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Forecasting spot oil price in a dynamic model averaging framework — Have the determinants changed over time?

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ABSTRACT

This paper is aimed on the analysis of monthly spot oil prices (WTI) between 1986 and 2015. The methodology is based on Dynamic Model Averaging (DMA) and Dynamic Model Selection (DMS) framework. The important feature of DMA method is an allowance for both time-varying coefficients and large state space model (i.e., the set of oil price determinants can change in time). Within this framework it was explicitly shown how the significance of oil price determinants vary in time. These determinants itself were chosen with respect to some previous studies. Contrary to the currently reported DMA applications in some other fields, no significant evidence was found that DMA is superior over, for example, ARIMA model. However, DMA could also not been rejected as a significantly worse model due to certain statistical tests. The performed DMA analysis was checked for robustness on various model parameters and for certain computational issues.

It was found, for example, that in the context of the 2008 oil price peak exchange rates and stock markets were important oil price drivers, whereas oil production or oil import were just minor determinants. Some role of the change in inventories was found, but not greater than the one in 1991. The role of China's economy as an oil price driver in 2008 was found to be relatively smaller than in other time periods. Also, the robustness of these findings was discussed.

1. Introduction

Predicting spot oil price is often assumed an intractable task, because the oil market is quite complex. For example, Yang et al. (2002) provided evidence how various factors can lead to non-linear and chaotic effects in this market. On the other hand, oil price is one of the most important factors in case of long-term energy forecasting. (Herein, if not stated otherwise by the oil price a spot price will be understood.) Therefore, it is quite common that researches focus only on supply–demand factors (Hagen, 1994; Dees et al., 2007). Actually, in such a context the high inelasticity of both supply and demand on the oil market should be noticed (Angelier, 1991).

Because of these, there is no fixed or commonly accepted forecasting technique for oil price. The most often used methods are those based on prices of future contracts. However, the predictive power of such methods is highly questionable — even in comparison with the naive forecasting (Alquist and Kilian, 2010). Moreover, the interaction of spot and futures prices can be quite complicated on the oil market (Acharya et al., 2013), leading to complicated or unsatisfactory methodology. Here it will be shown that certain Bayesian method can significantly beat future contracts-based forecasting.

Indeed, this research is a try to fill the existing gap in the literature by applying a certain, newly proposed Bayesian method, i.e., Dynamic Model Averaging (in short: DMA). This approach, with detailed explanations and references, was proposed in a paper by Raftery et al. (2010). As far as now, this framework has been successfully applied in economics to inflation, gold and U.S. house prices predictions (Koop and Korobilis, 2012; Baur et al., 2014; Aye et al., in press; Bork and Moller, 2015). Except a direct forecast this method allows to estimate the probability that a given determinant would be useful (i.e., included) in the forecasting model in a given time period. In other words, the degree of importance of a potential determinant can be calculated for a given time moment. Thus, DMA also helps to quantitatively detect oil price drivers in selected time periods. Indeed,

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in contrary with other already used econometric methods, DMA allows for both – a set of predictors (i.e., a model) and its coefficients – to change in time.

In view of literature indicating different determinants of oil price for different time periods, the above feature is of a great interest. The spirit of this research is to avoid preselection of a particular model (or models), but to focus on how likelihoods that certain predictors are indeed significant change in time. In DMA plethora of models can be considered. Of course, this leads to serious computing power problems. However, certain useful approximations (Raftery et al., 2010) are already at hand and can be used to avoid these obstructions. In particular, the hardest problem of estimation of a model transition matrix is not necessary. Still, both a model and its coefficients can change in time, and this feature distinguishes DMA from other already applied weighted forecasting methods. In DMA a weight of the model in a particular period is directly connected with the model's predictive likelihood based on the past information. Therefore, the dynamic feature unveils that weights, in fact, evolve in a certain recurrence scheme since the initial moment of time.

This paper is organized as follows. First, a brief literature review is presented. This serves as a foundation to select potential oil price determinants in consistence with the economic theory and previous empirical researches. It should be stressed that in DMA one includes just a potential driver, even if it is significant only in a short period. There is no need to argue that a given determinant is significant in the whole analysed period. Indeed, its significance can be quantitatively measured after the DMA model is estimated, and such a measurement is a great advantage of DMA. In other words, DMA is similar to Bayesian Model Averaging (BMA), which deals with a model uncertainty.

Next, the crucial steps of DMA are described in order to present how the numerical outcomes were derived. Finally, the results are presented and discussed. In particular, the forecast accuracy is discussed and compared with other techniques. It is also examined if and how the role of selected oil price determinants change in time and what the current research can bring for various energy market participants. In the end, a few remarks about further modifications of DMA are proposed.

