Crude oil price: demand, supply, economic activity, economic policy uncertainty and wars – from the perspective of Structural Equation Modelling

Qingfeng Wang[a] , Xu Sun[b]

a. Nottingham University Business School China, University of Nottingham, Ningbo, Chinab
b. Department of Mechanical, Materials and Manufacturing Engineering, University of Nottingham, Ningbo, China

Abstract

We studied the relationship between the change in the price of oil and some of its determinants, using the structural equation model. The demand for oil is confirmed to be inelastic to the change in oil price during our sampling period. Economic activity is found to be the most significant factor in explaining the dynamics of oil price. Wars and political tension, among the largest oil producing countries and neighbouring countries, are found to have a significant indirect effect on the price of oil through their effect on oil supply, but no significant direct effect was confirmed by the SEM.

Keywords: crude oil, wars, economic policy uncertainty, Killian economic index, structural equation modelling

1. Introduction

The price of oil can be determined by many factors in addition to(?) the demand and supply of oil, such as the global economic outlook, economic policy and regulatory uncertainty in countries with large oil consumption, and political stability in oil exporting countries. Historically, the price of oil has been closely associated with wars and political tension (Lieber 1992, Yergin 2012). In 1973, the Arab-Israeli war led to the OPEC oil embargo which resulted in a substantial increase in the oil price (Tignor et al. 2013). Disruptions in oil supplies, as a result of wars and political tension, have significant explanatory power in the fluctuations of oil prices (Kilian 2010). Wars and political tension in oil exporting countries, such as those in the Persian Gulf, create uncertainty in the oil supply which is reflected in the oil price development during ongoing war periods and the aftermath thereof (Kilian 2009). Previous research has confirmed that oil price can affect economic activity (Elder et al. 2010, Rahman et al. 2011, Hamilton 1983) via diverse channels, including monetary policy channels. At the same time, and to some degree, economic activities determine the dependency of economies on crude oil. Dramatic changes in the oil price create a considerable amount of economic uncertainty, which could be echoed in economic policies and regulations. Uncertainties in investment decisions made at a micro-level owing to oil price uncertainty, feed into policy decision making at a macro-level, which then generate a cyclical fluctuation at the macro-level (Bernanke 1983). For example, on the one hand, an increase in the oil price induced a rise in federal government purchases (Gelb 1988), while on the other hand, governmental subsidies on fuel consumption have driven oil prices to an exaggeratedly high level (Saporta et al

2009) and have made the demand for oil even more inelastic.

2. The empirical model

2.1 Data

In this study, we use both the West Texas Intermediate (WTI) crude oil price in Chicago and the Brent Europe crude oil price to measure the price of oil. Commonly, in previous empirical studies, only one of the two crude oil prices has been used to measure the price of oil. The differences between the two prices range from 0.01 to 27.31 dollars per barrel during our sampling period, hence the use of the two crude oil prices may capture different aspects of the dynamics of the price of oil. Data for the two crude oil prices are taken from the Federal Reserve Bank of St. Louis. As the price of oil data is a nonstationary, based on the Dick Fuller test, we have used the change in the price of oil as our dependent variable for this study.

We measure economic policy uncertainty using the economic policy uncertainty (EPU) index recently developed by Baker et al. (2013). This measure is a news-based measure of economic policy uncertainty.
We measure global economic activity using the US equity market uncertainty index, also developed by Baker et al. (2013), the FTSE 100, the Shanghai Stock Exchange (SSE) Composite Index, as well as the Killian Economic Index. The US equity market uncertainty index is constructed through an analysis of news articles containing terms related to equity market uncertainty, which aims to measure equity market-related economic uncertainty. The Killian Economic Index is a monthly data measure of global economic activity; the data has been taken from Killian's official website. Monthly data for both the FTSE 100 and the SSE Composite Index have been extracted from Yahoo Finance. The global demand for crude oil is measured by the monthly oil consumption in China, India, Germany, Japan and the US, as identified in the factor analysis among the countries with the highest levels of oil consumption. The global supply of crude oil is measured by the monthly oil supply from Algeria, Iran, Nigeria, Kuwait, Saudi Arabia, Russia, Venezuela and the United Arab Emirates, as identified in the factor analysis among the countries with the largest oil supply. Both data for oil demand and oil supply are taken from the US Energy Information Administration. Wars and political tension are measured by the interstate, societal, and communal warfare magnitude scores[1] which are taken from the Centre for Systemic Peace.

Hamilton (2013) classifies 1973 to 1996 as "the age of OPEC" and 1997 to the present as "a new industrial age." Our sample begins in Jan 1997 coinciding with this "new industrial age" but it was limited by the availability of some of our data series. All data series are at monthly frequencies except the data for wars (and political tension) which is annual data[2]. All data have been normalized; that is we have divided the data for each factor by the highest value from that factor. For example, every single piece of oil consumption data from the US is divided by the highest monthly quantity consumed during the sampling period for the US There are at least two advantages of implementing this normalization. Firstly,

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[1] Magnitude scores are with scale from 1 to 10: 1 (lowest) to 10 (highest) and 0 denotes no episodes of political violence.

