AESTIMATIO, THE IEB INTERNATIONAL JOURNAL OF FINANCE, 2013. **6**: 146-157

A Better Way to Predict Petroleum Prices… (and Commodity Prices in General)

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RECEIVED: 12 JULY 2012
ACCEPTED: 8 FEBRUARY 2013

Abstract

We study three main processes of expectation formation, following Frankel and Froot (1985), Meese and Rogoff (1983), Gourinchas and Rey (2007), Rogoff (2009) and Frankel and Rose (1994) to compare their forecasting accuracy. Regardless of whether or not expectations are rational, it is of interest to everyone to know how they are formed and how can they be predicted. We use daily-frequency oil prices from 1997-2011 to test two types of expectations (Regressive Expectations and Extrapolative Expectations), and we compare their performance behaviour to the Random Walk benchmark. Following Meese and Rogoff (1982) we used rolling regressions to re-estimate parameters of each model on every forecast period, running more than 3,600 regressions in all three cases, to determine the "goodness" of each type of expectation model. The same three statistics used by Meese and Rogoff (1982): Mean Error, Mean Absolute Error and Root Mean Square Error, were employed to measure out-of-sample accuracy. The results are most encouraging, we may have found a way to predict oil prices assuming that they follow a trajectory that is not totally random.

Keywords:

Random Walk, Regressive Expectations, Extrapolative Expectations, Mean Error, Mean Absolute Error and Root Mean Square Error, Market Efficiency.

JEL classification:

G12, G15, G17.

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Una mejor forma de predecir los precios del petróleo… **(y de los commodities en general)**

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Resumen

Hemos estudiado los procesos de formación de expectativas siguiendo los procedimientos establecidos por Frankel y Froot (1985), Meese y Rogoff (1983), Gourinchas y Rey (2007), Rogoff (2009) y Frankel y Rose (1994). Ello con el objetivo de comparar la certeza de los ejercicios de prospeccion con relacion a los precios del petroleo. Independientemente de que las expectativas sean racionales es de gran interés para todos comprender cómo se forman y cómo se pueden predecir. Para el ejercicio que nos interesa, hemos utilizado una frecuencia de precios del petróleo diarios desde 1997 a 2011. Con ellos hemos contrastado dos tipos de expectativas (Expectativas Regresivas y Expectativas Extrapolativas). Y hemos comparado su comportamiento con el conocido como Random Walk o Paseo Aleatorio. Siguiendo las pautas metodológicas establecidas por Meese and Rogoff (1982) hemos usado las llamadas 'rolling regressions' para re-estimar los parámetros de cada modelo para cada período de proyección. En total hemos corrido más de 3.600 regresiones para los tres casos aquí documentados y así poder determinar la "bondad" de cada uno de los tipos de modelo de expectativas. Para probar la certeza de la muestra hemos optado por usar las mismas tres estadísticas utilizadas por Meese and Rogoff (1982): Error Medio, Error Medio Absoluto y Raíz Cuadrada del Error Medio al Cuadrado. Los resultados son prometedores; todo indica que hemos encontrado una forma de predecir precios de petróleo bajo el supuesto de que no siguen trayectorias totalmente aleatorias.

Palabras clave:

Caminata aleatoria, Expectativas regresivas, Expectativas extrapolativas, Error medio, Error medio absoluto y raíz cuadrada del error medio al cuadrado, Eficiencia de Mercado.

1. Introduction

We are all involved in the crude oil market in one way or another, and most people have some degree of crude oil (or crude petroleun, to use the european term) knowledge. That and the fact that demand seems to be ‘hitting an all-time record’ (global demand has been projected to get closer to 90 million barrels per day by mid-2013) makes crude oil an important investment vehicle. If former president Bush is right and we are addicted to oil, we should understand its behavioral patterns to enhance investment portfolios and avoid market disequilibriums. That means we need to learn how to project prices. But projections can be—as Yogy Bera, the famous baseball player used to say-—very difficult, “particularly those about the future”, he added. What can help do better than what we do today? Well, Game Theory comes to mind.

