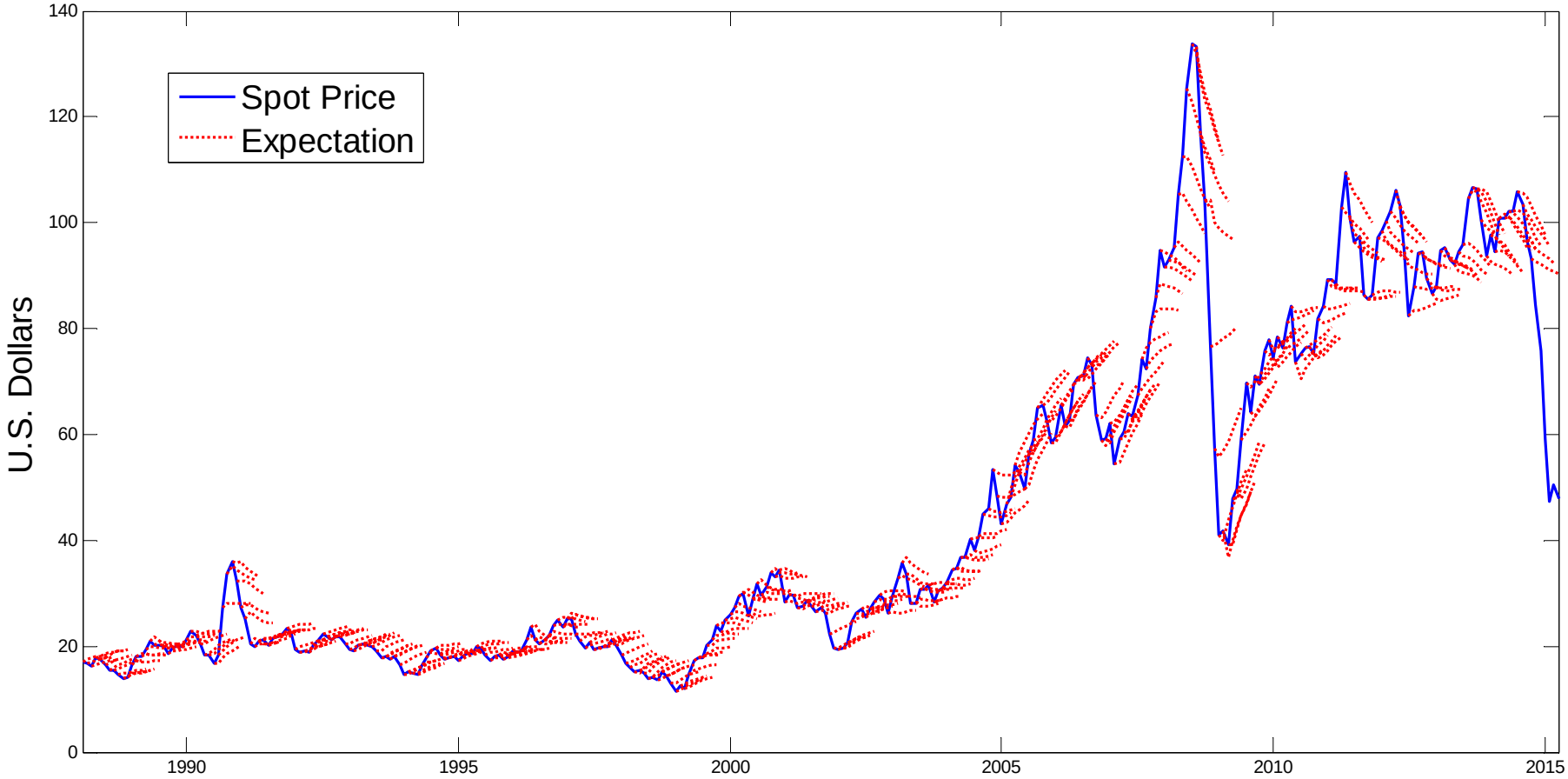
NOTES: The WTI oil price series is from the U.S. Energy Information Administration; the oil price has been deflated with the seasonally adjusted U.S. consumer price index for all urban consumers.

Figure 2: Monthly WTI Oil Price Expectations Measure Obtained from the Oil Futures Curve



