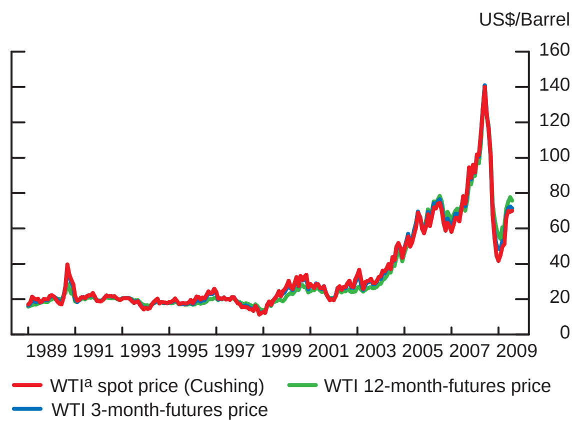
Crude Oil Futures: A Crystal Ball?

Ron Alquist and Elif Arbatli, International Economic Analysis

- *It is common for policy-makers and market analysts to use the prices of crude-oil-futures contracts to interpret developments in the global crude oil market. Based on recent research, this article discusses three ways that oil-futures prices can improve our understanding of current conditions and future prospects in this important international commodity market.*
- *First, the response of the oil-futures curve can be used to identify the persistence of oil-price shocks and to obtain an indicator of the rate at which a given shock will diminish.*
- *Second, the spread between the current futures price and the spot price of oil can be interpreted as an indicator of the precautionary demand for oil.*
- *Third, oil-futures prices can be used to forecast spot prices, but because such forecasts are volatile, they should be supplemented with other information to improve their accuracy.*

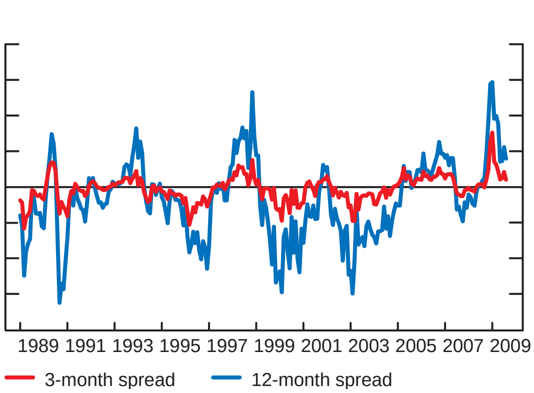
The run-up in the price of crude oil since 2002 and its sharp collapse in the autumn of 2008 have renewed interest in understanding the determinants of spot and futures prices in the oil market **(Charts 1** and **2)**. Such shifts highlight the importance of understanding the relationship between the prices of oil-futures contracts and market expectations. Indeed, it is common for policy-makers and market analysts to interpret the price of the crude oil-futures contract traded on the New York Mercantile Exchange, or NYMEX, as a measure of market expectations of the future spot price of oil. In light of this widespread use, it is important to understand the information that can be recovered from the prices of oil futures. Recent studies shed light on the information that these prices provide about developments in the global crude oil market.

Chart 1: Spot and futures prices for crude oil



a. West Texas Intermediate
Source: NYMEX

Chart 2: Futures-spot spread



Source: NYMEX

We begin by reviewing the theory of storage as a way to organize thinking about the relationship between spot and futures markets. In this type of model, commodity processors choose how much of the commodity they will use today versus tomorrow and, hence, determine the level of the spot price relative to the futures price. We then assess whether movements in the futures curve capture market expectations of the future path of oil prices, as predicted by the theory of storage under risk neutrality. Finally, we discuss three ways of using the prices of oil futures to understand current developments and future prospects in that market: namely, inferring the persistence of shocks from the response of the futures curve to shocks in the spot price; using the futures-spot spread as an indicator of shifts in expectations about future oil-supply shortfalls; and forecasting the spot price of oil in real time, using futures prices.

