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# Regime switching model of US crude oil and stock market prices: 1859 to 2013☆

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ABSTRACT

This paper examines the relationship between US crude oil and stock market prices, using a Markov-Switching vector error-correction model and a monthly data set from 1859 to 2013. The sample covers the entire modern era of the petroleum industry, which typically begins with the first drilled oil well in Titusville, Pennsylvania in 1858. We estimate a two-regime model that divides the sample into high- and low-volatility regimes based on the variance–covariance matrix of the oil and stock prices. We find that the high-volatility regime more frequently exists prior to the Great Depression and after the 1973 oil price shock caused by the Organization of Petroleum Exporting Countries. The low-volatility regime occurs more frequently when the oil markets fell largely under the control of the major international oil companies from the end of the Great Depression to the first oil price shock in 1973. Using the National Bureau of Economic research business cycle dates, we also find that the high-volatility regime more likely occurs when the economy experiences a recession.



## 1. Introduction

Macroeconomic policymakers consider wealth as an important driver of the economy and view asset prices as important predictors of the business cycle. Researchers have long followed the stock market in the US as an important predictor of the business cycle (Chauvet, 1998–1999; Moore, 1983; Siegel, 1991). For example, Siegel (1991) determines that for the 41 recessions observed since 1802, at least an 8-percent loss in stock returns preceded 38. On the negative side, 12 false signals occurred using this criterion, where no recession followed. Seven of these false signals happened after WWII. Other researchers consider the predictive ability of crude oil prices. Hamilton (2003, 2009) argues that oil price shocks proximately cause post-WWII recessions in the US.[1]

The existing literature contains several attempts to identify the effects of changes in crude oil prices on certain macroeconomic variables, such as, real GDP growth rates, inflation, employment, and exchange rates (Hamilton, 1983; Gisser and Goodwin, 1986; Mork, 1989; Hooker, 1996; Davis and Haltiwanger, 2001; Hamilton and Herrera, 2002; Lee and Ni, 2002; Hooker, 2002, and so on). These research papers differ from each other and do not produce a general consensus.

Fewer research papers examine the relationship between crude oil prices and other asset prices, such as stock prices or stock returns. Market participants want a framework that identifies how oil-price changes affect stock prices or stock market returns. On theoretical grounds, oil-price shocks affect stock market returns or prices through their effect on expected earnings (Jones et al., 2004). The relevant literature includes the following studies. Kaul and Seyhun (1990), Sadorsky (1999), Hong et al. (2004), O'Neil et al. (2008) and Park and Ratti (2008) report a negative effect of oil-price volatility on stock prices. Sadorsky (2001) finds, on the contrary, a positive relationship between oil prices and stock returns. Jones and Kaul (1996) show that international stock prices do react to oil price shocks. Huang et al. (1996) provide evidence in favor of causality effects from oil futures prices to stock prices. More recently, Faff and Brailsford (2000) report that oil-price risk proved equally important to market risk, in the Australian stock market. Pollet (2005) and Driesprong et al. (2008) find that oil-price changes predict stock market returns on a global basis, while Hammoudeh and Li (2004), Hammoudeh and Eleisa (2004) and Malik and Hammoudeh (2007) also discover the importance of the oil factor for stock prices in certain oil-exporting economies. Bittlingmayer

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[1] Even other views exist, however. For example, Leamer (2007) argues that "housing is the business cycle," showing that significant declines in housing construction preceded 8 of the last 10 recessions. Iacoviello and Neri (2010) estimate a DSGE model and consider the role of the housing market in the propagation of the business cycle. They conclude that "… spillovers from the housing market to the broader economy are non-negligible, concentrated on consumption rather than business investment, and have become more important over time, …" (p. 57).

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(2005) documents that oil-price changes associate with war risk and those associated with other causes exhibit an asymmetric effect on the behavior of stock prices. Sawyer and Nandha (2006), however, using a hierarchical model of stock returns, report results against the importance of oil prices on aggregate stock returns, while they retain their explanatory power only on an industrial (sectoral) level. Finally, Gogineni (2008) also provides statistical support for a number of hypotheses, such as oil prices positively associate with stock prices, if oil price shocks reflect changes in aggregate demand, but negatively associate with stock prices, if they reflect changes in supply. Moreover, stock prices respond asymmetrically to changes in oil prices.

Recently, however, researchers began asking whether changes in macroeconomic variables cause oil price changes, leading to the decomposition of those oil price changes into the structural shocks hidden behind such changes (Kilian, 2008a; Kilian and Park, 2009). That is, different sources of oil price changes may imply non-uniform effects on certain macroeconomic variables. More specifically, the relevant literature generates mixed views regarding the effect of such oil-price shocks on asset prices, such as stock prices. Chen et al. (1986) argue that oil prices do not affect the trend of stock prices, while Jones and Kaul (1996) present evidence that favors a negative association. This negative relationship, however, does not receive support by Huang et al. (1996) and Wei (2003).

Kilian (2008a) criticizes all these analyses, because researchers treat oil-price shocks as exogenous. Certain work, however, argues that oil prices respond to factors that also affect stock prices (Apergis and Miller, 2009; Barsky and Kilian, 2002, 2004; Hamilton, 2005; Kilian, 2008b). Thus, researchers must decompose aggregate oil price shocks into the structural factors that reflect the endogenous character of such shocks.