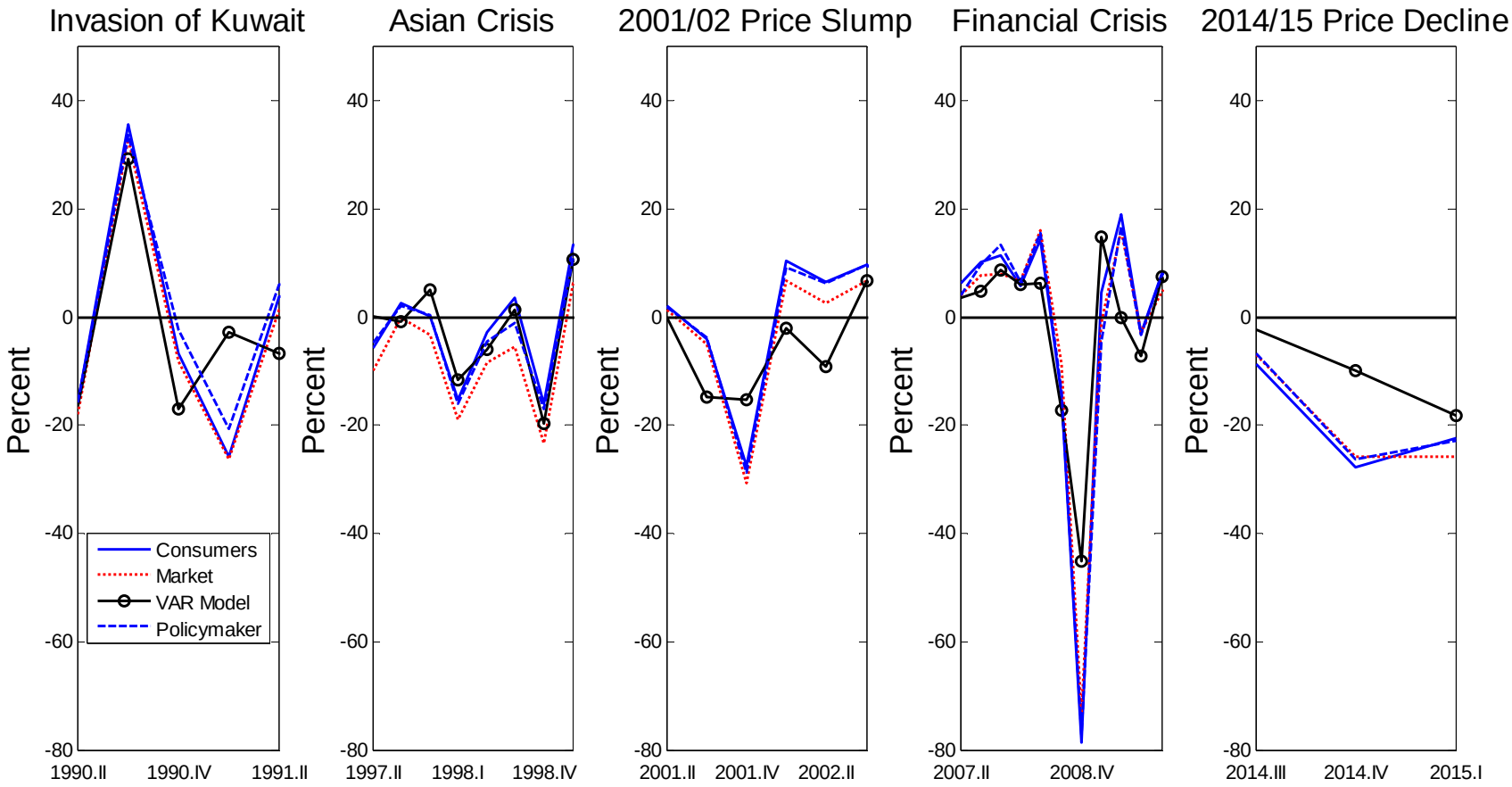
NOTES: The expectation of the WTI spot price for a horizon of h months is measured by the WTI oil futures price at maturity h. This approach ignores the possible presence of a risk premium (see Baumeister and Kilian 2014a).

Figure 3: Monthly Financial Market WTI Oil Price Expectations Obtained from the Risk-Adjusted Futures Curve



NOTES: The expectation of the WTI spot price for a horizon of h months is measured by subtracting from the WTI oil futures price at maturity h the estimated risk premium for that horizon. All risk premium estimates are constructed from the weekly term structure model proposed by Hamilton and Wu (2014), as implemented in Baumeister and Kilian (2014a).

Figure 4: Quarterly Shocks to Nominal WTI Price of Oil by Episode



NOTES: Each oil price shock series is constructed by averaging the monthly oil price expectations by quarter and expressing this average as a percent deviation from the quarterly average of the monthly oil price outcomes. The policymakers' expectation corresponds to the unadjusted WTI oil futures price. The financial market expectation is constructed by subtracting the Hamilton and Wu (2014) risk premium estimate from the futures price. The consumer expectation is proxied for by applying a no-change forecast to the real price of crude oil and adding the expected rate of inflation, motivated by the results for gasoline price expectations in Anderson, Kellogg, Sallee and Curtin (2011). The VAR model expectation is constructed from the reduced-form representation of the oil market model of Kilian and Murphy (2014) estimated on the full sample. The model includes an intercept and 24 lags of the real price of oil, the growth rate of global oil production, a proxy for the change in global crude oil inventories, and a measure of the global business cycle. The implied predictions are scaled as in Baumeister and Kilian (2014b) and converted to dollar terms using the same expected rate of inflation as that underlying the consumer forecast. The inflation forecasts are constructed using the fixed-coefficient gap model proposed in Faust and Wright (2014).

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