Price Determination in the Market for Crude Oil Futures

A standard framework for thinking about the determination of futures prices in the market for crude oil is the theory of storage, which is generally applicable to markets for storable commodities. The spot price is the price at which the commodity is immediately available, and the futures price is the price at which the commodity is available for delivery at a specified future date. Taking the supply of the commodity as given, the framework, in its simplest form, assumes that risk-neutral commodity processors operate in a competitive environment and will optimally choose the quantity of the commodity that they wish to consume today and the quantity that they wish to store.[1] The assumption of risk neutrality ensures that the current futures price equals the expected spot future price, adjusted for the costs and benefits associated with storing oil and having ready access to it.

In this model, the spread between the spot and futures prices adjusts to equate the marginal cost to the marginal benefit of storing a barrel of oil as inventory. The difference between contemporaneous spot prices and futures prices reflects the interest foregone from storing the commodity, the cost of physical storage, and the convenience yield associated with holding inventory. The convenience yield is the benefit of holding a barrel of oil as inventory that accrues to the firm storing oil. It reflects a precautionary motive for holding oil inventory and is assumed to exhibit diminishing marginal returns to storing oil.

Economists appeal to the idea of the convenience yield to explain an apparent puzzle observed in commodity-futures markets. Current futures prices often lie below the current spot price—that is, futures prices are backwardated—at the same time that firms carry over stocks of the commodity from one period to the next.[2] Firms therefore hold stocks at an apparent capital loss. If stocks of a commodity yield benefits to the firm, then it can be rational for a firm to hold inventories even when the futures market is backwardated. That is, the value of having ready access to a stock of oil can justify holding inventory when the futures curve is in backwardation. The West Texas Intermediate oil futures contract—the most liquid, widely traded, and closely monitored energy-futures contract in North America—is frequently in backwardation and yet refiners also hold positive levels of inventory (Litzenberger and Rabinowitz 1995).

A convenience yield associated with holding crude oil as inventory is consistent with the operational requirements of oil refineries. Because of technological constraints, oil refineries have a strong incentive to hold stocks of oil to optimize the production of different types of petroleum products (National Petroleum Council 2004). Stocks of crude oil give a

1 This type of model has a long lineage, beginning with Kaldor (1939), Working (1949), Brennan (1958), and Gustafson (1958). More recent papers include Scheinkman and Schechtman (1983), Williams and Wright (1991), Deaton and Laroque (1992), and Ng and Ruge-Murcia (2000).

2 When futures prices lie above spot prices, the market is said to be in contango. The terms “backwardation” and “contango” originated in the London Stock Exchange during the nineteenth century. “Backwardation” referred to a fee paid by the seller of a security for the right to delay delivery; and “contango” referred to a fee paid by the buyer of a security for the right to delay delivery and payment.

refinery operational flexibility, and the value of this flexibility can be captured by the convenience yield. Considine (1997) finds that the convenience yield net of interest and physical storage costs is about 20 per cent of the spot price on an annual basis.[3]

Futures Prices and Market Expectations

We can use futures prices as a measure of the expected spot price and interpret the term structure of futures prices as the expected time path of oil prices only if futures prices represent the rational expectation of the spot price of oil. The argument for using futures prices to represent market expectations thus relies on the premise that futures prices are unbiased predictors of the future spot price of oil. The available evidence is broadly consistent with that assumption. Although there is some evidence that the futures prices are biased predictors of the spot price, the bias is small, on average.

