Four Essays on Energy Prices and Resource Markets

Inauguraldissertation
zur
Erlangung des Doktorgrades
der
Wirtschafts- und Sozialwissenschaftlichen Fakultät
der
Universität zu Köln

2014

vorgelegt
von

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aus

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Tag der Promotion:	09. Dezember 2014

This thesis is dedicated to my parents, Melih Berk and Sermin Ozsimsir,
for their endless love, support and encouragement.

Acknowledgements

I would like to thank Prof. Felix Höffler for his supervision and guidance throughout this dissertation project. His constructive criticism and encouragement was the most important motivation for me in completing this thesis. I would also like to thank Dr. Oleg Badunenko not only for being the co-chair of this dissertation but also for his valuable feedback on different chapters of this thesis.

I am indebted to my co-authors, Prof. Hakan Yetkiner, Dr. Berna Aydogan and Jannes Rauch, for their collaborative work and valuable input. Moreover, special thanks go to Broghan Helgeson, Simon Mumford and John Thompson for critically editing different parts of the thesis.

Additionally, I would like to express my gratitude to both the Cologne Graduate School (CGS) and the Institute of Energy Economics (EWI) for their financial support and for providing an excellent research environment. Special thanks, in particular, go to Dr. Dagmar Weiler, managing director of the CGS, and Prof. Marc Oliver Bettzüge, director of EWI. I would also like to thank Monika Deckers from EWI for her tremendous support in handling administrative issues.

The essay in Chapter 2 benefited from the valuable comments of Prof. Adnan Kasman and the participants of the IAEE's 33rd International Conference. Chapter 3 benefited from the reviews of three anonymous referees and the editorial office of the journal "Sustainable and Renewable Energy Reviews", as well as from the comments of the participants of the IAEE's 33rd International Conference. Special thanks for Chapter 4 go to Ozgul Bilici, Prof. Stephen W. Salant, Dr. Banu Olcay and Dr. Jan Richter and the audiences of 2013 Young Energy Economists and Engineers Seminar in Stockholm, the PhD Workshop in Economics at the University of Minho in Braga and the Workshop on Behavioral Economics and Industrial Organization at the Corvinus University of Budapest for their valuable feedback. Finally, all essays of this thesis benefited from the discussions of the EWI research seminars.

Finally, I want to thank my family and my friends for their endless support and encouragement during this journey. Particularly, I am indebted to my parents, Melih Berk and Sermin Ozsimsir, my brother, Erhan Berk and my best friend, Ahmet Gucer. Their constant support helped me a lot to get through the ups and downs of my academic career.

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Chapter 1

Introduction

> "It is evident that the fortunes of the world's human population, for better or for worse, are inextricably interrelated with the use that is made of energy resources."
>
> — M.K. Hubbert (Hubbert, 1969)

1.1 Motivation

More than a century after William Stanley Jevons raised the "question concerning the duration of [...] present cheap supplies of coal" (Jevons, 1865, p.3), the world once again realized the threat of rising energy prices. The energy source was different, yet the threat was the same. After experiencing a relatively low and stable period, oil prices quadrupled during the two crises that occurred in 1973 and 1979. Since then, much has been written about the driving factors and the effects of energy prices. The essays in the thesis at hand attempt to contribute to this stream of energy economics literature by evaluating the effects of energy prices on economic activity (Chapters 2 and 3), the microeconomic foundations of prices for exhaustible energy resources (Chapter 4) and the financial regulatory activities to cope with the effects of fluctuating energy prices (Chapter 5).

"The pure theory of exhaustible resources is trying to tell us that if exhaustible resources really matter, then the balance between present and future is more delicate than we are accustomed to think...", stated Robert Solow in 1974 (Solow, 1974a, p.10). Within the same decade, OPEC supply cuts showed that exhaustible resources, indeed, matter.

Crude oil futures contracts and financialisation[1] of the oil market, which took place in the early 1980s, were meant to be the tools for the western economies to find the "delicate" balance in oil prices. However, since then, the effects of energy prices, specifically oil prices, on macroeconomic performance have become more complicated. Energy prices have established themselves as an important factor in sustainable development due to their influence on not only physical industrial activity but also on financial markets. Over the last decade, the financial markets of the developing countries, which attracted massive short-term capital inflow from developed nations, have become more sensitive to global economic and financial circumstances, such as the skyrocketed oil prices during the 2008 credit crunch. Chapter 2 attempts to identify the channels through which oil prices affect stock market activity by employing data from one particular emerging economy, Turkey.

The effects of energy prices are evident in all economies, not just developing ones. As correctly noted by Heinberg, "The historic, global shift from a regime of cheap fossil fuel energy sources to one of declining and expensive fossil fuels [...] will impact every living person, every community and every nation" (Heinberg, 2007, p.127). Because, the "human advances during the twentieth century" were closely related to the high consumption of fossil fuels, which led to current "high-energy civilization" (Smil, 2000, 2005). Hence, even the modern and developed economies, which are on a relatively steady-state growth path, are expected to be influenced by rising energy prices.

In order to support long-term economic growth, developed countries should implement sustainable energy policies to ensure energy supply at a "reasonable cost" (Evans, 2007, p.165). However, fossil fuel-driven energy prices would not allow energy costs to be kept at a reasonable and affordable level because they tend to increase, by nature, due to scarcity. This is commonly known as the Hotelling rule, named after Hotelling (1931). Although the short-run legitimacy of the Hotelling rule is extensively questioned, there has not yet been sufficient evidence against its long-term applicability. Within this context, Chapter 3 tries to identify and test the long-term effects of rising energy prices on economic growth for developed countries.

The inevitable long-run shift to a regime of expensive fossil energy sources does not necessarily mean that short-term declines in prices are impossible. For instance, during the aftermath of the OPEC crises in the 1970s, the world experienced a nearly 43% decline in oil prices in just 5 years (BP, 2014). This decline was not only due to the shrinking demand but also due to the supply enhancements. Higher oil prices let oil companies invest in the development of higher cost reservoirs outside the OPEC countries, such

[1] O'Sullivan defines "financialisation" of the crude oil market as the increasing involvement of financial investors (O'Sullivan, 2009).

as the North Sea. This adjustment by the industry to the high oil prices has emerged as the most important argument of economists and government institutions against the peak oil theorists. Hence, the 'optimists' tend to refer to the issue as 'the end of cheap oil' rather than 'the end of oil' (Tertzakian, 2007).

As correctly noted by Steven Gorelick, "Today, the oil industry is a high-tech business, with technological advances being adopted in areas ranging from discovery to recovery" (Gorelick, 2011, p.223). Technological progress driven by high oil prices, such as enhanced recovery techniques, directional drilling and cracking, are promising for the future global oil supply. In addition to the exploration or development of new fossil resources, mature reservoirs, mostly in OPEC, also need new investments to increase global oil supply capacity.

Currently, the oil market is dominated by two blocks of companies, namely the international oil companies (IOCs) and the national oil companies (NOCs). While the NOCs, particularly of OPEC countries, control the majority of the global oil supply and the reserves, the IOCs, with their extensive know-how and capital, are leading the market. According to Hartley and Medlock (2008), the NOCs operate less efficiently than the IOCs as they often need to consider the overall welfare of the society in the host country. Moreover, Marcel (2006) states that the NOCs need to acquire know-how for the mature reservoirs. The Oil Field Service (OFS) companies, such as Schlumberger or Halliburton, usually emerge as business partners for the NOCs. To this end, Chapter 4 analyzes a stylized model of an exhaustible resource market in which two firms compete in quantities for two consecutive periods. This two-period duopoly model is extended to a three-stage game with the inclusion of the rivalry in capacity investments at the interim stage. Within this context, the model is able to capture the short-term stylized characteristics of the most exhaustible resource markets in which occasional price drops are observed.

One other determinant in crude oil prices is, without a doubt, the financial market, particularly the futures market. Since the financialisation of the oil market in the 1980s, oil prices have begun to be determined by taking into account not only the physical market conditions but also the decisions and expectations of the increasing number of investors, hedge funds and speculators. Yet, this notable increase in the liquidity of the oil futures markets caused even more volatile and aggressive oil prices (Orwel, 2006, p.117). Especially during 2000–2008, the increase in oil prices was mostly attributed to speculation in the markets (Masters, 2008). Since then, the Commodities Futures Trading Commission (CFTC) has started to extensively monitor the crude oil futures markets. CFTC's main role has been to "ensure that the futures markets are able to perform their primary function of hedging prices for commercial producers and consumers of the commodity in question" (O'Sullivan, 2009, p.90). Within this context, Chapter 5 tests whether the CFTC was able to fulfill its duty as the main regulatory authority in the oil market by applying an event study analysis to oil-related stocks in US financial markets.

1.2 Outline of Thesis

This thesis consists of four essays, of which two are related to the economic impacts of energy prices, one to the microeconomic structure of resource markets and one to the effects of financial regulations on the stock returns of oil and gas companies. In Chapter 2, the effects of oil prices on stock market activity is investigated using data from one particular emerging economy, namely Turkey. Specific attention is given to global liquidity conditions in order to consistently explain the causal relationship. The essay in Chapter 2 is based on a revised version of the working paper entitled "Crude oil price shocks and stock returns: Evidence from Turkish stock market under global liquidity conditions" (Berk and Aydogan, 2012). Berna Aydogan co-authored the study, and contributions to all aspects of the essay were made in equal parts.

Chapter 3 of this thesis continues to analyze the effects of energy prices on macroeconomic indicators. The purpose of the essay in this chapter is to derive and test the impact of energy prices on economic growth. First, the paper establishes a theoretical relationship between energy prices and several macroeconomic variables. Next, the derived theoretical relationship is tested empirically by employing data for sixteen OECD countries. This chapter is based on the article, "Energy prices and economic growth in the long run: Theory and evidence" (Berk and Yetkiner, 2014), which is a joint study with Hakan Yetkiner, who equally contributed to all parts of the article.

The essay in Chapter 4 focuses on the strategic firm behavior in exhaustible resource markets within the context of a two-period duopoly model in which firms face endogenous intertemporal capacity constraints. Firms' capacity investments, which take place in between two periods, change the structure of the Cournot game in the second period. The main aim of this chapter is to show how the price of an exhaustible resource behaves if the firms' resource constraints are not exogenous. This chapter is based on the single-authored work entitled "Two-period resource duopoly with endogenous intertemporal capacity constraints" (Berk, 2014).