Game theory, (GT henceforth), is a study of strategic decision making. More formally, it is "the study of mathematical models of conflict and cooperation between intelligent rational decision-makers." (Myerson, 1991). It is worth noticing that eight game-theorists have won the Nobel Memorial Prize in Economic Sciences so far. A more descriptive name for the discipline should be interactive decision theory (Aumann, 2008).[2] Can Game theory be used to predict oil prices? It does, and in the context of zero-sum games, one person's gain is exactly equal to the other participant’s losses. We just need to formalize each person’s tactic to successfully better his results, given some one else’s approach.

Modern GT began with the idea of mixed-strategy equilibria created by John von Neumann. Von Neumann used Brouwer's fixed-point theorem on continuous mappings into compact convex sets, which considered cooperative games of several players to prove existance of at least one equilibria. Another use of GT is the mathematical and economic use of decision-making under uncertainty. But GT can only be of use in the case of projecting oil prices if we incorporate the notion of ‘expectations’ (or beliefs). And expectations in economics refers to the forecasts that an economic agent holds about future prices, sales, incomes, taxes, or any other key variable. The importance of expectations in any type of projection can not be overestimated.

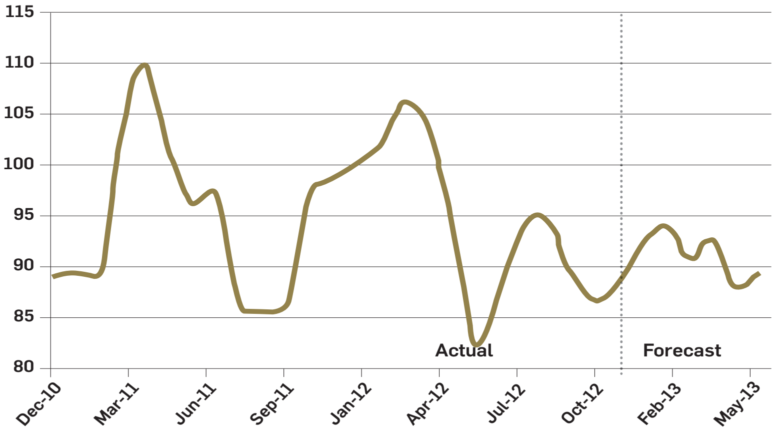
The question is then if expectations about oil prices are rational or irrational. The former are hypothesis which states that agents' predictions of the future value of economically relevant variables are not systematically wrong. That is, all errors are randomly distributed. Equivalently, the realization of a specific event equals an agent’s expectations given all the relevant information prior to that event. The alternative formulation is that agents inside the model assume the model's predictions as valid. To assume rational expectations is to assume that agent's expectations may be individually wrong, but are correct on-average. In other words, although the future is not fully predictable, agents' expectations are assumed not to be systematically biased and use all relevant information in forming expectations of economic variables.

This way of modeling expectations was originally proposed by John F. Muth (1961) and later became influential when it was used by Lucas and Prescott (1971). Modeling expectations is crucial in all models which study how a large number of individuals, firms and organizations make choices under uncertainty. Can expectations, even if we hold that they are rational, be formed when facing a random walk (RW) hypothesis?

For Markov chains (or Markov processes) they can. In our case however, we assume that oil prices do not move as RW and that players making their bets in a truly a global market follow, even if unconsciously, one of the infinite patterns of expectations' behavior. Thus indicating that the previous price of oil is, in some way or another, the best indicator to buy or sell. That being the case, we can, for example, follow the path the price of a fluctuating stock as we would trace a molecule as it travels in a liquid. In recent months, given the market stratification produced by the shale gas revolution in America and thus the wider difference between Brent and WTI (West Texas Intermediate) oil markers, investors are prospering by following a typical expectations rule: anyone who bought the best-performing stocks of the previous month would enjoy returns higher than someone who bought the previous month's "potential" performers. Game theory helps to explain that this 'anomaly' can be associated to the player's decision to push efficiency.