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Bias and the forecasting efficiency of futures prices

Forecast-efficiency tests are one way to detect if there is bias associated with using futures prices to predict the future spot price. The tests involve regressing the ex post percentage change in the spot price of oil on a constant and the futures-spot spread, the percentage difference between the current futures price and the current spot price.[4] The regression equation is

$$\Delta s_{t+h} = \alpha + \beta\left(f_t^{(h)} - s_t\right) + \varepsilon_{t+h}, \qquad (1)$$

where Δs_{t+h} denotes the ex post change in the log spot price; $f_t^{(h)}$ denotes the log price of a futures contract that matures in h months; s_t denotes the current spot price, and ε_{t+h} is a random error term. If futures prices are unbiased predictors of the future spot price, we expect that $\alpha = 0$ and $\beta = 1$.[5] It is common to interpret failing to reject the null hypothesis that $\beta = 1$ in such regressions as evidence against a time-varying risk premium (see, among others, Chernenko, Schwarz, and Wright 2004).

We estimate forecast-efficiency regressions for 3-, 6-, and 12-month contracts using data over the period January 1989 to August 2009. **Table 1** reports the results from these regressions. The average bias appears to increase monotonically with the maturity of the futures contract, but is significantly different from zero at only the 12-month horizon. We also fail to reject the null hypothesis that $\beta = 1$ at all horizons. These conclusions are very similar to those obtained in other studies that have used different subsamples, such as Chernenko, Schwarz, and Wright (2004), Arbatli (2008), Chinn and Coibion (2009), and Alquist and Kilian (2010). This evidence thus indicates that treating oil-futures prices as the expected future spot price is a good first approximation.

Table 1: Results of forecast-efficiency regressions for oil-futures contracts
January 1989-August 2009

	3-month contract	6-month contract	12-month contract
α (p-value)	0.02 (0.29)	0.04 (0.18)	0.09 (0.05)
β (p-value)	1.51 (0.46)	0.91 (0.85)	0.79 (0.54)
Reject H_0: $\alpha = 0, \beta = 1$	No	No	Yes
Adjusted R-squared	0.03	0.04	0.05
T	246	243	237

Notes: The p-values are based on standard errors that are robust to autocorrelation and heteroskedasticity.

At this juncture it is important to discuss a subtlety surrounding statistical tests of predictability that helps us to understand the relationship between these results and the evidence that futures prices tend to be

3 Considine (1997) derives the convenience yield from a crude oil refinery's dynamic profit-maximization problem, using disaggregated data on the type of petroleum products that refineries typically produce. He finds that significant cost savings are associated with adjusting oil stocks to minimize variable costs. Apart from a difference in sign, the cost savings are equivalent to the convenience yield.

4 Such tests implicitly assume that the goal of market participants is identical to that of the econometrician in that they both pick parameters α and β to minimize the sum of squared errors. If that is not the case, forecast-efficiency tests are biased in favour of the alternative hypothesis (see Elliott, Komunjer, and Timmermann 2005).

5 It is also possible to adjust for the cost-of-carry by including interest rates and the cost of storage. Of the two, only interest rates are directly observable, and including them does not affect the conclusion. The available evidence on the cost of storage from the Energy Information Administration indicates that changes in such costs occur at low frequency and, therefore, cannot account for the size of the high-frequency fluctuations in the futures-spot spread.

less accurate real-time predictors of the future spot price than the no-change forecast.[6] If the price of oil futures and the conditional expectation of the price of oil were equal, then the oil-futures price would be the most accurate predictor according to standard metrics for measuring forecast accuracy (Granger 1969). The forecast-efficiency tests are consistent with this assumption, but they are in-sample tests of predictability that use the full range of data available at a point in time. It is also possible to test for predictability using an out-of-sample test. This type of test employs a subsample of the available data to conduct a real-time forecast that uses data only up to a specific point in time. It is widely recognized among forecasters that there is no necessary connection between detecting significant in-sample predictability and detecting significant out-of-sample predictability, and the two tests can deliver different inferences (for example, Amato and Swanson 2001; Chao, Corradi, and Swanson 2001; and Inoue and Kilian 2006). Put differently, predictability that exists in a population may not be exploitable in real time. This fact explains why there is no logical tension between the forecast-efficiency regressions and the ability of the futures price to predict spot prices out-of-sample.