Finally, in Chapter 5, a different perspective on the effects of energy prices, particularly oil prices, on stock market fundamentals are given. During the credit crunch period in 2008, US financial authorities attempted to cope with rising oil prices by introducing a number of regulations (Masters, 2008). The actions of US Commodities Futures Trading

Commission (CFTC) to regulate the commodity markets caused significant changes in the oil price, which eventually affected the stock returns of oil and gas companies. The essay in this chapter analyzes the effects of CFTC regulations on oil- and gas-related stock returns. Chapter 5 is based on "The effects of the CFTC's regulatory announcements on US oil- and gas-related stocks during the 2008 Credit Crunch", a co-authored study with Jannes Rauch, who contributed equally to all parts of the work.

The following paragraphs briefly outline these four essays by introducing the background, the research question, the methodological framework and the major findings.

The primary objective of the essay "Crude oil price shocks and stock returns: Evidence from Turkish stock market under global liquidity conditions" in Chapter 2 is to analyze how significantly the crude oil price variations affect Turkish stock market returns. Turkey is one of the most energy import-dependent countries and crude oil constitutes a significant portion of the country's primary energy demand (Ediger and Berk, 2011). The Turkish economy appears to be sensitive to changes in the oil price not only because oil prices affect the country's trade balance but also due to the fact that oil prices directly influence the cost structure of industrial activity. Therefore, positive crude oil price shocks would negatively affect the cash flows and the market values of companies, causing an immediate decline in overall stock market returns. It would be beneficial for investors, market participants, regulators and researchers to shed more light on the causal relationship between crude oil prices and returns in the Turkish stock market, which exhibits characteristics different from the well-documented developed markets.

There has been extensive research on the effects of oil prices on stock market activity in a number of developed and developing countries. Most of the studies so far have succeeded in showing evidence that oil prices significantly affect stock markets of developed countries; yet the impact on developing countries has been found to be weaker.[2] One additional stream of literature concentrated on the stock returns of individual companies. The main findings show that an increase (decrease) in the oil prices would lead to a significant increase (decrease) in the stock returns of upstream oil companies while causing a decrease (increase) in those of other firms who use oil as an input.

Following the literature, we used a structural vector autoregression (VAR) methodology as proposed by Sims (1980). The VAR approach presents a multivariate framework that expresses each variable as a linear function of its own lagged value as well as the lagged values of all the other variables in the system. The main advantage of this approach is the ability to capture the dynamic relationships among the economic variables of interest. We used daily data of ICE's Brent crude oil prices and the 'National-100 Index' (ISE-100), the main market indicator of the Turkish Stock Market, covering the period

[2] Please refer to Section 2.2 for a detailed literature survey.

from January 2^{nd}, 1990 to November 1^{st}, 2011. It is to be expected that the oil price trend experienced some strong structural breaks in this relatively long time horizon. Therefore, we have divided the whole period into three sub-periods coinciding with specific oil price trends to allow for the testing of the performance of the Turkish stock market under different oil price regimes. During the first sub-period (from January 2, 1990 to November 15, 2001), oil prices followed a comparatively stable and horizontal trend. Within the second period (from November 16, 2001 to July 11, 2008), the crude oil market, along with other commodities, witnessed historical record prices after experiencing an upward trend. Finally, during the third sub-period (from July 14, 2008 to November 1, 2011), the credit crunch crisis caused crude oil prices to be highly volatile, first declining sharply and then increasing once again.

The variable that captures oil price variations is of central importance to this study. Although it is common to use the percentage change in oil prices as a proxy for the variation, some studies raise the issue of non-linear linkages between oil prices and other macroeconomic indicators (Hamilton, 1996, 2003, 2011, Kilian and Vigfusson, 2011b). In order to achieve robust empirical results, we employed two different proxy variables for oil price variation, namely linear log-return and non-linear scaled oil price increase (SOPI) variables.[3]

VAR methodology treats all variables as jointly endogenous and, for proper estimation, ensures that all variables employed in the model be stationary or an I(0) process. We, therefore, continue our analysis by performing two unit root tests, namely the Augmented Dickey-Fuller (ADF) and the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) tests, as proposed by Dickey and Fuller (1979, 1981) and Kwiatkowski et al. (1992), respectively.[4]

Our preliminary results show, in line with previous literature, that oil prices do not have a particular effect on Turkish stock market activity. In fact, we find that the effect is significant (yet still small) only during the third sub-period. This initial result would lead to a conclusion that Turkish stock returns respond, to some extent, significantly to the highly volatile oil prices. However, this interpretation may be biased either due to a bi-directional causality or if any other variable that drives both highly volatile oil prices and the Turkish stock market returns during this sub-period is omitted.

[3]The methodology for calculating SOPI was first proposed by Lee et al. (1995). Mork (1989) and Hamilton (1996) also proposed linear and non-linear transformations of oil prices, yet SOPI fits better for daily price data.

[4]Since all of the variables included in the VAR methodology are I(0) processes, a Vector Error Correction Model (VECM) was not conducted in this paper.

It has been shown recently in the empirical energy economics literature that bi-directional causality would lead to inconsistent estimates for the effect of energy prices on macroeconomic indicators, especially in the USA.[5] Although there is a consensus that endogeneity is not of significant importance when studying the stock markets of countries (apart from the USA), there is still a belief that the spill-over effects from the US or global markets would dominate the dynamics of such a causal relationship in developed economies (e.g., Park and Ratti, 2008). Moreover, it is also plausible to take these spill-over effects into consideration for the stock markets of the emerging economies, which attract a large amount of short-term capital from the major economies.

In order to avoid biased results which could emerge from these spill-over effects, we incorporate the global liquidity conditions into the analysis. We choose global liquidity conditions as the common factor for two reasons. First, the Turkish financial market has been attracting worldwide short-term capital inflow for the last few decades. As of November 2011, the foreign portfolio investments have been responsible for nearly 63% of total Turkish stock market capitalization. Thus, the Turkish stock market appears to be becoming more sensitive to global financial conditions. Second, with the increasing volume of oil futures contracts, financial (more specifically futures) markets have become the other major oil market since the late 1980s. Since then, crude oil prices have been determined in such a manner that accounts for the decisions made by investors, speculators, hedgers, and large investment funds in the future markets as well as the physical market conditions. Analyzing these "non-physical" market conditions, such as expectations about the market as well as the global financial and economic indicators, may offer an additional explanation of the empirical variations in crude oil prices.

Therefore, a proxy for global financial liquidity may not only serve as an explanatory factor in influencing stock market returns but also be used in explaining the variations in oil prices and thus in obtaining a 'purified' oil price shock variable that is related only to the oil market itself. In this essay, the evidence of such tridimensional interaction, e.g., the joint response of the stock returns to the purified oil prices and to the global liquidity conditions, is investigated. We employ the disentangling methodology proposed by Kilian and Park (2009) in order to obtain a purified oil price shock variable. Then, this variable along with Chicago Board of Exchange's (CBOE) S&P 500 market volatility index (VIX) as a proxy for global liquidity conditions is used in a trivariate VAR system to explain the variance decomposition of Turkish stock market returns.

Results of this trivariate VAR system suggest that global liquidity is the most plausible explanation for the changes in both the oil prices and the stock market returns. Three

[5] This reverse causality issue was first stressed by Barsky and Kilian (2004) and later empirically quantified by Kilian (2009).

deductions can be made from these results. First, oil prices seem to have a greater effect on the Turkish stock market during the period of high volatility. Second, the effect of oil prices are not persistent and rather weak. Finally, the liquidity shocks, rather than crude oil prices, are the primary factor in Turkish stock market movements.

In order to thoroughly understand the effect of energy prices on countries' economies, economic as well as financial indicators must be analyzed. Without a doubt, GDP growth rate, apart from stock market activity, is the other macroeconomic indicator that could be directly exposed to changes in oil price. In this respect, the essay in Chapter 3 theoretically and empirically analyzes the effects of energy prices on economic growth.

The seminal study of Hamilton (1983), which analyzes the correlation between increases in crude oil prices and US recessions, is accepted as the fundamental basis for subsequent studies on the effects of energy prices on macroeconomic indicators such as GDP growth rate, inflation and industrial activity. Since then, a number of empirical works have tested the relationship between energy prices and macroeconomic variables. Although there have been ongoing debates about the nature of the relationship such as non-linearities and asymmetries, it is widely accepted that energy prices would at least have a particular, if not pivotal, effect on economies.

In spite of abundant empirical literature, theoretical growth economists have yet to pay substantial attention to the matter, possibly because they perceive it as a short-run issue. Although the mainstream economic growth literature following Hotelling (1931) has so far concentrated on the optimal depletion of exhaustible resources, the endogenous economic growth literature has focused on a number of energy-related issues such as transition between energy sources, directed technical change in energy-intensive economies and induced energy-saving technologies. Hence, an analysis of the effect of energy prices on economic growth seems to be an unexplored area in the theoretical economic growth literature.

The essay in Chapter 3 tries to fill this gap by studying a stylized economy in which a long-term energy price–economic growth nexus is developed and tested. A two-sector (investment goods and consumption goods) market economy is developed following Rebelo (1991). The derived theoretical relationship between energy prices and economic growth is further (empirically) tested and quantified using the panel cointegration test and the panel Autoregressive Distributed Lag (ARDL) approach, respectively. In addition to the theoretical contribution,[6] this study sheds light on the empirical evidence of the economic effects of energy prices by performing a long-run analysis. Although there

[6]Authors are aware of only two previous studies theoretically testing the energy price–economic growth nexus using different setups, i.e., Van Zon and Yetkiner (2003) and Bretschger (2013).

has been extensive research on the long-term effects of energy consumption on economic growth,[7] the long-term effects of energy prices seem to be an untapped area of research.

In the theoretical part of the essay, we modify the original model of Rebelo (1991) by including energy along with the capital as inputs of the production function in the consumption goods sector. Employing energy as an input in the consumption goods sector is the first crucial assumption. This assumption is based on the fact that the demand of the consumption goods sector constitutes a significant portion of global primary energy consumption. More specifically, the combined share of the transportation and residential sectors have reached more than 60% since 1990 and, according to the IEA's 2012 World Energy Outlook, are expected to remain slightly below that level upto 2035 (Birol et al., 2013). This is also supported by recent empirical regularity (e.g. Edelstein and Kilian, 2009, Kilian and Park, 2009, Lee and Ni, 2002).

The second important assumption made in this essay is that the price of energy input is growing at an exogenous rate. As previously mentioned, exogenous energy prices, especially oil prices, with respect to the macroeconomic indicators creates empirical problems when US or global data is used. Yet, the stylized model studied in this essay proposes a closed economy and uses a broader definition of energy prices, i.e., the price of energy services used in the consumption goods sector. While it is clearly possible to endogenize the energy prices in the model, with regards to our research objective it is more convenient to keep it as an exogenous variable.