As mentioned, oil trades with some small but widening differences in different locations around the world, create opportunities for investors that see many baskets of equities available highly correlated and sensitive to market restrictions. The WTI, the benchmark crude for North America (Figure 1), shows such trend clearly when one associates the trajectory to geoplitical and sector-specific actions. Every government around the world, whether they are a consuming or producing nation, pays a great deal of attention to the international price of crude oil; which says something about how universal and strategic oil is, but also what kind of factors are key to impact on them. Ben Bernanke, the Chairman of the U.S. Federal Reserve, never gives a speech or comments without referring to the international price of crude oil. It is as if the world's spotlight were constantly on crude oil. But how can anyone guess the level or tendency of a future price, continues to be a mystery.

■ Figure 1. **Crude Oil Prices**
(Past Trend & Future Projection. West Texas Intermediate. US Dollars per barrel)



SOURCE: FROM INTERNET: Y-CHARTS. WTI CRUDE OIL SPOT PRICE HISTORICAL DATA

Elroy Dimson, Paul Marsh, and Mike Staunton of the London Business School (LBS) looked at the largest 100 stocks in the British market since 1900 (The Economist, June 2011). They calculated the return from buying the 20 best performers over the past 12 months and then holding them, rebalancing the portfolio every month. This (similar to following a Regressive Expectations Model) produced an annual average of 10.3 percentage points more than a strategy of buying the previous 12 months' worst performers. Following that procedure, an investment of $1.00 in 1900 would have grown into $2.5 million by the end of 2010. A similar amount invested following the Extrapolative Expectations Model would have turned into just $49.00.

Although it is firmly established that expectations play a central role in the determination of prices, little is known about their exact nature. How do we empirically test hypotheses about prices when expectations are unobservable? In the past, a popular way to get around this problem was to use the gap between future and spot prices as a proxy for the expected price. There are many obvious drawbacks to this approach; so, to avoid the joint nature of conventional hypothesis testing, an increasing number of researchers have recently begun to use survey data in tests involving price expectations. These analysts suscribe to the wide and growing camp of economists who believe that all information is contained in the price. They show strong professional resistance to the use of nonmarket data since there is no assurance that economic agents have enough incentive to disclose their truthful expectations and no precise link seems to exist between average (or individual) expectations and collective (marginal) prices in the commodities' market.

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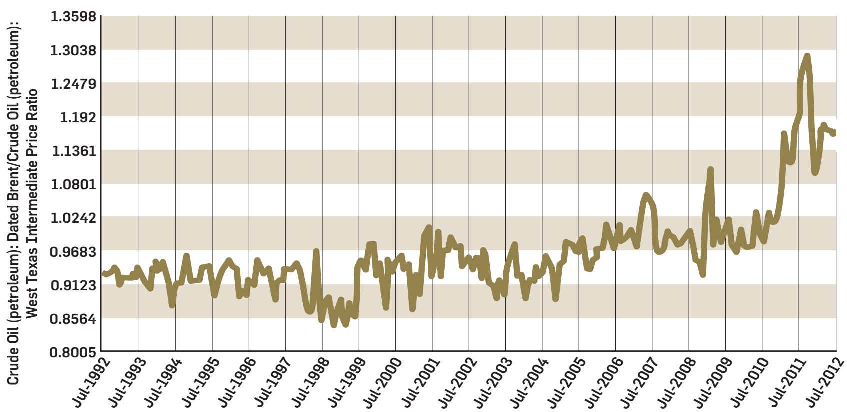
2. What *really* drives oil prices? A brief note on the evolution of oil prices and Expectations Formation

In the absence of better alternatives, an empirical literature based on survey data of oil price expectations has been expanding in recent years. For instance, Saudi Arabia (Aramco) recently and unilaterally increased production by 700,000 barrels per day, a year ago. The International Energy Agency (IEA) also approved the release of 60 million barrels from strategic reserves (half of that from the U.S.). Although Aramco's were to cushion the demand, that move actually had an effect on demand increases in China, India, Indonesia, Brazil, and Russia. And, as we now know, substantial increases in the supply of oil, given expectations of market reductions for emerging countries, which translated into increases in the need for more oil.

