



Financial risk network architecture of energy firms

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HIGHLIGHTS

- Directional connectedness measures among the 20 biggest oil companies are estimated.
- A total connectedness index is estimated from January 2002 and November 2016.
- Directional net spillovers between oil firms are dynamically estimated.
- Risk connectedness networks within the biggest oil companies are constructed.

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ABSTRACT

We assess volatility spillovers and directional connectedness among stock returns of the biggest 20 oil companies listed in the New York Stock Exchange (NYSE) between January 2002 and November 2016. The methodological approach we employed allows the study of the total average connectedness, statically and dynamically, as well as pairwise spillovers within oil firms during the sampled period. For instance, estimation results on full sample connectedness measures show that the system average connectedness is 84.7%. Based on the net pairwise spillovers estimates, we construct risk network representations for days of abnormal behavior in oil prices. This allows the identification of potential shock transmitters and receivers within the sample. The estimates provided can be used for portfolio decision purposes and for designing regulatory policies.

0. Introduction

Production and exploration challenges faced by oil firms have been highlighted as the main areas of concern in the literature.¹ Such a focus is expected, considering the fact that the world's production economy is dependent on oil production and exploration activities. Energy firms and, to a large extent, oil firms are in charge of the energy supply that guarantees the provision of an ever-increasing world demand for consumption goods, which continues to emerge as a result of the ever growing global population. Nevertheless, other than the technical problems related to production and exploration of oil, the firms in this domain also face economic and financial risks (like other firms) in their daily operations. Most of the relevant financial risks are invariantly related to stock and commodity markets.

The existing literature has also focused consistently on such risks,² which can jeopardize operations, projects of future expansion, or the

survival of any energy firm. As highlighted by [1], the oil-producing sector features idiosyncratic characteristics. For instance, oil production is based on a scarce non-renewable resource, whose reserves are concentrated in specific geographic areas across the globe. Due to the latter, oil firms produce within a bifurcated supply environment. Specifically, oil supply can be divided into oil that is offered by companies from the Organization of the Petroleum Exporting Countries (OPEC) and oil produced by companies from non-OPEC countries. The quantity of oil supplied by these agents differs substantially owing to the varied production costs and exploration costs of available oil reserves. Owing to these idiosyncratic characteristics and scarcity of oil reserves, the production decisions and reserve utilization of oil companies might have a significant impact on the oil prices and might, indirectly, affect their peers' revenues. Therefore, the market relationships across energy firms are complex and of outstanding importance for the world economy, which is still heavily dependent on fuels.

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¹ See for example [62–67].

² See for example [42,68,13,20,49,69] and Section 1 here.

The understanding of these complex relationships assumes crucial relevance in the current context of increasing oil supplies and relatively low oil prices. According to the accounting and audit firm Deloitte, 35 oil companies with a cumulative debt of approximately US\$ 18 billion, filed for bankruptcy protection between July 2014 and December 2015.³ Low crude oil prices have not been benefiting the oil companies in the current environment. In fact, recently, about 35% (175) of the exploration and production companies listed worldwide experienced high leverage and low debt coverage ratios, and 26% of these companies currently face a high bankruptcy probability, according to Deloitte. The situation of oil companies might not improve unless there is a sharp recovery in oil prices or a sensible capital injection by oil firms in the future. These are considered unlikely prospects of improvement as oil markets have recently witnessed pronounced price meltdowns. For instance, the price of crude went from USD/bbl 147 in July 2008 to USD/bbl 30 in February 2016. The oil price recovered moderately during 2017; although it does not show great prospects of achieving the 2008 growth levels.⁴

This study aims to shed light on the financial linkages between global oil companies. To this end, we describe the time dynamics of energy firms' relationships, and we estimate and analyze the main vulnerabilities in the financial network architecture of energy firms in the global stock market. This analysis is particularly relevant in the current context of high bankruptcy risk faced by oil related firms. Specifically, to the best of our knowledge, this is the first study to reveal the financial network architecture that describes the interactions of the biggest energy firms in the stock market. We focus on the propagation of the financial risk embedded in the stock prices of the 20 biggest oil-related companies worldwide, in terms of market capitalization. This also helps us to analyze the systemic risk in the oil sector, as has been done before for other sectors, such as commodity markets, banks, and insurance companies (see for instance [2–8]).