The stylized economy, which is framed as a general equilibrium neoclassical growth model, is solved using dynamic optimization.[8] While representative consumer's utility function is defined to be isoelastic, AK and Cobb-Douglas functions are employed for the investment goods sector and for the consumption goods sector, respectively. First, the profit maximization conditions, i.e., input demand functions, from both the investment and consumption goods sectors are derived. Second, dynamic utility maximization for the representative consumer is solved using a present-time Hamiltonian model. First order conditions from the Hamiltonian maximization problem along with the input demands lead to three equations, which are the major findings of the theoretical part. With these equations, we are able to show that the growth rate of energy prices has a negative effect on the growth rates of energy and capital input demands, as well as on that of the total output in this economy, i.e., the GDP growth rate.

The derived theoretical relationships are simple enough to be linearized and thus be used for empirical purposes. To this end, the panel cointegration and the panel ARDL

[7]Ozturk (2010) provides an extensive survey of the literature on the energy consumption-economic growth nexus beginning with the seminal study of Kraft and Kraft (1978).

[8]Please refer to Barro and Sala-i Martin (1995) for examples of dynamic optimization problems.

models are used to test two theoretical relationships: between energy prices - energy consumption and energy prices - real GDP.[9] The sample covers panel data for energy prices (from the IEA (2013)) real GDP per capita and energy consumption per capita (both from the The World Bank Group (2013)) for sixteen countries; namely Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, Japan, Luxemburg, the Netherlands, New Zealand, Portugal, Spain and Sweden, over the period between 1978 and 2011.[10] Although in the theoretical part we assume a closed economy to keep algebra tractable, the countries used in the empirical part are open economies. Yet, it is rational to expect that these OECD countries will end up with a long-term trade balance and, hence, they can be used as proxies for closed-economies in the long run.

Our sample may exhibit usual time-series problems since this study employs a panel data whose time dimension is larger than the cross-sectional dimension. Therefore, two panel-unit root tests, namely Levin-Li-Chu (LLC) (proposed by Levin et al. (2002)) and Im-Pesaran-Shin (IPS) (proposed by Im et al. (2003)) are employed. The unit root test results suggest that all variables are integrated of order one, i.e., I(1), and hence can be used in the cointegtaration and ARDL methodologies. Panel cointegration methodology, applied in this essay, was proposed by Westerlund (2007) and is preferred over other tests, such as the one proposed by Pedroni (1999), because it avoids the problem of common factor restriction. This test proposes four different alternative hypotheses against the null hypothesis of no-cointegration. While two of these alternatives test countries individually, the remaining two jointly test whether cointegration exists over all countries. Results yield evidence of significant cointegration between energy prices and real GDP per capita as well as between energy prices and energy consumption per capita.

The cointegration test is followed by panel ARDL methodology to quantify the long-term effects of energy prices on both energy consumption and real GDP. Two estimators, namely the Pooled Mean Group (PMG) and the Mean Group (MG) (proposed by Pesaran et al. (1995, 1999)) are used. While the MG estimator is based on estimating the time-series regressions N-times and averaging the coefficients, the PMG estimator reveals pooled coefficients. The PMG estimator is more efficient yet is only consistent when the model is homogenous in the long run, i.e. the long-run coefficients are equal across countries. The MG estimator is preferred because it is consistent even when the panel data exhibits heterogeneous characteristics, which is common in cross-country studies.

[9] Once the log-linearization process has been applied to the equations, the growth rates of the variables are converted to log-levels. Thus, in the empirical section of this essay, levels rather than the growth rates are used for the respective variables.

[10] USA is excluded from the analysis due to the issue of energy price endogeneity.

These two estimators give consistent estimates even when the assumption of strict exogeneity in the regressors is violated (Pesaran et al., 1999). Thus, ARDL methodology is appropriate to analyze the long-run causal relationship between energy prices and real economic output. According to estimation results, energy prices have significant and negative effect on both GDP per capita and energy consumption per capita in the long run. These are expected results and are in accordance with the theory proposed in this essay, as well as with existing empirical literature.

Both the theoretical and empirical findings suggest significant long-term welfare losses due to the fact that increasing energy prices lead to "under-capacity" or "below-capacity" economic growth. Thus, even for the developed countries, in order to sustain stable long-term economic growth, policy makers need to prevent, or at least to restrict, increases in energy prices. Recall that both the theoretical and empirical sections implicitly assume that energy price variable represents the price of non-renewable energy sources. In the theoretical part, the price of energy is assumed to be exogenously increasing, which is a common assumption for the long-run prices of exhaustible energy sources.[11] Correspondingly, the empirical findings are based on the energy price variable, which is driven by prices of fossil fuels.[12]

Therefore, one of the most appropriate channels to achieve the policy goal of stable energy prices is to subsidize the renewable energy sources. Although there has been extensive research on the positive impacts of renewable energy sources on sustainable development, this stream of literature has so far neglected the potential benefit of renewable energy sources in increasing the public welfare by avoiding long term increases in energy prices. Thus, the essay in Chapter 3 also contributes to the literature on energy and sustainable development.

Given the importance of energy prices for economic activity, it is valuable to shed some light on the microeconomic foundations of price formation in energy markets. To this end, in Chapter 4 a dynamic (two-period) duopoly model is studied. Due to the fact that current energy prices are mostly driven by fossil fuels, the model developed in this essay focuses on exhaustible resource markets in which two firms compete in quantity. Each firm decides how much to supply with regard to the capacity constraint it faces at each period and given the initial resource endowment. An important aspect of the strategic firm behavior in exhaustible resource markets is the allocation of the initial resource endowment. Yet, the issue becomes more complicated once this initial endowment is endogenous and firms can invest in order to increase the endowment (to a certain extent).

[11] This rule is referred to as the Hotelling rule, which suggests that the price of nonrenewable energy sources will increase gradually due to the scarcity or depletion of resources (Hotelling, 1931).

[12] IEA (2013) defines the energy prices to be the weighted average of oil products, coal, natural gas and electricity consumed by households and industry.

This essay tries to answer the question of how resource firms act in a market if their capacity constraints are endogenous.

The essay is related to three streams of literature that deal with (1) the optimal depletion of exhaustible resources following Hotelling (1931),[13] (2) the microeconomic structure of resource markets[14] and (3) the strategic firm behavior under capacity constraints. Specifically, the third stream of literature is the most relevant for this essay. Pioneering works in this stream are Levitan and Shubik (1972) and Osborne and Pitchik (1986), both of which are based on price competition under exogenous capacity constraints. Important contributions are made, among others, by Bikhchandani and Mamer (1993), Gabszewicz and Poddar (1997), Besanko and Doraszelski (2004), Laye and Laye (2008), Biglaiser and Vettas (2004) and van den Berg et al. (2012). The essay in Chapter 4 contributes to the literature as it is among the first to address strategic firm behavior under a two-period resource duopoly model with intertemporal capacity constraints. In fact, Biglaiser and Vettas (2004) and van den Berg et al. (2012) are the only works within this context examining price and quantity competition, respectively.

The current essay extends the model of van den Berg et al. (2012) by relaxing the assumption of exogenous capacity constraints. Hence, in this setting, besides quantity competition, firms also enter into a rivalry in capacity investments, which leads to endogenous capacity constraints. The two-period resource duopoly model framed here is a three-stage game. At the beginning of the first stage (the first period of production) each firm is endowed with a fixed amount of exhaustible resource stock and chooses the production strategy with regard to this initial endowment. At the second stage (in between two periods of production / interim period), they are allowed to invest in capacity in order to increase their resource stock, thus choosing the level of capacity investment. By doing so, their second period (the third stage) capacity constraints become endogenous. At the third stage of the game, firms choose the quantity to produce with respect to their remaining endogenous resources, i.e., the left-over capacity from the first stage plus the additional capacity due to the investment at the second stage.

In order to solve the model algebraically, it is assumed that the costs of exploring the initial resource stock and of the resource extraction are equal to zero. On the other hand, the costs of additional capacity, i.e., the capacity investment function, is defined to be strictly convex in added capacity. A cost ("reverse efficiency") parameter is included in the function as a cost shifter. Moreover, a linear inverse demand function for the resource is proposed.

[13]See, for example, Solow (1974b), Dasgupta and Heal (1974), Stiglitz (1974), Loury (1978), Pindyck (1978)

[14]See, for example, Salant (1976), Gilbert (1978), Lewis and Schmalensee (1980), Eswaran and Lewis (1984), Loury (1986), Salo and Tahvonen (2001), Benchekroun et al. (2009, 2010).

Besides these simplifying assumptions, it is assumed that the initial resource endowment for each firm would be within a certain range. The upper bound of the interval guarantees that the second period capacity constraints are binding for each firm and that firms invest in capacity additions. If this part of the assumption is violated, then the problem is less interesting as it reduces the typical dynamic Cournot game with exogenous intertemporal constraints, such that equilibrium is achieved without positive capacity investments. The lower bound, moreover, guarantees that each firm carries some of its initial resource endowment to the second period. If this is violated, then the capacity constraints are no longer intertemporal. In this case, firms would use up all of their initial capacity in the first period, generate new capacities in the interim period and, then use them again in the second period. This is the most crucial assumption as it is needed to obtain a unique Nash equilibrium.

The sub-game Perfect Nash Equilibrium (SPNE) concept is employed to solve the model. SPNE suggests that the strategy of each player at each instant of time is a function of prior decisions made by both itself and its rival. Therefore, the solution methodology is referred to as 'backward-induction'. For instance, in our setting, for any state of the game at the beginning of the third stage, each firm solves the profit maximization problem by deciding how much to produce with respect to its rival's strategy given the first and second stage decisions. Using the same solution methodology in the second and first stages and we end up with the Nash equilibrium of the game. Given the assumptions, SPNE concept leads to a unique Nash equilibrium in which the firms decisions about quantity supplied at the first stage, capacity addition at the second stage and quantity supplied at the third stage are described as functions of exogenously given variables, i.e., the initial resource stocks, the demand shifter and the capacity cost parameters.

The most important result of this essay is that the price weakly declines over two periods. This contradicts the Hotelling-based reasoning, i.e., that the prices would increase gradually due to scarcity (Hotelling, 1931). This reasoning is also confirmed by van den Berg et al. (2012), which, as mentioned previously, is based on the exogenous capacity constraint. Thus, the essay shows that once firms in resource markets are allowed to invest in capacity, occasional price drops can be observed. This result, in fact, captures the short-term stylized characteristics of exhaustible resource markets. For instance, exploration of new oil reserves would lead to declining prices as a result of supply enhancements. However, this finding may not be applicable if this model is extended to an infinite time horizon since in this case, the capacity addition cost function should have a different structure, capturing the fact that it becomes harder to add capacity as the cumulative capacity increases.