Other measures of market expectations

Another way to assess whether futures prices for crude oil represent market expectations of future spot prices is to compare the market expectations recovered from futures prices with those provided by market commentaries and professional forecasters. The comparison provides another source of evidence regarding the relationship between futures prices and market expectations. One advantage of such a comparison is that it permits us to link developments in oil markets to movements in futures prices and to understand more clearly the relationship between real-time developments in the crude oil market and futures prices.

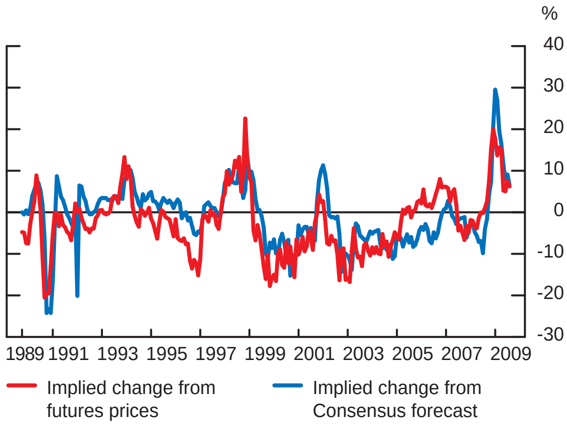
Arbatli (2008) compares the market expectations obtained from the futures curve with those from two other sources: commentaries in the *Oil & Gas Journal* and forecasts published by Consensus Economics. The *Oil & Gas Journal* is a major industry journal that contains commentaries on developments affecting the spot and futures markets for oil. This procedure is similar to that used in other studies to identify oil-price shocks associated with exogenous events (for example, Cavallo and Wu 2006). Arbatli identifies episodes with large movements in oil prices, because such episodes are associated with news about underlying supply and demand conditions in the global crude oil market, making the relevant events easier to detect.

She finds that changes predicted by the futures curve, as captured by the slope of the curve, coincide with the predictions suggested by market commentaries. For example, during the Gulf War there was a sharp upward spike in the spot price of oil, whereas the price of long-horizon futures contracts did not move very much. Market commentaries during that episode reveal that oil industry analysts expected the change in the spot price to be transitory. A similar picture emerges from studying the behaviour of oil prices during the Asian financial crisis of 1997–98. During that period, the spot price fell significantly, whereas the price of the long-dated futures contract did not, again suggesting that the market perceived the decline in oil prices to be transitory. Similarly, Arbatli identifies periods during which expectations of more persistent changes in underlying supply and demand conditions are detectable in the prices of oil futures. During such episodes, the entire futures curve shifts up or down. Examples of persistent changes in the price of oil are the collapse in prices in 1986 and the run-up in prices during 2003–06. Both periods were associated with commentaries that emphasized the persistent nature of the price changes.

Since interpreting market commentaries requires forming a subjective judgment about the implications of the statement for the future price of oil, Arbatli uses forecasts from Consensus Economics. **Chart 3** reproduces and extends the data from that paper. It plots the difference between the forecasts for prices 12 and 3 months ahead from Consensus Economics relative to the current spot price and compares that with the difference between prices for 12- and 3-month oil futures relative to the current spot price for the same month. The gap between the 12- and 3-month-ahead forecasts reflects what market participants expect to happen to prices. A positive number indicates that the market expects an increase in prices; a negative value indicates an expected decrease in prices. The chart shows that there is a strong historical correlation between the futures-based forecasts and those obtained from professional forecasters. In one sense, this finding is unsurprising: It may simply demonstrate that professional forecasters use futures prices to inform their forecasts. Furthermore, while the correlation between Consensus forecasts and futures-based forecasts is high, it is not perfect. Evidently, forecasters use futures prices, as

6 The no-change forecast uses the current spot price to forecast the future spot price.

Chart 3: Implied change in the spot price of crude oil



Sources: Consensus Economics and NYMEX

well as other sources of information, to predict the future path of the price of oil.

