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An incentive-oriented early warning system for predicting the co-movements between oil price shocks and macroeconomy

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HIGHLIGHTS

- Oil price shock incentives should be considered.
- ROSE^2 is presented to forecast the co-movement of economy and oil price shocks.
- Apply ROSE^2 to forecast the oil price shock-macroeconomy relationship is valid.

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ABSTRACT

Different oil price shock incentives under different domestic and international environment will cause different oil price shocks and bring different impacts to China's macroeconomy. However, there are few empirical studies on early warning prediction of the co-movements between oil price shocks and macroeconomy. This paper presents an incentive-oriented artificial intelligent (AI) early warning system (EWS) with ontology supported case based reasoning (CBR) method, called "relationship between oil price shocks and economy-an early warning system (ROSE^2)", to forecast the co-movements between macroeconomy and oil price shocks in China. Simultaneously, multi-galois lattice (MGL), which is more suitable for matching multiple attributes, is used to improve the recall and precision capability of ROSE^2. Finally, several practical queries called Q1–Q4 are presented for verifying the validation and efficiency of the ROSE^2 system.

1. Introduction

As a special energy commodity, oil price shocks will not only affect the energy market but also affect the performance of macroeconomy. Oil price crises since 1973 and the subsequent recession have given rise to a great deal of researches on the relationship between oil price shocks and macroeconomy. Hamilton [1] is the most influential article in this field. He demonstrated that all but one of the US recessions since the end of World War II was caused by a dramatic oil price increase. After Hamilton, a large number of researches were carried out in various branches. See Huang [2], Ghosh [3], Zhang and Wang [4], and Ju et al. [5]. Rapid and large increase of oil price experienced over the last years has caught widespread concern about its impacts on macroeconomy, especially those major oil importing and developed countries. See Lee et al. [6], Chang and Wong [7], Gronwald [8], Oladosu [9], Ismael et al. [10], Rumi et al. [11], Sajjadur and Apostolos [12], and Tiago and Tovar [13]. There are also some studies focused on China (Fan et al. [14]; Du et al. [15]; Tang et al. [16]; Ou et al. [17]). However, results are still inconclusive.

Oil price is strongly influenced by some exogenous factors such as irregular events (Zhang et al. [18]), global economic status (Chen and Hsu [19]), speculation activities (He et al. [20]) and political and social attitudes (Ozdemir et al. [21]), whose effects on macroeconomy are sometimes hard to quantify (Yu et al. [22]). Therefore, further research on the macroeconomic performance of oil price shocks is necessary for understanding how macroeconomy reacts to oil price shock uncertainty.

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2. Literature review

Technically, different models have been used for quantifying the impacts of oil price shocks on macroeconomy. From statistical point of view, these models can be classified into linear and nonlinear ones. Earlier studies, such as Darby [23] and Gisser and Goodwin [24] assumed a linear/log-linear relationship between oil price and macroeconomy. Sometimes, oil price is determined by its supply and demand, but in most instances, it is strongly influenced by irregular past/present/future events. So the relationship between oil price shock and macroeconomy has the characteristics of complex nonlinearity, dynamic variation and high irregularity. The dynamic and unstable oil market environment increases the difficulty of linear modeling. As such, nonlinear statistical models have recently received increasing attention. Cuñado and Gracia [25] analyzed the impact of oil prices on inflation and industrial production indexes for many European countries and account for the possible non-linear relationships using different transformation of oil price data. Fan et al. [14] built a Chinese Computable General Equilibrium (CGE) model to simulate the impact on the China's economy of international crude oil price. Tang et al. [16] developed a structural Vector autoregression (SVAR) model to investigate how and to what extent oil price shocks impact China's economy. He et al. [26] applied Vector Error Correction Model (VECM) model to investigate the co-integration relationship between crude oil prices and global economic activities. To name but a few. There are some limitations on the traditional nonlinear models, first, traditional nonlinear statistical models are often built upon some strong assumptions, which may not be suitable for the uncertain nature of oil prices. Second, although CGE models can solve large number of variables, the data used in CGE are usually yearly or quarterly, which limits the time effectiveness of the models (Ou et al. [17]).