Another important result depicted by the model is that if the firms have the same capacity addition cost structure, i.e., symmetric cost function, any asymmetric distribution of initial reserves does not lead to changes in the equilibrium price. On the other hand, if the firms have different cost parameters, this result does not hold. As an illustration, let us assume that the initial distribution of resources is altered in favor of the more efficient firm, i.e., the one with lower a cost parameter. Then, the equilibrium price increases due to a decrease in total output. In this case, the market moves to a more concentrated structure in the second period (the third stage of the game) since the efficient firm dominates the market share. It is also shown that the initial resource endowment of the firm has a positive effect on its supply levels and a negative effect on capacity addition.

The essay in Chapter 4 interprets the results of the model for the oil market, one of the most important exhaustible resource markets. The initial resource stock of the firms and the capacity investments in the case of oil market could refer to the initial recoverable reserves and the reserve growth investments, respectively. The oil market has been dominated by two blocks of companies, i.e., the international oil companies (IOCs) and the national oil companies (NOCs), since the 1970s. Therefore, a duopoly model can be applied. Additionally, there exist asymmetries in capacity addition cost structures that are caused by the differences in know-how, technology or investment capabilities between the IOCs and the NOCs. In the 'extreme' case, we can assume that NOCs have an infinitely large cost parameter. This case with the asymmetric capacity additions is solved and the results are compared with the 'general' case. As expected, it is found that when only one firm is allowed to invest in capacity, the market moves to a more concentrated structure. Finally, the essay conducts a welfare analysis in order to compare these two different cases with the first-best solution of the welfare maximization problem. According to the results, we were able to prove that the general case scenario is superior to the extreme case scenario in every aspect, as it yields higher total output, lower prices and lower total capacity investment.

A different perspective regarding the energy prices is introduced in Chapter 5. Prior to the credit crunch in 2008, a surge in commodity prices, specifically oil prices, raised concerns of possible market manipulation. In order to avoid possible speculation and market manipulation, the Commodity Futures Trading Commission (CFTC), the major financial market regulator in the USA, started to monitor and regulate the commodity futures markets more intensively. Recently, the literature on energy economics provided evidence that the surge in oil prices prior to 2008 was not driven by speculation.[15] Nevertheless, increasing non-commercial trading volumes in the crude oil futures market stimulated the CFTC to take actions against market manipulation (Masters, 2008).

[15]See, for example, Büyüksahin and Harris (2011), Kilian and Murphy (2012), Fattouh et al. (2013), Alquist and Gervais (2013), Elder et al. (2013), Kilian and Hicks (2013).

The CFTC can affect commodity markets through two channels. First, it can measure and correct any deviations from the fundamental price of the commodity, which are often caused by speculative activity. This channel can not explain the CFTC's involvement in the oil market during the 2008 credit crunch period since the prices were not driven by speculation. Second, the CFTC can take action against increasing riskiness, whose main indicator is volatility. As correctly noted by Fattouh et al. (2013), the aim of regulatory efforts in oil markets has so far been to reduce volatility. Hence, we suggest in this essay that the CFTC's regulatory efforts meant to decrease the riskiness of the oil market through suppressing the volatility.

The essay in this chapter analyzes the effects of the CFTC's regulatory announcements on oil- and gas-related stocks listed on the New York Stock Exchange (NYSE) around the time of the credit crunch, i.e., the period surrounding the financial crisis of 2008. Given knowledge of how oil prices and stock market activities are interrelated, it is commonly assumed that if the CFTC announcements have profound effects on the oil market, then the oil- and gas-related stocks would also respond to these announcements. Stock market returns are mostly driven by the expectations and perceptions of the traders. Thus, if the CFTC is able to decrease the volatility, and hence the riskiness, of the oil market, then the oil-related stocks would be significantly affected. This would show that the CFTC's regulatory announcements have a direct influence on the stock returns of firms from the oil and gas sector.

Apart from the literature on the relationship between oil prices and stock market activity, the essay in Chapter 5 also relates to the literature on the consequences of sector-specific announcements in the crude oil market.[16] The main finding of this stream of literature is that the OPEC announcements significantly affect oil prices. In addition, Guidi et al. (2006) suggest that the stock markets in the USA and the UK are significantly affected by the OPEC announcements. Our essay contributes to the literature in two regards. First, to the authors' best knowledge, there is no other study investigating the effects of the CFTC announcements on oil- and gas-related stocks. Second, despite the existence of extensive literature on whether speculation is a driving force in the oil market, the impacts of regulatory efforts have not yet been investigated entirely.

Event study methodology is applied to a comprehensive daily data set of 122 oil-related stocks listed on the NYSE for the period between 2007 and 2009. Seven energy related indices, namely Dow Jones US Oil & Gas Index, PHLX Oil Service Sector Index, SIG Oil Exploration & Production Index, NYSE ARCA Oil Index, NYSE ARCA Natural Gas Index S&P Global Oil Index and NYSE Energy Index, are used to determine the

[16] See, for example, Draper (1984), Deaves and Krinsky (1992),Horan et al. (2004), Wirl and Kujundzic (2004), Lin and Tamvakis (2010), Demirer and Kutan (2010)

companies to be included. Analyses are conducted on these indices in addition to the individual companies and total industry returns, which are compiled as the average of stock returns of all companies included in all analyses.

The most crucial step of the event study methodology is, without a doubt, the selection of announcements. Initially, 40 CFTC announcements related to energy futures commodities (specifically oil and gas) are collected from the CFTC's official website by searching keywords including "oil", "gas", "WTI" and "energy". However, some of these announcements took place in quick succession and hence led to the problem of confounding events. As suggested by McWilliams and Siegel (1997) this would cause biased results. As a result, we had to delete five of the confounding events. When two announcements overlapped, we kept the announcement that was thought to be of greater importance for the oil and gas market.

The event study methodology, which is first proposed by Brown and Warner (1980, 1985), is based on capturing the stocks' abnormal returns (AR), i.e., the firms' ex post stock return minus the firms' normal return during the event window. Normal returns are estimated using the market model proposed by Brown and Warner (1980) in which S&P 500 index returns are used as the overall market returns. Moreover, we define the event window to be the time period prior to and after the announcement takes place. Although it is possible to use different event windows, the most common in financial applications, which are based on high frequency data, is 2 days before and 2 days after the announcement.[17] Once the ARs over the five days of the event window are estimated, the cumulative abnormal return (CAR), which is the summation of ARs over the event window, is calculated for each and every company. Subsequently, index and industry CARs are calculated by taking the average of the CARs of the respective stocks.

In addition to the analyses on the overall market and indices, stock returns of the five biggest oil companies, namely BP, Chevron, Exxon, Shell and Total, are investigated in detail. Moreover, we analyze whether the firms' stock price reactions depend on their geographic location and therefore test whether the effects of the CFTC's announcements are more pronounced for firms that are based in the US and Canada (North America) than for firms that are located in other countries (Non-North American). Finally, we continue our analyses by subdividing the firms with respect to their business model into three sub-categories: Upstream, Mid & Downstream and Oil field service. Given the differences across business models (e.g., upstream–related firms should benefit from rising oil prices while downstream–related firms should suffer), an examination of the reaction to CFTC announcements may provide valuable findings for regulators and shareholders.

[17] In order to end up with robust results, we also represent different event windows, which yields similar results. Please refer to the Table B.4 of the Appendix B.

It is found that the overall industry stock returns significantly responded to 16 out of the 35 CFTC announcements. Most significant CARs are observed during the three announcements that aim for tighter regulation of the crude oil futures market. The announcements with greater effects generally subject severe punishments against market manipulation. Thus, results suggest that the CFTC regulatory efforts may, in general, affect the stock returns of oil- and gas-related companies. A CAR plot over the whole period also reveals the fact that the CFTC's regulatory announcements have a more profound effect on stock returns around the time of the financial crisis. This shows that during a period of high-assumed speculation, the CFTC can better interfere with the stock market activity by properly fulfilling its purpose as the regulatory body in the energy sector. Apart from the overall industry response, it is found that the stock returns of five biggest companies, namely Chevron, BP, Shell, Exxon and Total, react similarly to the CFTC's announcements. Their responses were also more significant and higher during the credit crunch period.

Our analyses on how companies from two different geographical locations, i.e., North America and Non-North America, react to the CFTC announcements reveal no significant asymmetry between these two groups. In most cases, positive (negative) stock market reactions of North American companies are accompanied by positive (negative) stock market reactions of Non-North American companies. Furthermore, the stock price reaction of the different subcategories of firms in the oil and gas sector (Upstream, Mid-downstream and Oil field service) also shows no evidence of asymmetry. The CARs of all three industry subcategories show strong co-movement over the whole period. Hence, it is concluded that the CFTC announcements lead to comparable effects for all types of firms in the oil and gas sector, irrespective of the firms' geographic location or industry subcategory.

The essay in Chapter 5 concludes that the CFTC announcements can, in general, affect the stock returns of oil and gas companies. Strong reactions are found during the peak of credit crunch, i.e., the Lehman Brothers failure. Most of the announcements during this period have positive effects on the stock returns, yet negative stock reactions are also observed. These negative responses may be explained by alternative events that took place simultaneously. Hence, our overall results could not prove that the CFTC's announcements always cause positive stock price reactions; yet it is plausible to state that it at least fulfilled its duty as the primary regulatory authority during this period of high uncertainty. These findings are of notable importance for shareholders of the companies, whose market capitalization are highly interrelated with the efforts made against speculation in financial markets.

Chapter 2

Crude oil price shocks and stock returns: Evidence from Turkish stock market under global liquidity conditions

2.1 Introduction

Since the first oil crisis experienced in 1973, the impact of oil price changes on macroeconomic activity has been widely discussed by academic researchers, investors and policy makers. In this respect, the pioneering study of Hamilton (1983), which concludes that there is significant correlation between increase in crude oil prices and US recessions, has been accepted as the fundamental basis for the subsequent studies on the effects of crude oil price shocks on macroeconomic indicators such as GDP growth rate, inflation, and industrial activity.[18] According to these studies, the price of crude oil, which is the primary fuel of industrial activity, plays a significant role in shaping the countries' economic and political developments, not only by directly affecting the aggregate indicators, but also by influencing companies' operational costs, and thus their revenues. When the stock market is efficient, positive crude oil price shocks would negatively affect the cash flows and market values of companies, causing an immediate decline in the overall stock market returns.