All said, it is important to keep in mind that sub-markets can have a great effect on how global expectations are formed. To understand how they work is important. Demand figures are registered by the London benchmark (BRENT) and are used more often to determine prices in regions other than the U.S., where WTI (West Texas Intermediate, the preferred oil marker for the U.S.) traded in New York is used. WTI is sourced from around North America and priced from the trading hub of Cushing, Oklahoma.

Brent crude is sweet light oil sourced from fifteen fields in the North Sea. "Sweet" refers to the sulfur content. The lower the sulfur content the easier it is to refine. "Light" relates to the ability of the oil to flow freely, which makes it easier to transport and refine (in comparison, oil from the Alberta tar sands is considered to be heavy as it is transported as diluted bitumen or "dilbit" and is much more difficult to refine). WTI is lighter and sweeter than Brent with a sulfur content of 0.24% compared to 0.37%.

Figure 2. **Monthly ratio of the nominal price of Brent divided by the price of WTI**



SOURCE: INDEXMUNDI.COM

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Petroleum products and crude oil produced in the North Sea, Africa, and the Middle East are generally priced relative to Brent oil prices, which price roughly two-thirds of the world's oils. As Figure 2 shows, Brent prices are now close to $20-a-barrel higher than WTI. Historically Brent prices lagged behind WTI until Brent began selling for more than WTI in the early 2000s for the first time. Since then Brent has gradually pulled away from WTI.

Let us take the most recent "crystal ball" estimates for the price of the global oil benchmark Brent barrel of oil: Goldman Sachs projects it will average $110 in 2013, while Morgan Stanley believes it will average $115. At the low end, Raymond James sees it averaging just $80. Deutsche Bank says the spread between analysts is even wider, with a $50 gap between the high and low forecasts. On the other hand, Paul Kedroski, a well-known analyst, wrote that the universe of oil price forecasts for 2015 shows less spread than you might expect. While some predict prices ranging from $200 and $250, others have a preponderance of forecasts between $80 and $140.

Thus, many factors affect the price of crude oil and crude oil products. World events also affect crude oil prices. The relative strength or weakness of the global economy and the economies of individual countries contribute. Weather and catastrophes can affect the price of crude oil. Fukushima and Hurricane Katrina were factors affecting prices. Political stability or instability in oil producing nations will also affect the price of crude oil. However, the Fundamental factor continues to be the supply-and-demand interaction. The effect caused by OPEC meetings debating whether to raise or lower production has a large impact on the future price of the commodity because it controls the supply available to consumers all over the world. The increase of demand in China and India also affects the fundamentals reported by both the U.S. Department of Energy and the American Petroleum Institute and therefore the level of crude oil and oil product stocks in the U.S.

In previous analysis that we have undertaken (see Villamizar and Villamizar, 2011) we see three factors that seem to be fundamental to determine the competiveness of oil companies: infrastructure (location), efficiency (productivity), and technology. New pipelines, better organizations, higher productivity and improved innovations are at the root of the price spread between Brent crude and WTI.