Forecasters use futures prices, as well as other sources of information, to predict the future path of the price of oil.

In conjunction with the statistical evidence obtained from the forecast-efficiency regressions, the narrative evidence supports the view that futures prices, imperfect as they are, provide a way to measure market expectations. In the next section, we examine in greater detail how to use futures prices to shed light on real-time developments in the global crude oil market.

Interpreting the Behaviour of Crude Oil Futures Prices

The persistence of price shocks and the futures curve

If we assume that the futures curve represents a measure of the expected future path of spot prices, it can be used to capture expectations about the persistence of shocks to the spot price of oil. Bessembinder et al. (1995), for example, estimate the rate at which the price of oil reverts to its mean, using the response of the slope of the futures curve to a change in the spot price. Within their framework, a large response of the slope to changes in spot prices suggests a large expected mean reversion in spot prices. According to estimates presented in the paper, almost half of a spot-price shock is expected to be reversed within eight months. This estimate of mean reversion is consistent with other estimates based on the futures curve (see, for example, Arbatli 2008). In a similar vein, Schwartz and Smith (2000) use the term structure of futures prices to construct a real-time decomposition of the spot price into a long-run and a short-run component. The identification procedure in that paper relies on the assumption that the change in futures prices over different maturities constitutes the impulse response of the spot price to oil-price shocks. Arbatli (2008) uses the same assumption to identify permanent and transitory shocks to oil prices and, hence, to summarize the information about the persistence of shocks embedded in the futures curve.[7]

In conjunction with other models, the permanent-transitory decomposition derived from the futures curve provides information that can guide the conduct of monetary policy. In general, the optimal response of monetary policy to oil-price shocks depends on the persistence of the shock, because of lags in the effect of monetary policy on the economy. If the oil-price shock is expected to be reversed quickly, a more aggressive policy response may be destabilizing and, therefore, inappropriate. In an oil-exporting country like Canada, a persistent increase in the price of oil represents a positive terms-of-trade shock that can generate a large and persistent real appreciation of the exchange rate. Although the appreciation exerts downward pressure on prices through less-expensive imports, the wealth effect of such a persistent change in the price of oil also exerts upward pressure on prices. The permanent-transitory decomposition can suggest the type of shock to feed into a structural macroeconomic model to study the response of the economy and, thus, to design the appropriate policy response.[8] The increasing liquidity in the oil-futures market and the expanding range of actively traded maturities open up the possibility of using long-dated futures contracts to obtain more reliable estimates of the persistence of oil-price shocks.

7 Since both papers include a constant in their specification, they admit the possibility that futures prices are biased predictors of the future spot price.

8 The permanent-transitory decomposition provides an estimate of the long-run price of oil and its behaviour over time. It is important to recognize that the estimated long-run price is not necessarily an estimate of the long-run equilibrium level of the price of oil. The reason is that the market for long-horizon contracts is illiquid, and therefore the longest maturity contract used in both papers is 12 months.

The futures-spot spread and precautionary demand

Alquist and Kilian (2010) propose a model in which the futures-spot spread may be viewed as an indicator of shifts in expectations about future oil-supply shortfalls. In their model, an oil-producing country exports oil to an oil-consuming country that uses the oil to produce a final good to be traded for oil or consumed domestically. Oil importers may insure against uncertainty about oil-supply shocks by holding above-ground oil inventories or by buying oil futures. Oil producers may sell oil futures to protect against endowment uncertainty.

One implication of the model is that increased uncertainty about future oil-supply shortfalls causes the oil-futures spread to fall and raises the current real spot price of oil, as precautionary demand for oil inventories increases. Increased uncertainty about future oil-supply shortfalls thus causes the real price of oil to overshoot and then to decline gradually to a new steady-state value that is higher than the original one.