Although there exists a major consensus in the literature that endogeneity is not an issue when analyzing the impacts of oil prices on stock markets of the countries apart from

[18] Please see Section 2.2 for corresponding studies

USA, some studies (e.g., Park and Ratti, 2008) suggest that there would, at least, be some sort of spillover from US or global financial markets to that of developed, mostly European, countries. It also seems plausible to consider this interrelationship when studying stock markets of emerging economies, which attract large amount of short-term capital movement from major economies. This paper extends the understanding on the issue of global spillover effects on the dynamic relationship between oil prices and stock market returns by employing data from one particular emerging economy, Turkey.

The purpose of this paper is to investigate the impacts of oil price shocks on the Turkish stock market for the period between January 1990 and November 2011 using the vector autoregression (VAR, hereafter) model. A proxy variable capturing liquidity conditions in the global financial system is included into the analyses in order to examine the above-mentioned spillover effect. Since Turkey has limited domestic oil production and reserves, imports make up a significant portion of its oil consumption. Therefore, Turkish economy appears sensitive to oil price changes, similar to other developing and crude oil import-dependent countries. Moreover, over the last decades Turkish financial market, through a condense trade liberalization, has been attracting worldwide capital inflow. As of November 2011 foreign portfolio investments have been responsible for nearly 63% of total Turkish stock market capitalization.[19] Thus, Turkish stock market returns have become sensitive to the shocks created in international financial markets.

One more reason for including financial liquidity is that financial, more specifically futures, markets have been the other major crude oil market since the early 1990s. This was the result of increasing volume of crude oil future contracts traded, which exceeded global oil production/consumption during late 1980s.[20] Since then crude oil prices have been determined in a manner that accounts for the effects of decisions made by investors, speculators, hedgers, and large investment funds in the future markets, as well as physical market conditions. Analyzing these "non-physical" market conditions, such as expectations about the market, global financial and economic indicators, would increase the possibility to shed some more light on the empirical variations in crude oil prices.

Therefore, a proxy for global financial liquidity will not only serve as an explanatory factor that influences stock market returns, but also be used to explain variations in oil prices. In the current study, the evidence of such tridimensional interaction, e.g. joint respond of stock returns and oil prices to liquidity, is investigated using the disentangling methodology proposed by Kilian and Park (2009).

[19]Data from website of Istanbul Stock Exchange (IMKB): http://www.ise.org/Data/StocksData.aspx

[20]Using data for global crude oil production/consumption from BP's Statistical Review of World Energy 2011 and for the volume of WTI crude oil futures contracts from NYMEX official website exact year can be derived as 1988.

Understanding the impact of crude oil prices on Turkish stock market is potentially beneficial for investors, market participants, regulators and researchers, as it is likely to exhibit characteristics different from those observed in well-documented developed markets. Thus, our study explores an underexploited area of potentially valuable research in Turkey with a very comprehensive data set, ranging from January 1990 and November 2011. This relatively long time horizon has been divided into three sub-periods coinciding with specific oil price trends to allow testing of the performance of the Turkish stock market under different oil price regimes.[21] Empirical results suggest that oil prices have significant impacts on Turkish stock market returns only during the third sub-period, during which crude oil prices represented extreme volatile structure. On the other hand, whenever the financial liquidity conditions are incorporated into the analyses, it is found out that liquidity is the most plausible explanation for the changes in both oil prices and stock market returns.

The remainder of this paper is organized as follows. The next section provides relevant literature about the relationship between financial markets and oil price shocks. Section 2.3 outlines the econometric methodology concerning VAR analysis and disentangling. The data set and empirical results are presented in Section 2.4. Finally, Section 2.5 contains discussion of results and concluding remarks.

2.2 Literature Review

Since Hamilton (1983), a plethora of studies have analyzed the interrelation between macroeconomic activity and oil price changes, most of which demonstrated a negative correlation.[22] However, according to the studies on the relationship between oil prices and stock markets, oil price shocks influence various industries' stock prices differently and the relationships between oil price shocks and financial markets are, for many countries, complex and ambiguous. A commonly held view is that an upward trend in oil price is beneficial for oil producing companies' stock returns and oil exporting countries' market activity, yet has an adverse effect on most of other sectors and oil importing countries.

[21] Sub-period I: January 1990–November 2001; Sub-period II: November 2001–July 2008; Sub-period III: July 2008–November 2011. Please see Section 2.4.1 for details of sub-periods.

[22] Please refer to: Mork (1989), Kahn and Hampton Jr (1990), Huntington (1998), Brown and Yücel (1999, 2002), Gao and Madlener (1999), Hamilton (2003), Dickman and Holloway (2004), Guo and Kliesen (2005), Rogoff (2006), Sill (2007), Kilian (2008b), Oladosu (2009). Moreover, a number of researchers have examined the role of crude oil prices in monetary policy (e.g. Bernanke et al., 1997, Hamilton and Herrera, 2004) and impacts of oil prices on exchange rates (e.g. Chen and Chen, 2007, Coudert et al., 2007).

A firm-specific study by Al-Mudhaf and Goodwin (1993) investigated the returns from 29 oil companies listed on the NYSE and demonstrated a positive impact of oil price shocks on ex-post returns for firms with significant assets in domestic oil production. Further, Huang et al. (1996) analyzed the relationship between daily oil future returns and US stock returns by employing an unrestricted VAR model and found evidence that oil futures clearly lead some individual oil company stock returns. Faff and Brailsford (1999) used market model to investigate several industry returns in the Australian stock market, finding significant positive oil price sensitivity of Australian oil and gas, and diversified resources industries. In contrast, industries such as paper and packaging, banks and transport appear to display significant negative sensitivity to oil price hikes. Sadorsky (2001) indicated that stock returns of Canadian oil and gas companies are positively sensitive to oil price increases. Boyer and Filion (2007) employed a multifactor framework to analyze the determinants of Canadian oil and gas stock returns, finding similar results to Sadorsky (2001). Although El-Sharif et al. (2005) demonstrated that the oil prices have significantly positive impacts on oil and gas returns in the UK, evidence for the oil price sensitivity existing in the non-oil and gas sectors is generally weak. In this context, Henriques and Sadorsky (2008) measured the sensitivity of the financial performance of alternative energy companies to changes in oil prices using VAR model in order to investigate the empirical relationship between alternative energy stock prices, technology stock prices, oil prices, and interest rates. They indicated that technology stock price and oil price each individually Granger causes the stock prices of alternative energy companies. More recently, Oberndorfer (2009) analyzes the interrelationship between oil prices and European energy companies and finds both oil prices and oil price volatility negatively affects the stock prices of utility companies.

Jones and Kaul (1996) examined whether the reaction of international stock markets to oil shocks could be justified by current and future changes in real cash flows, or changes in expected returns. They provided evidence that aggregate stock market returns in the US, Canada, Japan and the UK are negatively sensitive to the adverse impact of oil price shocks on the economies of these countries. Contradicting to Jones and Kaul (1996), Huang et al. (1996) found no evidence of a relationship between oil futures prices and aggregate stock returns using daily data from 1979 to 1990. However, Ciner (2001) challenged the findings of Huang et al. (1996), and argued for the need for further research to produce evidence from international equity markets to support the robustness of the results. He concluded that a statistically significant relationship exists between real stock returns and oil price futures, but that the connection is non-linear. Moreover, Huang et al. (2005) investigated the effect of oil price change and its volatility on economic activities in the US, Canada and Japan. They indicated that when exceeding a certain threshold, oil price change and volatility possess significant explanatory power for the outcome of economic variables such as industrial production and stock market returns.

Theoretically, in oil exporting countries, stock market prices are expected to be positively affected by oil price changes through positive income and wealth effects. In an analysis of the effects of oil price shocks on stock markets in Norway, Bjørnland (2009) argued that higher oil prices represent an immediate transfer of wealth from oil importers to exporters, stating that the medium to long-term effects depend on how the governments of oil producing countries dispose of the additional income. If used to purchase goods and services at home, higher oil prices will generate a higher level of activity, and thus improve stock returns. In addition, Gjerde and Saettem (1999) demonstrated that stock returns have a positive and delayed response to changes in industrial production and that the stock market responds rationally to oil price changes in the Norwegian market.

A negative association between oil price shocks and stock market returns in oil importing countries has been reported in several recent papers. Nandha and Faff (2008) examined global equity indices with 35 industrial sectors, showing that oil price rises have a negative impact on stock returns for all sectors except the mining, and oil and gas industries. O'Neill et al. (2008) found that oil price increases led to reduced stock returns in the US, the UK and France. In a study of the connection between oil price shocks and the stock market for the US and 13 European countries, Park and Ratti (2008) reported that oil price shocks had a negative impact on stock markets in US and many European countries, while the stock exchange of Norway showed a positive response to the rise in oil prices. These authors also provided evidence that stock markets in oil exporting countries are less affected by oil prices relative to oil importing countries. The results of Chiou and Lee (2009) study confirmed the existence of a negative and statistically significant impact of oil prices on stock returns. Their findings also provided support for the notion that oil shocks drive economic fluctuations, with the evidence indicating that with changes in oil price dynamics, oil price volatility shocks have an asymmetric effect on stock returns. Examining whether the endogenous character of oil price changes affect stock market returns in a sample of eight developed countries, Apergis and Miller (2009) found evidence that different oil market structural shocks play a significant role in explaining adjustments in international stock returns. Aloui and Jammazi (2009) study focused on two major crude oil markets, namely WTI and Brent, and three developed stock markets, namely France, UK and Japan and was based on the relationship between crude oil shocks and stock markets from December 1987 to January 2007. The results indicated that the net oil price increase variable plays an important role in determining both the volatility of real returns and the probability of transition across regimes.

More recently, Arouri and Nguyen (2010) used different empirical techniques namely, market model and the two-factor market and oil model, to test the causality between oil prices and twelve European sector indices listed on Dow-Jones for the period from January 1998 to November 2008. They found asymmetries in response of the different sector indices to oil price changes. Fan and Jahan-Parvar (2012), studying the interrelation between U.S. industry-level returns and oil prices, found no evidence that oil prices have significant predictive power for industry-level returns. Chortareas and Noikokyris (2014) has more recently investigated the effects of oil supply and demand shocks on U.S. dividend yield components, i.e. dividend growth, real interest rate, equity premium. Following disentangling methodology proposed by Kilian (2009) they showed that that although positive relationship between oil price increase and dividend yield is evident, the persistence of relationship is highly dependent on the driving force of the oil price increase.