[2] Annual frequency data on magnitude score is transformed to a monthly frequency based on the following method: if the current year's magnitude scores minus the previous year's magnitude scores = 0, then monthly data in the current year will have the same magnitude score as the previous year; if the difference in the magnitude scores is > 0 (<0) between the current year and the previous year, then monthly data in the current year is the previous year's magnitude score plus (or minus) $\frac{sequential\ order}{12} *$ the absolute difference.

the normalized dataset inherits exactly same pattern of the original data.

uncertainty at a global level can be difficult to measure and is prone to error if

Table 1 FACTOR ANALYSIS

Constructs	Factors	Factor Loadings	AVE [3]
Economic Policy Uncertainty (EPU)	China, France, Germany, UK, US	.794 -.938	.766
Oil Consumption (OC)	China, India, Germany, Japan, US	.674 -.921	.658
Oil Supply (OS)	Algeria, Iran, Nigeria, Kuwait Saudi, Russia, Venezuela United Arab Emirates	.642 -.980	.769
Wars (and political tension)	Iran, Kuwait, Saudi, Iraq	.578 -.921	.563
Economic Activity (EA)	The Kilian Economic Index, London FTSE 100; US Equity market index; Shanghai Stock Exchange Composite	.697 -.798	.706
Price of Oil (PoOil)	West Texas Intermediate crude oil price; Brent Europe crude oil price	.993, .997	.990

measured directly, but it can be measured more accurately by using country level data from countries which have been confirmed to be significant in measuring the overall economic policy uncertainty based on the factor analysis. A sample size of approximately 200 cases (cf. Hoogland and Boomsma 1997) is needed to provide a reasonably good estimate of parameters in the SEM

. The sample size of our dataset is equal to 191 as the price of oil in 1997:1 is used to compute the first change in the price of oil. Based on the previous studies mentioned in the introduction section, our conceptual model is depicted in Fig. 1.

Secondly, we can compare the magnitudes of effects made by different variables on the price of oil as all data have been scaled to the same interval of $(0, 1]$.

2.2 Factor analysis

Factor analysis with varimax rotation is used to confirm the factors to be used to measure each construct. Only factors with a factor loading >0.5 are used to measure their corresponding construct. The average variance extracted (AVE) of each construct was used to confirm the measurement model. Convergent validity is achieved if the AVE for each construct is greater than 0.50 (Fornell and Larcker 1981). The AVE for each of the constructs is well above 0.50 and, therefore, convergent validity is supported. Those factors which have been selected to measure each construct are presented in Table 1.

2.3 Structural equation modelling

In structural equation modelling, multiple factors are used to measure each latent construct. For example, economic policy

[3] AVE was calculated based on the formula given by Fornell and Larcker(1981), AVE $= \frac{\sum_{i=1}^{n} \lambda_i^2}{n}$ where λ is the factor loading, and n is the number of factors.

$$\text{PoOil}_t = \omega_1 * WTI_{oil_t} + \omega_2 * BRENT_{EUROPE_{oil_t}} + \zeta_7,$$

Table 2 ESTIMATIONS RESULTS (SEM)

		Estimate	***S.E.***	***C.R.***	***P-value***
EPU	→ the Price of Oil	.074	.042	1.767	.077
Oil Consumption	→ the Price of Oil	-.031	.633	.049	.961
Oil Supply	→ the Price of Oil	-.532	.073	-7.248	***
Wars	→ the Price of Oil	.002	.001	1.131	.258
Economic Activity	→ the Price of Oil	2.516	.789	3.190	***
Wars	→ Oil Supply	-.051	.007	7.136	***
Economic Activity	→ Oil Consumption	.008	.193	.042	.966

NOTES: *** Denotes significance <0.1%

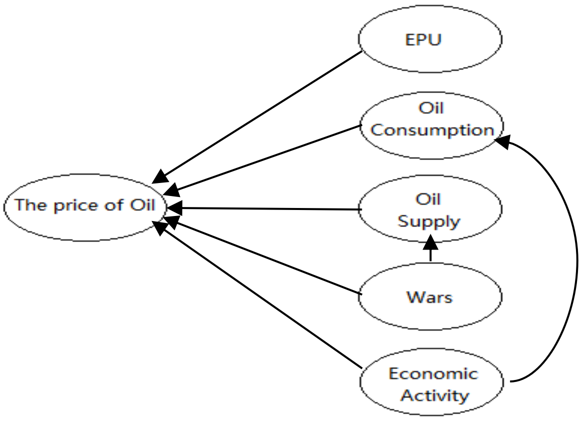

Fig. 1 Conceptual model

With SEM, we are able to examine the direct effect of the demand for oil, the supply of oil, and wars, economic activity and economic policies on the price of oil at an aggregate level, utilizing a measurement model that measures each construct with several factors (i.e., a time series of(?) data from several countries), and then structure a model that estimates simultaneously the parameters of interest. Estimated parameters in the SEM minimize the difference between the estimated covariance matrices of the best fitting model and the actual covariance matrices representing the relationships between variables. The structural equations for this model are