Drastic moves in crude oil prices in one location can and will affect the price of the crude oil on a global basis. But the most definite factor that can be attributed to price changes is *changing expectations* of world economic and crude oil consumption growth. Uncertainty over additional oil supply disruptions and long-term supply estimates of OPEC spare production capacity nicely reflect risks and therefore changes in the price of oil. One procedure used to measure expected price volatility

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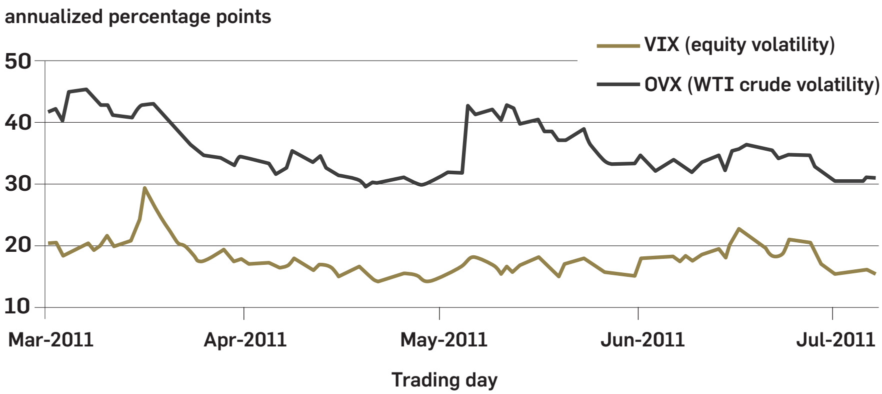
by the Chicago Board Options Exchange (CBOE) is the Oil Volatility Index (OVX). Contrasting the OVX and the VIX (Equity Volatility Index), as can be seen in Figure 3, provides a good measurement of comparative risk in both markets.

■ Figure 3. **Comparison of the OVX and the VIX (Equity Volatility Index)**



SOURCE: US EIA, CME GROUP

Nevertheless, even in light of all these factors affecting price movements and uncertainty, most analysts believe that the prediction power of the President of Exxon is not too different from that of your neighbor's 13-year-old daughter. That is why most simply flip the coin or look at time-series and "see" (with naked eyes) how well they can "incorporate" past changes and experiences into future perception trends.

3. Projecting Confidence Level: Our selection

According to the classification popularized by Frankel and Froot (1987), expectation can be extrapolative, adaptive, and regressive. This line of thinking coincides with what is called the "Chartist" Models (as opposed to "Fundamentalist" Models). The purpose of our statistical exercise is to use Chartists Models to compare the "goodness of fit" of a time-series of WTI daily prices assuming regressive, random walk, and extrapolative models. It should be noted in this exercise that no attempt is being made to determine which of the three expectations mechanisms is correct or even closest to actual expectations, only, which can better predict what has happened in the past.

Short-Run and Long-Run Expectations

Short-run (generally shorter than one month) and long run (generally longer than three months) expectations have been known to display strikingly different behavior. There is a belief that short-run expectations respond to lagged oil prices in the same direction, while long-run expectations tend to respond to lagged movements in opposite directions. This behavioral difference has generated considerable interest in recent years, but little empirical evidence has been given by either camp: the chartists or the fundamentalists.

The three types of expectations selected

We chose a first mechanism of expectation formation known as **extrapolative expectations.** It is presented in Equation (1)), where "S" stands for oil prices. This mechanism involves forecasting changes in energy prices with the use of past movements of the same frequency (i.e. past daily/monthly changes are used to forecast next period's daily/monthly changes).

$$S^{e}_{t+k} - S_t = \alpha_0 + \alpha_1 (S_t - S_{t-k}) + \varphi_t \qquad (1)$$

The fact that the expected oil price movement for the next period is given by the past currency movement for the most recent period—as indicated in Equation (1)—indicates that an extrapolated expectation of the spot price of oil for period $t + j$ is similar to a weighted average of the current spot price and the lagged price for period $t - j$. Different values of alpha may show a case of distributed lag, static expectation, or the case of bandwagon expectations.