Jammazi and Aloui (2010) explore the impact of crude oil shocks on stock markets of three developed countries, UK, France and Japan, using a combined approach of wavelet analysis and Markov Switching Vector Autoregression. They evaluated the issue in two phases of stock markets and found that while oil shocks do not affect stock markets during recession phases, they have significant negative impact during expansion phases. While Jammazi (2012b) uses the same approach with Jammazi and Aloui (2010) to analyze the effect of crude oil shocks on stock market returns of USA, Canada, Germany, Japan and UK, Jammazi (2012a) uses a transformation of wavelet analysis with "Haar A Trous" decomposition to explore the interactions between crude oil price changes and stock returns of same five countries. The results of these studies reveal that both approaches are more accurate then the methodologies used in existing literature when the focus is to account for changing intensity of crude oil shocks over time. Reboredo and Rivera-Castro (2014) also used wavelet-based analysis to investigate the impacts of oil prices on different stock market indices, including S&P 500, Dow Jones Stoxx 600 and sectoral indices, and found positive interdependence especially during post credit crunch period.

Contrary to the work done on developed markets, relatively little research has focused on the relationship between oil prices and stock markets of emerging – oil exporting or importing – economies. Hammoudeh and Aleisa (2004) examined the relationship between oil prices and stock prices for five members (Bahrain, Kuwait, Oman, Saudi Arabia, and the United Arab Emirates) of the Gulf Cooperation Council (GCC), all of which are net oil exporters, for the period 1994–2001, while Zarour (2006) investigated the same countries during 2001 to 2005. Hammoudeh and Aleisa's findings suggested that most of these markets react to the movements of the oil futures price, with only Saudi Arabia having a bidirectional relationship. By analyzing the impulse response function, Zarour concluded that the sensitivity of these markets to shocks in oil prices has increased, with responses becoming more rapid after rises in prices. Arouri and Fouquau (2009) investigated the short-run relationships between oil prices and GCC stock markets. To examine the phenomena of stock markets' occasional non-linear response to oil price shocks, they examined both linear and nonlinear relationships. Their findings pointed to a significant positive relation between oil prices and the stock index of Qatar, Oman and UAE, but for Bahrain, Kuwait and Saudi Arabia, they found no such influence. As another GCC study, Naifar and Al Dohaiman (2013) using Markov regime-switching model, found that the relationship between those markets and oil price volatility is dependent upon the regime.

Employing an error correction representation of a VAR model, Papapetrou (2001) concluded that oil price is an important factor in explaining the stock price movements in Greece, and that a positive oil price shock tends to depress real stock returns. Maghyereh (2004) studied the relationship between oil prices changes and stock returns in 22 emerging markets, conducting VAR model from 1998 to 2004, without finding any significant evidence that crude oil prices have an impact on stock index returns in these countries. In contrast to this conclusion, Basher and Sadorsky (2006), analyzing the impact of oil price changes on a large set of emerging stock market returns for the period 1992 to 2005, proposed that emerging economies are less able to reduce oil consumption and thus are more energy intense, and more exposed to oil prices than the developed economies. Therefore, oil price changes are likely to have a greater impact on profits and stock prices in emerging economies. Cong et al. (2008) apply multivariate vector autoregression methodology to analyze the interactive relationship between oil price shocks and Chinese stock market activity. Authors find no evidence that oil price shocks have significant effect on stock returns except for manufacturing index and some oil companies'. Similarly, Narayan and Narayan (2010) investigated the impact of oil prices on Vietnam's stock prices and concluded that oil price have a positive and significant impact on stock prices. Finally, Soytas and Oran (2011) examined the causality between oil prices and Turkish stock market (ISE-100) aggregate and electricity indices. They concluded that while oil prices do not Granger cause aggregate index, they have significant impact on electricity index.

2.3 Methodology

This study employs VAR approach in order to examine the dynamic interactions between oil price shocks and the Turkish stock index, and compare results, which take into account global financial liquidity conditions with those that do not. The VAR model introduced by Sims (1980), presents a multivariate framework that expresses each variable as a linear function of its own lagged value and lagged values of all the other variables in the system. The main advantage of this approach is the ability to capture the dynamic relationships among the economic variables of interest. The methodology treats all variables as jointly endogenous, and for proper estimation in a multivariate stable VAR system, all variables employed in the model must be stationary or I(0) process. Although there are many tests developed in the time-series econometrics to test for the presence of unit roots, two tests in particular the Augmented Dickey-Fuller (ADF hereafter) test (Dickey and Fuller, 1979, 1981) and the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS hereafter) test (Kwiatkowski et al., 1992) have been employed to investigate the degree of integration of the variables used in the empirical analysis.[23]

Case I: Simple Model

Here, we start with a simple model, which takes the relationship between oil prices and Turkish stock market into account and neglects effect of global liquidity constraints. In this model we needed to transform oil prices into shock variables. Besides linear ones, some nonlinear transformations of oil prices have also been proposed in the literature.[24] Therefore, in order to achieve robust empirical results we have used both linear and nonlinear transformations of oil prices. Two types of variables for oil price shocks employed in this study are log return and scaled oil price increase (SOPI hereafter). The log return of oil prices, o_t, is from $t-1$ to t calculated as:

$$o_t = log(p_t/p_{t-1}) \tag{2.1}$$

where p_t denotes oil prices at time t. The oil price shock variable is also calculated by the method of SOPI developed by Lee et al. (1995).

$$SOPI_t = \max\left[0, (\hat{u}_t)/\sigma_t\right] \tag{2.2}$$

where $\hat{u}_t$ is the residuals and σ_t is the square root of the volatility (${\sigma_t}^2$), which are derived from equation system (2.3), and $SOPI_t$ captures positive oil price shocks for the subjected date. For this specification, GARCH(p,q) model, which has been first proposed by Bollerslev (1986) and has become popular, particularly, due to its explanatory power for dependence in volatility, is estimated as follows:

[23]Since all the variables included in the VAR methodolog are I(0) process, Vector Error Correction Model (VECM) was not conducted in this paper.

[24]Please refer to Mork (1989), Lee et al. (1995) and Hamilton (1996).

$$
\begin{aligned}
o_t &= \mu + \sum_{m=1}^{l} \eta_m o_{t-m} + u_t \\
\sigma_t^2 &= \alpha_0 + \sum_{k=1}^{q} \alpha_k u_{t-k}^2 + \sum_{j=1}^{p} \beta_j \sigma_{t-j}^2
\end{aligned}
\tag{2.3}
$$

where u_t is white noise with $(u_t|u_{t-1}) \sim N(0, \sigma_t^2)$.

Furthermore, we have proposed a bivariate VAR(p) system with daily return of Turkish stock index and two types of oil price change variable to analyze the variance decomposition structure. The model is written in the reduced form of structural VAR representation as follows:

$$
\begin{aligned}
rs_t &= \beta_{10} + \sum_{i=1}^{p} \beta_{1i}\; rs_{t-i} + \sum_{i=1}^{p} \alpha_{1i}\; X_{t-i} + u_{1t} \\
X_t &= \beta_{20} + \sum_{i=1}^{p} \beta_{2i}\; X_{t-i} + \sum_{i=1}^{p} \alpha_{2i}\; rs_{t-i} + u_{2t}
\end{aligned}
\tag{2.4}
$$

where rs_t is the log-return of daily Turkish stock exchange index price, and X_t is the corresponding oil price shock variable, either o_t or $SOPI_t$.

Case II: Incorporating Global Liquidity Conditions

The dynamic system in equation (2.4) may lead to a conclusion that oil price shocks have significant impacts on stock returns, however this result may be biased if any variable, which affects both oil prices and stock returns in the long-run, is omitted. In order to avoid such a consequence, we should obtain a 'purified' oil price shock variable, related only to the oil market itself. In order to obtain such purified oil market specific price shock variable we have employed disentangling methodology, proposed by Kilian and Park (2009). A proxy variable for global financial liquidity conditions, which is thought to be responsible for variations in oil prices besides physical oil market conditions, is incorporated into the analyses.

Chicago Board of Options Exchange's (CBOE, hereafter) S&P 500 market volatility index, *vix*, is chosen as the proxy for global liquidity and its first difference, *dvix*, is used in VAR framework:[25]

[25] First difference of CBOE's volatility index $dvix_t$ is because vix is $I(1)$ process.

$$\begin{aligned}
o_t &= \delta_{10} + \sum_{i=1}^{p} \delta_{1i}\ o_{t-i} + \sum_{i=1}^{p} \phi_{1i}\ dvix_{t-i} + u_{o,t} \\
dvix_t &= \delta_{20} + \sum_{i=1}^{p} \delta_{2i}\ dvix_{t-i} + \sum_{i=1}^{p} \phi_{2i}\ o_{t-i} + u_{vix,t}
\end{aligned} \tag{2.5}$$

The first equation of this dynamic system allows to capture residuals, $\hat{u}_{o,t}$, which can be used as purified oil market specific shock variable. This residual series and $dvix_t$ are, further, used in the VAR framework proposed below instead of oil price shock variable, X_t, to examine their effects on Turkish stock index returns' variance decomposition structure. The proposed dynamic system, hence, becomes a tri-variate VAR with a following representation:

$$\begin{aligned}
rs_t &= \gamma_{10} + \sum_{i=1}^{p} \gamma_{1i}\ rs_{t-i} + \sum_{i=1}^{p} \kappa_{1i}\ \hat{u}_{o,t-i} + \sum_{i=1}^{p} \varphi_{1i}\ dvix_{t-i} + \epsilon_{1t} \\
\hat{u}_{o,t} &= \gamma_{20} + \sum_{i=1}^{p} \gamma_{2i}\ \hat{u}_{o,t-i} + \sum_{i=1}^{p} \kappa_{2i}\ dvix_{t-i} + \sum_{i=1}^{p} \varphi_{2i}\ rs_{t-i} + \epsilon_{2t} \\
dvix_t &= \gamma_{30} + \sum_{i=1}^{p} \gamma_{3i}\ dvix_{t-i} + \sum_{i=1}^{p} \kappa_{3i}\ rs_{t-i} + \sum_{i=1}^{p} \varphi_{3i}\ \hat{u}_{o,t-i} + \epsilon_{3t}
\end{aligned} \tag{2.6}$$

Variance decomposition analysis of this tri-variate VAR system will enlighten whether Turkish stock returns react to oil market specific shocks, or to shocks created in global markets due to the liquidity conditions.