Essentially, our results constitute a practical implementation that can be used by governments and firm managers to identify sources of vulnerability to the operations of energy firms. The tools provided and the analyses carried out in this study may be utilized on a regular basis by sector experts to enhance the kit of tools currently available for financial management of energy firms. We calculated total spillovers and identified firms that transmit and receive shocks, as well as the size of volatility shocks. Our results would allow energy managers to mitigate the risks arising from the financial energy markets and would help energy agencies to gain an accurate understanding of the dynamics of energy markets.

We followed a recently proposed statistical methodology that permits the construction of directional pairwise spillovers and graphical networks based on [9–11]. These directional spillover measures are dynamic and facilitated the determination of the importance of oil firms, in terms of risk transmission, across time. Consequently, this methodology allowed us to explore the evolution in the propagation of shocks across the market prices of energy firms in the period running from January 1, 2002 to December 31, 2016, on a daily basis. In this context, dynamics are important because some firms might be more resilient than others under different macroeconomic conditions, for example, under different price regimes of the crude oil markets. We highlight this factor through our observations. Our contribution has important insights and implications not only for energy firms that are directly involved in the domain but also for market regulators and international hedge fund managers that allocate part of their portfolios to energy stocks. This has become particularly important after the global financial crisis (2007–2009), especially due to the *financialization* of

commodity markets that has taken place following the crisis.⁵ To the best of our knowledge, this is the first analysis that has been carried out at the level of oil firms.

First, our main findings show that risk spillovers between energy firms are unusually high, ranging from 70.7% (Petrobras) to 92.7% (Total Fina Elf), with a total system average of 84.7%. Compared to spillovers in the stock markets (39.5%), global banks (78%), credit spread (74.78%), or exchange rates (76%), the numbers for energy firms are outsized. Second, systemic risk in the oil market increased considerably during the final phase of the sampled period, going from around 50% in April 2014 to above 85% in December 2016. The nature of connectedness in energy firms is also very volatile; it reached its highest point in the aftermaths of the global financial crisis (from 2008 to 2009), the European debt crisis (2010–2011), and during the upsurge in the conflict between Russia and Ukraine in 2014. At the level of firms, we identified the most vulnerable firms (Total Fina Elf, Exxon, and Eni) and those that, on an average, contribute toward highest shock transmission in the system (Petrobras, Canadian Natural Resources, and Anadarko). Finally, regarding the propagation of risk under different regimes of the crude oil price, our graphical network analysis shows that the pairwise connectedness structure changed across time and that it behaves differently depending on market events.

Financial risk, like the ones uncovered and measured in this study, are as important for energy management as may be the practical implementation of novel energy conversion or conservation systems or relevant changes concerning energy policy and the optimal use of energy sources. Essentially, financial risks of energy firms comprises a broad interest for energy managers. Moreover, concerning the current environment of financial distress for oil firms, financial issues discussed in this study are considered capable of jeopardizing entire operations of energy markets. The information provided through our results can help governments that are seeking to reduce the impact of a possible unpaid operation by a big energy firm that is under financial distress.

The remainder of this study is organized as follows. Section 1 provides a literature review. Section 2 summarizes the directional connectedness approach employed in our empirical calculations. In Section 3, we present a full sample analysis of connectedness within oil companies and we also perform dynamic estimations using rolling windows to study the connectedness dynamics across time. Additionally, in the same section, we build graphical network representations based on connectedness measures. In section 4, we provide some concluding remarks.

1. Literature review

After the *subprime* crisis, commodities and related markets have become crucial for investors as they can serve portfolio diversification purposes. This fact has brought academic attention to the behavior, dynamics, and performance of these markets; it has also highlighted their relationship with different economic variables and sectors, especially the relationship between the fluctuations in the oil price and the performance of commodity and financial markets. The vast literature that has analyzed these relationships can be classified into the following three broad categories: those dedicated to studying the interaction between commodity and oil markets; studies analyzing the interaction between crude oil and stock markets; and those devoted to studying the interaction between energy firms, energy assets, and energy sub-sectors within financial markets.

Regarding the first category, Ref. [12] used a Vector Error Correction (VEC) approach to investigate price and volatility spillovers in crude oil and natural gas markets in the US, Europe, and Japan. They found the evidence of price and volatility spillovers from crude oil markets to natural gas markets. Following this strand, Ref. [13] studied

³ “The crude downturn for exploration and production companies,” Deloitte Center for Energy Solutions.

⁴ According to the U.S. Energy Information Administration (EIA) annual oil price forecast for 2018, WTI and Brent crude oil prices will average US\$ 56 and US\$ 60 per barrel, respectively.

⁵ Refer to [70–73] for studies on the financialization of commodity markets.

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