Thus, this paper investigates the relationship between the Standard and Poor's S&P 500 (SP500) stock market index and the West Texas Intermediate (WTI) spot crude oil price from September 1859 through December 2013, using a Markov-switching vector error-correction (MS-VEC) model. The MS-VEC model includes two regimes — high- and low-volatility regimes. One unique feature of our analysis is that the sample period runs from the beginning of the modern era of the petroleum industry with the drilling of the first oil well in the US at Titusville, Pennsylvania in 1859.[2] The world economy experienced the Great Depression, leading to an 86-percent decline in the SP500 index from October 1929 through June 1932 and a 68-percent decline in the WTI price from January 1929 through May 1933. Fig. 1 documents that the WTI price remained relatively stable from World War II until the effective emergence of Organization of Petroleum Exporting Countries (OPEC) in 1973. That is, although OPEC formed in 1960, they did not exert significant control over world crude oil prices until the countries in OPEC nationalized their domestic oil industry. Fig. 1 also shows that the WTI price experiences much more volatility post-1973.

Our findings imply that the high-volatility regime more frequently existed prior to the Great Depression and after the 1973 oil price shock caused by the OPEC. The low-volatility regime occurred more frequently during the period of time from the end of the Great Depression to the first OPEC oil price shock, where the oil markets fell largely under the control of the major international oil companies. We also find a proclivity for the high-volatility regime to occur when the economy experiences a recession.

The paper unfolds as follows. Section 2 outlines the methodology used in the analysis. Section 3 implements the several steps in estimating the MS-VEC – data description, unit-root tests, cointegration tests, MS-VEC estimation, calculation of smoothed probabilities of the high-volatility regime, and impulse response analysis – and discusses the findings. Section 4 concludes.

## 2. Methodology

Conventional wisdom suggests that macroeconometric time-series models must address structural change and/or regime shift (see Granger, 1996). Indeed, the survey paper by Hansen (2001) or Perron (2006) affirms that econometric applications should distinctly consider regime shifts.

Econometricians recently developed new models that can tackle sufficiently certain types of structural changes. One appealing method, the Markov switching (MS) approach proposed by Hamilton (1990) and later extended to multivariate time-series models by Krolzig (1997, 1999), can address structural breaks. Hamilton (1990) introduced univariate Markov switching autoregressive (MS-AR) models while Krolzig (1997, 1999) developed multivariate extensions to Markov switching vector autoregressive (MS-VAR) and Markov switching vector error correction (MS-VEC) models. The MS models fall within the category of nonlinear time-series models that emerge from nonlinear dynamic processes, such as high-moment structures, time-varying parameter, asymmetric cycles, and jumps or breaks in a time series (Fan and Yao, 2003). The long sample period includes several influential prior events, such as the Panic of 1907, the Great Depression, World War I and II, the first and second OPEC oil-price shocks, and more recently the global financial crisis and Great Recession of 2008. The data also includes a significant number of influential business cycles. MS models can provide a good fit to such time series data with business cycles features and regime shifts.

Several studies successfully use MS models to analyze aggregate output and business cycles (e.g., Diebold et al., 1994; Durland and McCurdy, 1994; Filardo, 1994; Filardo and Gordon, 1998; Ghysels, 1994; Hamilton, 1989; and Kim and Yoo, 1995). Numerous studies also utilize MS models in the context of stock market returns (e.g. Kim and Nelson, 1998; Kim et al., 1998; Pagan and Schwert, 1990; Schwert, 1989 and Tyssedal and Tjostheim, 1988). Following these studies, we consider the MS-VEC model, which, with its rich structure, can accommodate the dynamic features of oil and stock price data in our sample. The model choice unlike other traditional models not only efficiently captures the dynamics of the process in a co-integration space, but also possesses an appealing structural form and provides economically intuitive results.

The method chosen uses a vector-error-correction (VEC) model with time-varying parameters where, given our objectives, the parameter time-variation directly reflects regime switching. In this approach, we treat changes in the regimes as random events governed by an exogenous Markov process, leading to the MS-VEC model. A latent Markov process determines the state of the economy, where the probability of the latent state process takes a certain value based on the sample information. In this model, inferences about the regimes reflect the estimated probability, which measures the probability of each observation in the sample coming from a particular regime. The MS-VEC model analyzes the time-varying dynamic relationship between the monthly spot crude oil and stock prices and extends the class of autoregressive models studied in Hamilton (1990) and Krishnamurthy and Rydén (1998).

[2] The modern era began in the middle of the 19th Century with the discovery of how to refine kerosene (and paraffin) from crude oil and the invention of the kerosene lamp. Kerosine replaced whale oil as the fuel of choice for lamps. The discovery by Edison of the first commercially practical incandescent light bulb in 1879 led to a phasing out of kerosene lamps. The invention of a commercially successful internal combustion engine in 1879 boosted the demand for gasoline and other petroleum distillates for transportation purposes. As we see from Fig. 1, the early part of our sample sees boom and bust cycles in the WTI series. That is, crude oil production and demand experienced significant swings after the birth of the modern era. As the petroleum industry matured, price wars among the major international companies in the 1920s led to the 1928 Achnacarry Agreement, which established the international petroleum cartel (Federal Trade Commission, 1952). The Agreement divided markets, fixed prices, restricted production, and limited competition. The fixed prices supported the profitability of "high-cost" producers of petroleum and the market divisions and production restrictions attempted to prevent "low-cost" producers from lowering prices to expand their market shares.