2.4 Data and Empirical Results

2.4.1 Data

The data of this study consists of daily observations of ICE's Brent crude oil prices (p_t), log-return of ISE-100 stock market index (rs_t), and CBOE volatility index (vix_t). The 'National-100 Index' (ISE-100) is the main market indicator of the Turkish Stock Market. The data for Brent crude oil prices, ISE-100 index prices and VIX obtained from the US Energy Information Administration, the Matrix Database[26] and CBOE's official website, respectively. The data covers the period from January 2, 1990 to November 1, 2011, realizing a total of 5,194 observations. In order to examine stock market behavior under different oil price regimes, the data set is divided into three sub-periods. The first

[26]Matriks is a licensed data dissemination vendor located in Turkey. It provides data and information on global financial markets as well as selected macroeconomic indicators.

sub-period consists of 2833 observations, namely from January 2, 1990 to November 15, 2001, where oil prices follow a comparatively stable and horizontal trend, ranging between 9 US Dollars per barrel ($/bbl hereafter) and 41 $/bbl. The second consists 1604 observations from November 16, 2001 to July 11, 2008, during when the crude oil market, as with other commodities, witnessed historical record prices after an upward trend reaching to approximately 145 $/bbl. During the third, from July 14, 2008 to November 1, 2011, with the credit crunch period, crude oil prices immediately fell from 145 $/bbl barrel to nearly 40 $/bbl, and then increased again to approximately 125 $/bbl, representing high volatility, which led to extremely large positive and negative returns within a relatively short time period.

The descriptive statistics for Brent crude oil returns (o_t), ISE-100 stock index returns (rs_t), and first difference of CBOE's S&P 500 market volatility index ($dvxi_t$) series are provided in Table 2.1. All three descriptive series display non-Gaussian characteristics with negative skewness for Brent crude oil returns and positive skewness for ISE-100 stock index returns, and CBOE's market volatility index. Moreover, all series exhibit excessive kurtosis, a fairly common occurrence in high-frequency financial time series data, and suggest that the observed excessive kurtosis may be due to heteroskedasticity in the data, which may be captured with the GARCH models. Excessive kurtosis would also explain the reasoning for high Jarque-Bera statistics, which reject the null hypothesis of normality for all return series. Values for coefficient of variation (CV) represent extreme and relatively high variance clustering around the mean of $dvxi_t$ and o_t. The volatility index variable, by definition, captures variance of CBOE market; hence high CV is expected for $dvix_t$. On the other hand high CV value for o_t suggests further analyzing the variance structure of oil returns.

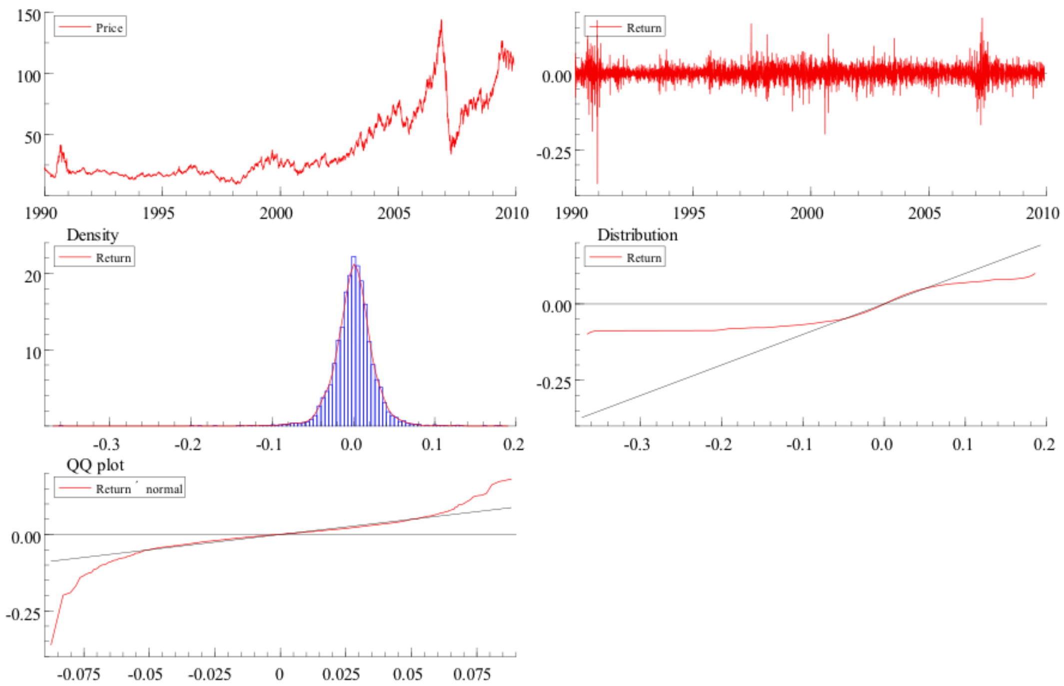
Table 2.1: Descriptive Statistics of Sample Series

	o_t	rs_t	$divx_t$
Mean	0.0003	0.0015	0.0034
Median	0.0008	0.0014	-0.0600
Maximum	0.1813	0.2655	16.5400
Minimum	-0.3612	-0.2033	-17.3600
Standard Deviation	0.0247	0.0290	1.5876
Coefficient of Variation	82.33	19.33	466.94
Skewness	-0.7742	0.0469	0.6606
Kurtosis	17.29	8.58	21.46
Jarque-Bera Stat	44736.01***	6745.03***	74148.06***
# of observations	5193	5193	5193

Notes: SD indicates standard deviation. Jarque-Bera normality test statistic has a chi-square distribution with 2 degrees of freedom. *** denotes statistical significance at 1% level.

Volatility clustering is immediately evident from the graphs of daily oil returns, which suggests the presence of heteroskedasticity (Figure 2.1). The density graphs and the QQ-plot against the normal distribution show that return distribution exhibits fat tails, which the QQ-plots reveal are not symmetric. Oil prices show the greatest volatility and excess kurtosis, and the corresponding returns are positively skewed. This short but important preliminary descriptive and graphical analysis of the series indicates that the chosen statistical model should take into account the volatility clustering, fat tails and skewness features of the returns.

FIGURE 2.1: Brent Crude Oil Prices, Returns and Tail Distribution with QQ-Plot



Note: The Brent crude oil price, daily returns, daily returns density and QQ-plot against the normal distribution. The time period is from 02.01.1990 – 01.11.2011

2.4.2 Empirical Results

Before investigating the impacts of oil price shocks on the stock market, we proceed to examine the stochastic properties of the series considered in the model by analyzing their order of integration on the basis of a series of unit root tests. Specifically, the Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests are performed for the three sub-periods and the findings, summarized in Table 2.2[27], indicate that the first differences of all series are stationary, I(1) for all periods, allowing us to model the dynamic interactions with VAR model.

Table 2.2: Unit Root Test Results

		Level		First Difference	
		ADF	KPSS	ADF	KPSS
Brent Crude Oil (o_t)	Sub-Period I	-2.76	0.603*	-17.905*	0.038
	Sub-Period II	0.272	0.429***	-38.524***	0.137*
	Sub-Period III	-5.120***	0.338***	-27.608***	0.289***
	Whole Period	-2.852	1.341***	-11.308***	0.022
ISE-100 (rs_t)	Sub-Period I	-2.129	0.976***	-13.685***	0.035
	Sub-Period II	-1.531	0.297***	-40.282***	0.136*
	Sub-Period III	-1.227***	0.407***	-12.278***	0.143*
	Whole Period	-2.157	1.434***	-14.754***	0.035
VIX (vix_t)	Sub-Period I	-4.181***	0.901***	-19.364***	0.018
	Sub-Period II	-2.002	0.802***	-17.837***	0.041
	Sub-Period III	-2.726	0.277***	- 8.907***	0.053
	Whole Period	-5.046***	0.273***	-13.629***	0.014

Notes: *** and * indicate the statistical significance at 1% and 10% level, respectively.

As represented in equation system 2.4, VAR analysis is conducted on two types of oil price shock variables. In order to estimate $SOPI_t$ type shock variable, volatility of Brent crude oil returns is modeled with AR(1)-GARCH(1,1)[28] specification and the test results are indicated in Table 2.3. All of the parameter estimates of the AR(1)-GARCH(1,1) model are found to be highly statistically significant. The persistence in volatility as measured by sum of β_1 and α_1 in GARCH model is closer to unity for each period. As shown in Table 2.3, the estimated β_1 coefficient in the conditional variance equation is coniderably larger than α_1 coefficient. The implication is that the volatility is more sensitive to the previous forecast of volatility in the market place.

To check the performance of our model, ARCH-LM specification test was conducted on the normalized residuals, and there should be no ARCH effect left in the normalized residuals. Table 2.4 reports ARCH-LM test results for all three sub-periods. The results indicate that no serial dependence persists left in squared residuals of Brent crude oil returns after volatility modeling for sub-periods I and III, and also for the whole period.

[27]Note that null hypothesis (H_0: unit root exists in time series) for ADF test is the alternative hypothesis (H_A) for KPSS test.

[28]Different AR(q)-GARCH(p,q) models were initially fitted to the data and compared on the basis of the Akaike and Schwarz Information Criteria (AIC and SIC) from which a AR(1)-GARCH(1,1) model was deemed most appropriate for modeling.

Table 2.3: GARCH Variance Estimation Results

	μ	η_1	α_0	β_1	α_1
Sub-period I	0.0001	0.0765***	0.0000***	0.8926***	0.1032***
Sub-period II	0.0016***	-0.022	0.0000***	0.8620***	0.0400***
Sub-period III	0.0009	0.0013	0.0000**	0.9328***	0.0600***
Whole Period	0.0005**	0.0328**	0.0000***	0.9154***	0.0747***

Notes: *** and ** indicate the statistical significance at 1% and 5% level, respectively.

Although test statistics for sub-period II rejects the null hypothesis of "no serial dependence between squared residuals", it is statistically significant only at the 10% level of significance. Hence, the results suggest that AR(1)-GARCH(1,1) model is reasonably well specified to capture the ARCH effects.

Table 2.4: ARCH-LM Test Results

	Constant Term	Squared Residuals	F-Statistics	LM-Statistics
Sub-period I	1.003 (0.0000)	-0.004 (0.8280)	0.0472 (0.8280)	0.0473 (0.8279)
Sub-period II	1.037 (0.0000)	-0.041 (0.0986)	2.7306 (0.0986)*	2.7293 (0.0985)*
Sub-period III	1.013 (0.0000)	-0.010 (0.7773)	0.0801 (0.7773)	0.0803 (0.7769)
Whole Period	1.006 (0.0000)	-0.0072 (0.6026)	0.2712 (0.6026)	0.2712 (0.6025)

Note: The numbers in parenthesis are p-values. * denotes rejection of null hypothesis at 10%.

Since the volatility modeling has succeeded in capturing the oil prices variance to a significant degree, the GARCH model and derived residual terms were further used in equation 2.2 to calculate $SOPI_t$ data. Then we employed VAR framework as in equation system in 2.4 with ISE-100 daily returns and two of the oil price shock variables, log returns (o_t) and $SOPI_t$, separately for each period. The results of Wald test for block significance and generalized variance decomposition of ISE-100 due to the oil price shocks are summarized in Table 2.5 and Table 2.6 respectively. According to the block-significance test results, oil prices found to have a statistically significant impact on stock returns only during the last sub-sample period. Yet the impact is rather small as represented in variance decomposition results.