Alquist and Kilian present three pieces of evidence consistent with the model's predictions. First, the proposed indicator moves as expected during events, such as the Persian Gulf War, that a priori should be associated with large shifts in the precautionary demand for crude oil. They also find evidence of such shifts in the spread associated with the Asian financial crisis, the attacks on September 11, and the 2003 Iraq War. Second, their indicator is highly correlated with an independent estimate of the precautionary demand component of the spot price of oil that is proposed by Kilian (2009). That alternative estimate is based on a structural vector autoregressive model of the global crude oil market that does not rely on data from the market for oil futures. The model decomposes unexpected changes in the real price of oil into shocks attributable to changes in the global supply of crude oil, shocks to global real economic activity, and oil-specific demand shocks that can be interpreted as precautionary demand shocks (see Kilian 2009). Over the period from January 1989 to December 2006, the two measures exhibit a very high correlation. Third, they show that the overshooting pattern in the response of the real price of oil to a precautionary demand shock in the Kilian model is consistent with the predictions of the theoretical model.[9]

This evidence lends credibility to the interpretation of the futures-spot spread as an indicator of fluctuations in the spot price of oil driven by shifts in the precautionary demand for crude oil. Although such shifts in expectations can be difficult to quantify in real time, the paper provides a way to interpret such movements using readily available price data. The availability of such data is especially important in light of the evidence presented in Kilian (2009) that the contribution of oil-supply shocks to changes in the price of crude oil has been smaller than previously thought. He concludes that demand shocks in general and precautionary demand shocks in particular play an economically important role in explaining the variability of oil prices. Since the data on which Kilian's argument is based are not readily available in real time, one can use the futures-spot spread as a real-time indicator of the shifts in expectations associated with precautionary demand shocks.

Using futures prices to forecast the spot price of crude oil

In this section, we survey the evidence on the ability of futures prices to forecast the spot price of oil out-of-sample.[10] The main conclusion is that while futures prices tend to produce forecasts that are correct on average, such forecasts are also highly volatile relative to no-change forecasts. Therefore, futures-based forecasts may be very inaccurate at a given point in time. The variability of futures-based forecasts makes it advisable to use the information contained in oil-futures prices in conjunction with other types of information when arriving at a judgment about the future trajectory of oil prices.

Some early studies found evidence that futures prices were accurate out-of-sample predictors of the future spot price of oil. Ma (1989) reports that futures prices outperform the no-change forecast, as well as other simple time-series models, in out-of-sample forecasting exercises. Kumar (1992) reaches similar conclusions.

9 It is important to point out that the economic environment in the Alquist and Kilian model is risk neutral. Although risk aversion can imply a precautionary motive for holding stocks of crude oil, it is not required. For example, a convenience yield can arise from the convex adjustment costs of firms rather than from the risk aversion of consumers (see Pindyck 1994). Thus, the existence of a convenience yield is equally consistent with risk-averse and risk-neutral preferences.

10 There is a related literature on the use of forward contracts traded in currency markets as indicators of the expected spot price of foreign currency (see Froot and Thaler 1990).

He finds that futures prices provide more accurate forecasts than those obtained from alternative time-series models, including the random-walk model.

In a study that uses data through the end of 2003, Chernenko, Schwarz, and Wright (2004) provide evidence that futures-based forecasts have a marginally lower mean-squared prediction error than the no-change forecast. Three related papers are Chinn, LeBlanc, and Coibion (2005), Wu and McCallum (2005), and Chinn and Coibion (2009). Chinn et al. conclude that futures-based forecasts are unbiased predictors of the spot price of oil and that they perform better than the random-walk forecast according to the mean-squared prediction error. Chinn and Coibion (2009) update the results from their earlier paper, and find that futures prices do not systematically outperform the random-walk forecast although they are superior to forecasts generated by other types of time-series models. Moreover, while Wu and McCallum report that futures prices tend to be less accurate than the no-change forecast, they also observe that spread regressions have a lower mean-squared prediction error than the no-change forecast at short horizons. Similarly, Coppola (2008) obtains improvements in forecast accuracy only at the 1-month horizon, and at longer horizons finds no improvements in forecast accuracy compared with the no-change forecast.