Apart from the nonlinear models used for the relationship between oil price shocks and macroeconomy, increasing attentions have been paid on artificial intelligent (AI) algorithms, such as genetic algorithms (GA), neural network (NN), and some other simulation methods. Yu et al. [22] proposed a decomposition–ensemble methodology with data-characteristic-driven reconstruction for crude oil price forecasting, in order to enhance prediction accuracy and reduce computation complexity. Haruna et al. [27] proposed an alternative approach based on a genetic algorithm and neural network (GA-NN) for the prediction of the West Texas Intermediate (WTI) crude oil price. Comparative simulation results suggested that the proposed approach is better than the baseline algorithms in terms of prediction accuracy and computational efficiency. Zhang and Zhang [28] employed the Markov regime switching model with dynamic autoregressive coefficients to explore the oil price movement regimes of Brent and WTI after the financial crisis. Ji and Fan [29] investigated the dynamic integration of the international crude oil market and explores the leading/lagging relationship between the world's major crude oils—WTI, Brent, Dubai, Tapis and Nigeria—using a time-varying average distance measurement and an error correction model combined with a directed acyclic graph technique. Paresh et al. [30] insisted that price clustering can be a source of market inefficiency. In that case, they considered five different forms of oil futures contracts and test for evidence of price clustering. Empirical findings implied that price clustering can potentially be a source of oil market inefficiency, which can influence trading strategies. Wang et al. [31] developed a novel hybrid AI system framework is developed by means of a systematic integration of artificial neural networks (ANN) and rule based expert system (RES) with web-based text mining (WTM) techniques. Within the hybrid AI system framework, a fully novel hybrid AI forecasting approach with conditional judgment and correction is proposed for improving prediction performance. Wang et al. [32] proposed a new methodology for handling complex systems—TEI@I methodology by means of a systematic integration of text mining, econometrics and intelligent techniques, in order to forecast the oil price trend. Yu et al. [33] proposed a knowledge-based forecasting system: rough-set-refined text mining (RSTM) approach, for crude oil price tendency forecasting. From the motivation point of view, the existed researches devoted to forecast the possible trend of oil prices in the future, while the purpose of our research is to catch the co-movement relationship between oil price shock and macroeconomy. From the research perspective point of view, existed researches focused only on the oil price itself, while ignoring the incentives of oil price shocks. According to the relationship between oil price shock and macroeconomy, shock incentives should be a key factors which should be considered, which is one of the main contributions of our research.

Early warning system (EWS) has become a hot topic in recent years, and it is regarded as an efficient way for predicting probable crises and reducing risks. Most of the EWSs are used for forecasting various kinds of crisis (Goldstein et al. [34]; Kim et al. [35]; Oh et al. [36]; Oh et al. [37]; Lin and Wu [38]; Ali and Nermin [39]), while some others are focused on the forecast methods (Dimitras et al. [40]; Zopounidis and Doumpos [41]; Yu [42]). There are still some papers working in other fields of EWS (Chen et al. [43]; Andres et al. [44]). Most of the existing EWSs use statistical methods for forecasting. In statistical EWSs, the macroeconomic effects of oil price shocks should be measured with dummy variables, so that information loss is inevitable. How to construct an AI-based EWS to detect the co-movements between oil price fluctuation and macroeconomic performance is a complex and challenge task, and there's few successful application until now.

In our opinion, when we come to the co-movements between oil price shocks and macroeconomy, it is critical to take oil price shock incentives into consideration, because different oil price shock incentives under different domestic and international environment will cause different oil price shocks and further bring different impacts on macroeconomy. However, as the different social and cultural backgrounds, different experts have different definitions for a certain incentive of oil price shock. In that case, we have to give a unified and widely accepted description for each oil price shock incentive. Ontology is a conceptual model that specifies terms and relationships between them, which represents the knowledge of a certain domain (Antoniou and Harmelen [45]), and case-based reasoning (CBR) enables us to solve the new problem with the old experience. In that case, *Relationship between Oil Price Shocks and Economy-an Early warning system* (ROSE^2), an incentive-oriented artificial intelligent early warning system built on Ontology and CBR, is presented in this article, for predicting the potential economic crisis caused by different kinds of oil price shocks. The advantages of Ontology based case based reasoning approach is that it builds a case retrieving process, which provides a more explicit and formal specification of a conceptualization and advanced knowledge organization techniques for decision support and crisis forecasting.

As the second largest oil consumer and the second largest oil importer in the world, China plays an important role in international oil market. Due to its immature oil pricing mechanism and lacking of early warning system, China's macroeconomy often respond slowly to the oil price fluctuation. Another aim of this paper is to provide complementary explanations for China's macroeconomic effects caused by unexpected oil price shocks that cannot be attributed to fundamental factors.

The rest of the paper is organized as follows: Section 3 gives a brief introduction of the theoretical background of this paper. Section 4 describes the framework, modules, and some key