2. Literature review

Oil price fluctuations are crucially important for both oil-importing and oil-exporting countries. Indeed, oil price is a key for many macroeconomic forecasts. Therefore, they are of high interest not only for private investors, but also for several government agencies and central banks. There are various theoretical approaches to modelling oil price. From the econometrics point of view, a short review of most popular ones is presented in Table 1. Herein, in DMA approach one focuses on building possibly large set of potential oil price predictors. Actually, this method can be used to analyse which of these predictors drive oil price in various time periods. In order to construct such a set, one has to collect many potential predictors. Therefore, one should not argue that a given predictor is significant in the whole sample period, but just that there is evidence that such a predictor might be significant in some subperiod of the whole analysed period. Consequently, it is crucial to review the current state of the art and collect quite many predictors out of the already existing studies.

Table 1
Selection of various forecasting methods.

Method	Reference
Time-series models	Lanza et al., 2005; Pindyck, 1999; Silva et al., 2010; Wei et al., 2010; Vo, 2009
Financial models	Agnolucci, 2009; Alexander and Lazar, 2006; Alizadeh et al., 2008; Coppola, 2008; Fong and See, 2002; Nomikos and Pouliasis, 2011; Sadorsky, 2006; Schwartz and Smith, 2000; Yousefi et al., 2005; Zeng and Swanson, 1998
Structural models	Dees et al., 2007; Huntington, 1994; Kaufmann et al., 2008; Lalonde et al., 2003; Merino and Ortiz, 2005; Mirmirani and Li, 2004
Artificial neural networks	Kulkarni and Haidar, 2009; Shambora and Rossiter, 2007; Yu et al., 2008
Support vector machines	Fernandez, 2007; Xie et al., 2006
Qualitative methods	Gori et al., 2007; Morana, 2001; Yu et al., 2005; Wang et al., 2004

First of all, Hotelling (1931) suggested that a non-renewable resource's price should depend on the interest rate. Indeed, such relationship can be empirically found on the oil market. Moreover, this dependency was also found to vary in time (Arora and Tanner, 2013; Lin, 2009).

However, up to 1980s it was generally agreed that fundamental factors like supply and demand almost solely determine the oil market, among others, by reflecting OPEC decisions. However, a large amount of literature has been produced after the recent global financial crisis of 2007, questioning such an approach. Indeed, even earlier, in 1990s the long-term oil price path was rather stable, except short-term fluctuations due to Iraq war and Asian financial crisis, but this has changed shortly afterwards. Except standard explanations based on the impact of geopolitical events around oil-exporting countries, structural breaks in the oil market itself have been discussed in a much wider context (Blanchard and Riggi, 2013; Fattouh and Scaramozzino, 2011). Therefore, examination of oil price determinants in a time-varying context is an important task (Ji, 2012; Stefanski, 2014).

Depending on the proposed model and time period analysed various determinants were found. Nazlioglu and Soytas (2012) examined the dynamic relationship between oil price and agricultural commodities prices. The analysis covered over 30 year period, and provided evidence that the oil price affects agricultural commodities prices, as well as, agricultural commodities prices affect the oil price. Zhang and Wei (2010) found a significant positive correlation between gold and oil price for 2000–2008 period. Also, a long-term equilibrium path was proved (Beckmann and Czudaj, 2013a).

Bernabe et al. (2004) and Yousefi and Wirjanto (2004) stressed that supply and demand market forces, gross domestic product, stock market activity, exchange rates and even weather conditions greatly influence oil price. Indeed, certain seasonal drifts occur due to demand peaks during the winter season (as the distillate heating oil and residual fuels consumption increases).

Mensi et al. (2013) argued that oil market is significantly affected by volatility of stock markets. Arouri et al. (2011) examined this relationship more carefully, i.e., separately for U.S. and European markets. Du and He (2015) found significantly positive risk spillovers from stock markets to oil market. Creti et al. (2013) argued that these relationships change in time.

There is also evidence that oil price and exchange rates are significantly linked (Chen and Chen, 2007). This fact was extensively examined for developed economies (Wang and Wu, 2012). Recently it was carefully studied also for emerging markets (Bal and Rath, 2015).

The standard explanation is that an appreciation of a domestic currency against the currency in which the oil price is denominated lowers the oil price expressed in the domestic currency. As a result a demand increases, which can further result in an oil price increase (Akram, 2009). In this sense, Aloui et al. (2013) linked a dollar depreciation with the oil price increase.

However, Beckmann and Czudaj (2013b) argued that the relationship between exchange rates and the oil price strongly depends on the choice of the exchange rate measure. Also, Uddin et al. (2013) argued that the relationship between exchange rates and oil price is still ambiguous, and moreover, the strength of this relationship changes over the time horizon. However, Brahmasrene et al. (2014) found that there exists the Granger causality from exchange rates to oil price in the short-term. Reboredo (2012), Reboredo and Rivera-Castro (2013) and Turhan et al. (2013)