This evidence seems to suggest that the futures price is a useful tool for forecasting the spot price out-of-sample, at least over certain horizons. But in a comprehensive recent study, Alquist and Kilian (2010) consider the price data available from January 1989 through February 2007 and conduct out-of-sample forecasts using data available in real time. They conclude that futures-based forecasts are not more accurate than the no-change forecast for horizons out to 12 months. This finding is robust at all horizons from 1 month to 12 months and for a range of loss functions, including the quadratic and absolute loss functions. In particular, the no-change forecast tends to be more accurate than forecasts based on futures prices, other econometric models, and professional survey forecasts of the price of oil.

The difference between Alquist and Kilian's conclusions and those of prior studies can be traced to the longer sample period. Sensitivity analysis suggests that evidence of accuracy gains, sometimes obtained in shorter samples, tends to vanish when the full sample is examined. The inability of alternative models to forecast more accurately than the random walk may also be attributable to a risk premium, so that adjusting forecasts by the risk premium can improve the model's ability to forecast out-of-sample (Sadorsky 2002; Pagano and Pisani 2009). But the forecast-efficiency regressions reported in Alquist and Kilian, which are qualitatively similar to those reported in this article, do not reveal evidence consistent with the presence of a risk premium.

Alquist and Kilian document why futures-based forecasts are inferior to the no-change forecast. Whereas the bias of futures prices relative to the no-change forecast is small, the variability around the no-change forecast is not. At a point in time, the discrepancy between the futures price and the spot price may be large and may go in either direction. This variability in the deviation of futures prices from spot prices, rather than differences in the mean, drive the larger mean-squared prediction error of futures-based forecasts. Thus, policy-makers and financial analysts who use futures prices to forecast the spot price of oil will tend to be correct on average, but they will also run the risk of obtaining a very inaccurate forecast at a given point in time. This conclusion suggests that it is important not to rely solely on oil-futures prices to predict the future price of oil and instead to use them in conjunction with other pieces of information to arrive at a view of what the price of oil will be.

Policy-makers and financial analysts who use futures prices to forecast the spot price of oil will tend to be correct on average, but they will also run the risk of obtaining a very inaccurate forecast at a given point in time.

Although there is no single rule of thumb that guarantees being able to forecast the price of oil reliably, forecasters can take consolation in the fact that this conclusion is consistent with the views of oil-industry experts. For example, in a 2007 speech to petroleum economists, Peter Davies, chief economist for British Petroleum, noted that "we cannot forecast oil prices with any degree of accuracy over any period whether short or long" (Davies 2007). Thus, even economists with detailed knowledge of the technological and geological constraints related to the extraction of oil find it challenging to produce accurate forecasts.

Concluding Remarks

The findings discussed in this article have immediate policy implications. The decomposition of oil-price shocks into permanent and transitory components can be used to estimate the persistence of oil-price shocks in real time. Such an estimate can be used to simulate the effects of an oil-price shock with particular time-series characteristics. The result of such a policy experiment can guide and inform decisions about the appropriate response to a given type of oil-price shock. Another implication is that one should exercise caution in using futures prices to forecast the future spot price of oil out-of-sample. Such forecasts will be correct on average, but at a given point in time they tend to be very inaccurate.

The findings also suggest some avenues for further study. A natural next step, for example, would be to get a better understanding of the microeconomics of storage in the market for crude oil. Given the available evidence on the significance of the convenience yield in the crude oil market, as well as the importance of precautionary demand shocks as a driver of oil-price shocks at the macroeconomic level, it makes sense to examine the nature and implications of the precautionary motive for holding stocks of crude oil in finer detail. Studying the incentives facing oil refineries for storing oil would shed light on both the details of this important commodity market, as well as on the wider implications of the decision to store oil.

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