The second mechanism, presented in Equation (2), is called **regressive expectations** and it incorporates deviations of energy prices with respect to a long-run equilibrium value, $\overline{S_t}$, in order to forecast future price movements. This process implicitly assumes that prices "regresses" (at speed γ_1) towards this long-run value, which can take the form of a constant, moving average, Purchasing Power Parity rate, or others.

$$S^{e}_{t+k} - S_t = \gamma_0 + \gamma_1 (S_t - \overline{S_t}) + \omega_t \qquad (2)$$

In this formulation, the expected oil prices can also be expressed as a weighted average of the current oil prices and the long-run equilibrium oil prices.

4. Results

Our statistical exercise consisted of estimating the same three valuation statistics chosen in Meese and Rogoff (1982) (Mean Error, Mean Absolute Error and Root Mean Square Error) to measure out-of-sample accuracy for several expectations models containing the three mechanisms explained above. Three models were finally selected based on the results obtained: the Regressive model, the Random Walk model, and the Explorative model. Table 1 summarizes the results obtained. As can be seen, the Regressive model out-performs both the Random Walk and the

Explorative model, showing the lowest numerical values for the three valuation statistics chosen.

Table 1. Comparison of predicting expectation models

	Regressive	Random Walk	Extrapolative
Mean Error	1.1	1.8	–1.7
Mean Absolute Error	**84.1**	84.2	84.9
Root Mean Square Error	**136.9**	137.0	137.3

Below, the definitions used to measure out-of-sample accuracy for the three models chosen.

$$\text{Mean Error} = \sum_{i=0}^{N_k\text{-}1} \frac{P_x(wti_{t+1+i} - wti_{t+1}) - (wti_{t+1+i} - wti_{t+1})}{N_k}$$

$$\text{Mean Absolute Error} = \sum_{i=0}^{N_k\text{-}1} \frac{|(wti_{t+1+i} - wti_{t+1}) - (wti_{t+1+i} - wti_{t+1})|}{N_k}$$

$$\text{Root Mean Square Error} = \sum_{i=0}^{N_k\text{-}1} \left\{ \frac{[P_x(wti_{t+1+i} - wti_{t+1}) - (wti_{t+1+i} - wti_{t+1})]^2}{N_k} \right\}^{\frac{1}{2}}$$

Where N_k is the total number of forecasts and $P_x = x(x'x)^{-1}x'$ is the projection matrix of the expected devaluation onto the covariates "x" of each specified model. Our main criterion to compare model's performance is the root mean square error, but we also use the mean absolute error in case the exchange rate contains a fat tail distribution or follows a non-normal Paretian process with infinite variance. Mean errors are also published to evidence under-prediction or over-predictions (depending on the sign) of the different models.

5. Conclusion

Whether you are a trader, an investor, or an academic, it is comforting to know that there is light, that more work in longer and more complex regressive expectations can lead to more accurate oil price predictions. We consider it a great step forward to have found that by using short term frequency oil prices to test two types of expectations (Regressive Expectations and Extrapolative Expectations) and comparing their performance behavior to the Random Walk benchmark, oil prices did not always behaved in a completely random fashion. As shown, we studied three main processes of expectation formation, following well-known methodologies used to compare their forecasting accuracy. People generate expectations (not all rational) to make decision about their future behavior. Thus, by using a rich database of oil prices from 1997-2011 (daily, weekly, and monthly) we were able to test different types of expectations against the Random Walk benchmark. When using rolling regressions to re-estimate parameters of each model for every period and measuring out-of-sample accuracy by running more than 3,600 regressions, we obtained a "goodness" of fit on the Regressive Expectations assumption that out-performed both the Random Walk and the Explorative model. If this result holds for a wider time period and different oil price database (e.g., using Brent time series data), we are facing a break-through: oil prices are not (always) a Random Walk in nature. Therefore, if oil prices are not totally random, there is a new window of opportunity to research the volatile determinants that act upon it. Our friendly advice to traders and investors is to put their money where they have put it before, regressively, even if unknowingly so; in addition, to look deeper into past behavior and re-construct their regressive expectations more accurately… That would, we believe, considerably lower future investment risks.

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