$$\text{PoOil}_t = \alpha_1 * EPU_t + \alpha_2 * OC_t + \alpha_3 * OS_t + \alpha_4 * Wars_t + \alpha_5 * EA_t + \zeta_1$$

$$\text{EPU}_t = \gamma_1 * CN_{EPU_t} + \gamma_2 * FR_{EPU_t} + \gamma_3 * GE_{EPU_t} + \gamma_4 * UK_{EPU_t} + \gamma_5 * US_{EPU_t} + \zeta_2$$

$$\text{OC}_t = \gamma_1 * CN_{OC_t} + \gamma_2 * IND_{OC_t} + \gamma_3 * GE_{EPU_t} + \gamma_4 * UK_{OC_t} + \gamma_5 * US_{OC_t} + \gamma_6 * EA_t + \zeta_3$$

$$\text{OS}_t = \beta_1 * ALG_{OS_t} + \beta_2 * IRA_{OS_t} + \beta_3 * NIG_{OS_t} + \beta_4 * KUW_{OS_t} + \beta_5 * SAU_{OS_t} + \beta_6 * RUS_{OS_t} + \beta_7 * VEN_{OS_t} + \beta_8 * UAE_{OS_t} + \beta_9 * Wars + \zeta_4$$

$$\text{Wars}_t = \lambda_1 * \text{IRA}_{\text{Wars}_t} + \gamma_2 * KUW_{Wars_t} + \gamma_3 * SAU_{Wars_t} + \gamma_4 * IRQ_{Wars_t} + \zeta_5$$

$$\text{EA}_t = \upsilon_1 * Kilian_t + \upsilon_2 * FTSE_t + \upsilon_3 * US_{EqIndx_t} + \upsilon_4 * SHSEC_{Index_t} + \zeta_6$$

where, for example, CN is the abbreviation for China, FR is for France.

The estimation results are presented in Table 2. Our principle results show that economic activity, measured by the Killian economic index and equity market indices[4], had the largest positive and significant effect on the price of oil. Boosts in economic growth and positive economic outlooks contribute to higher oil prices, while sluggish economic growth and negative economic outlooks put pressure on the price of oil. Oil supply has been identified as the second most influential factor in explaining the changes in the

[4] The equity (stock) markets have traditionally been viewed as an indicator of the performance of economies.

price of oil, next to economic activity. For example, a 1% increase in the global supply of oil could lead to a decrease in the price of oil of approximately 5.3%. Economic policy uncertainty is only found to have some mild explanatory power on the change in the price of oil. Wars is not confirmed to have a direct effect on the price of oil during the sampling time periods, but is confirmed to have a highly significantly negative direct effect on the oil supply. Wars (and political tension) can affect the price of oil indirectly through their effects on the supply of oil. Oil consumption is found to be insignificant in explaining the dynamics of the price of oil during the sampled time periods, which is probably due to the fact that the demand for oil is strongly price inelastic during these time periods (Cooper 2003).

3. Conclusion

Crude oil is considered to be strategically important to the global economic system (Hamilton 1983). Most previous research on the study of the price of oil has used either GARCH, initially proposed in Bollerslev (1986), or the VAR model (cf. Park and Ratti 2008; Cunado and Perez de Gracia 2013), which was initially proposed by Sims (1980). We believe there is merit in using SEM in the study of the relationship between the price of oil and its determinants, as well as other economic and social science research. The use of SEM can raise the explanatory power of our regression on explaining changes in the price of oil and, at the same time, can avoid potential multicollinearity when all variables are simultaneously included in a regression directly. It can be difficult to measure the effects of oil consumption on the price of oil at the aggregate level by using the GARCH and VAR models, but this can be done easily by using the measurement model in SEM. In determining the effect of oil consumption on the price of oil, one may simply add together the oil consumption of large oil importing countries to measure the aggregate oil consumption at a global level. This method may have ignored the valuable idiosyncratic patterns of the oil consumption observed in these countries, while SEM can both measure the aggregate oil consumption and distinguish the importance of the oil consumption in different countries in determining the price of oil, as different weights are assigned to the oil consumption in different countries in the measuring of the aggregate oil consumption at a global level. Furthermore, our findings suggest that the effect of wars on the price of oil between Feb 1997 and Dec 2012 is mainly through their impact on the supply of oil. This indirect effect can also be difficult to identify with the GARCH and VAR models, but is feasible with SEM.

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