TABLE 2.5: Block Exogeneity Wald Test Results for System in 2.4

	Implied Coefficient Restrictions	$SOPI_t \rightarrow rs_t$ χ^2-stat	$o_t \rightarrow rs_t$ χ^2-stat
Sub-period I	$\alpha_{1i} = 0$, for $i = 1, 2, 3, 4, 5$	1.8095	1.5544
Sub-period II	$\alpha_{11} = 0$	1.3681	1.8308
Sub-period III	$\alpha_{11} = 0$	6.5633***	10.1163***
Whole Period	$\alpha_{1i} = 0$, for $i = 1, 2, 3, 4, 5, 6$	4.3473	6.7199

Note: AIC determines the lag-length for VAR model as 5 for the first sub-period, 1 for the second sub-period, 1 for the third sub-period and 6 for whole period. *** indicates the significance at 1% confidence level.

TABLE 2.6: Generalized Decomposition of Variance of ISE-100 in Response to Oil Price Shock Variables

Days after Impulse	Sub-period I $SOPI_t$	o_t	Sub-period II $SOPI_t$	o_t	Sub-period III $SOPI_t$	o_t	Whole Period $SOPI_t$	o_t
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0344	0.0258	0.0854	0.1144	0.8094	1.2432	0.0148	0.0011
5	0.0486	0.0522	0.0861	0.1147	0.8098	1.2433	0.0148	0.0234
10	0.0553	0.0593	0.0861	0.1147	0.8098	1.2433	0.0148	0.1322

Moreover, in order to include global financial liquidity conditions into the analyses, VAR methodology between Brent crude oil prices and CBOE's S&P 500 volatility index (Eq. 2.6) was used to capture the variance decomposition, which is provided in Table 2.7. Although the block-significance test results imply a unidirectional lead-lag relation between first difference of VIX and crude oil returns for all three sub-periods, it is only during the third sub-period that shocks from VIX create a comparatively higher variance on crude oil returns.[29] On the other hand, regardless of the magnitude of the effect of global financial liquidity condition on variance of crude oil prices, it would still be considered possible to be able to capture residuals for oil returns that will be used as oil market specific price shocks purified of global liquidity constraints.

Once oil market specific shock, $\hat{u}_{o,t}$, and financial liquidity shock, $dvix_t$, are captured by the disentangling methodology, they are considered as two separate variables, along with stock prices in the VAR framework. Therefore, we have also used this multivariate framework to investigate the interrelationship between ISE-100 returns, oil price shocks and global financial liquidity shocks for the whole periods. The results, which are provided in Table 2.8, imply that the global liquidity statistically increases the variance of ISE.

[29] According to the Block Exogeneity Wald Test, there exists a significant unidirectional causality from first difference of VIX to log-returns of Brent crude oil prices at 1% level for all three sub-periods.

Table 2.7: Generalized Decomposition of Variance of Brent Crude Oil Returns in Response to Global Financial Liquidity

Days after impulse	Sub-period I	Sub-period II	Sub-period III	Whole Period
1	0.0000	0.0000	0.0000	0.0000
2	0.0912	0.6183	1.9680	0.1580
5	0.3545	0.6482	2.6108	0.2253
10	0.6819	0.6487	3.8427	0.3578

Note: AIC determines the lag-length as 7 for the first sub-period, 4 for the second sub-period, 1 for the third sub-period and 7 for the whole period.

Table 2.8: Block Exogeneity Wald Test Results for System in 2.6

	Imp. Coef. Restric.	$divx_t \rightarrow rs_t$ χ^2-stat	Imp. Coef. Restric.	$\hat{u}_{o,t} \rightarrow rs_t$ χ^2-stat
Sub-period I	$\varphi_{1i} = 0$ for $i = \{1, 6\}$	24.4151***	$\kappa_{1i} = 0$ for $i = \{1, 6\}$	4.2867
Sub-period II	$\varphi_{11} = 0$	34.1651***	$\kappa_{11} = 0$	1.4218
Sub-period III	$\varphi_{11} = 0$	95.7573***	$\kappa_{11} = 0$	3.1124*
Whole Period	$\varphi_{1i} = 0$ for $i = \{1, 6\}$	85.0101***	$\kappa_{1i} = 0$ for $i = \{1, 6\}$	6.0041

Notes: AIC determines the lag-length as 6 for the first sub-period, 1 for the second sub-period, 1 for the third sub-period and 6 for the whole period. *** and * indicate the significance at 1% and 10% confidence level respectively.

Table 2.9: Generalized Decomposition of Variance of ISE-100 in Response to Oil Price Shock with Global Financial Liquidity

Days after Impulse	Sub-period I		Sub-period II		Sub-period III		Whole Period	
	$divx_t$	$\hat{u}_{o,t}$	$divx_t$	$\hat{u}_{o,t}$	$divx_t$	$\hat{u}_{o,t}$	$divx_t$	$\hat{u}_{o,t}$
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.6894	0.0052	2.0763	0.0874	10.051	1.7774	0.1153	0.0415
5	0.7595	0.0259	2.1237	0.0897	10.361	1.7871	0.1797	0.0884
10	0.9007	0.1582	2.1237	0.0897	10.361	1.7871	0.2186	0.1542

According to the results from variance decomposition analyses, provided in Tables 2.6 and 2.9, three deductions can be made. First of all, the contribution of oil price shocks to the Turkish stock market is greater in the third sub-period than that of the first and second. This is an expected result such that, since oil prices move in a considerably more volatile manner in the third sub-period they create a higher impact on the ISE-100 returns. Secondly, the impact on variance decomposition starts with the second day of the impulse and dies out immediately without changing the structure of the trend of ISE-100. This may be the result of a non-linear relationship between oil prices and stock market returns, as proposed by prior researches (e.g., Arouri and Fouquau, 2009, Jawadi et al., 2010). Finally, the liquidity shock variable seems to be a considerable source of volatility for ISE-100 returns during the third sub-sample period, contributing more than 10%. This means that liquidity shocks, rather than crude oil prices, are the primary factor in stock market movements.

2.5 Discussions and Concluding Remarks

In this paper, we have investigated the impacts of crude oil price variations on the Turkish stock market using structural VAR model for the period between January 2, 1990 and November 1, 2011. ISE-100 index is used as a proxy for the performance of the Turkish stock market. The interactions between oil prices and ISE-100 have been analyzed by dividing this long time horizon into three sub-periods in order to test the response of Turkish stock market during different oil price regimes.

The empirical results suggest that the oil price changes significantly and rationally affect the Turkish stock market activity during only the third sub-period, which begins after the credit-crunch of 2008. Moreover, when the global financial liquidity conditions have been incorporated into the model, CBOE's market volatility index (VIX), which is used as an indicator for global financial liquidity, has been found to significantly affect both oil prices and ISE-100 returns. In this trivariate VAR analysis results also suggest that the most significant impacts of global liquidity shocks on stock market returns occur in the third sub-period.

The overall results suggest that the global financial liquidity conditions are the most plausible explanation for the changes in Turkish stock market returns. Although there exists some evidence that purified oil price shocks still have an impact on stock market returns, this effect is smaller and less significant than the liquidity constraints. This is an expected result provided that Turkish stock market, through widespread trade liberalization, has been attracting worldwide capital inflow, which makes it more vulnerable to shocks created in global financial markets.

This study can be extended by obtaining a comparable firm-based dataset and by analyzing the behavior of each firm after oil price shocks. The empirical findings will prove to be extremely useful information to investors who need to understand the effect of oil price changes on certain stocks across industries, as well as for the managers of certain firms who require deeper insight into the effectiveness of hedging policies, which are affected by oil price changes.

Chapter 3

Energy prices and economic growth in the long run: Theory and evidence

3.1 Introduction

There has been a plethora of empirical studies on short- or medium-term interactions between energy (especially oil) prices and macroeconomic indicators following the pioneering study of Hamilton (1983). Although there has been debate over the nature of the relationship, such as non-linearities (Hamilton, 1996, 2003, 2011, Kilian and Vigfusson, 2011b) and asymmetries, i.e. differences in response to positive and negative shocks (Balke et al., 2002, Huntington, 1998, Kilian and Vigfusson, 2011a, Mork, 1989) there seems to be a consensus on the fact that oil price changes would at least have a particular, if not pivotal, effect on macroeconomic variables.[30]

On the other hand, the impact of (rising) energy prices has never received substantial attention from growth economists, possibly because this has been perceived as a short run issue. The main concentration of the mainstream economic growth literature has been on the optimal depletion and the price path of exhaustible resources, following the original study of Hotelling (1931).[31] More recently, the 'new' growth economics , i.e. the endogenous economic growth literature, has focused on transition/substitution between energy sources (Chakravorty et al., 1997, Just et al., 2005, Tahvonen and Salo, 2001, Tsur and Zemel, 2003), directed technical change in an economy with energy sources

[30]Please additionally see: Kahn and Hampton Jr (1990), Brown and Yücel (1999, 2002), Sill (2007), Kilian (2008a,b), Oladosu (2009), Edelstein and Kilian (2007, 2009), Kilian and Lewis (2011).

[31]Seminal works in this stream are as follows: Solow (1974a,b), Dasgupta and Heal (1974), Stiglitz (1974, 1976), Heal (1976), Loury (1978), Pindyck (1978, 1981).

(André and Smulders, 2013, Eriksson, 2004, Groth, 2007, Smulders and De Nooij, 2003, Van Zon and Yetkiner, 2003, Yang et al., 2006) and induced energy-saving technologies and environmental issues (Goulder and Schneider, 1999, Nordhaus, 2002, Smulders, 1995). Therefore, the issue of effects of energy prices on economic growth seems to be an unexplored area in the theoretical economic growth literature.

For this purpose, we study a stylized model of an economy, in which an energy price-economic growth nexus is developed and tested. In the theoretical part of the paper, we showed that energy price growth has a negative effect on the growth rates of GDP per capita and energy demand by developing a two-sector market economy à la Rebelo (1991). In our setup, the source of endogenous growth in the economy, i.e. the investment goods sector, uses only physical capital, while the consumption goods sector uses both energy and capital as inputs. Using energy as an input in consumption function has been supported by relatively recent empirical literature (e.g., Edelstein and Kilian, 2009, Kilian and Park, 2009, Lee and Ni, 2002). Additionally, it is known that the consumption goods sector has been responsible for the majority of world energy consumption. According to EIA's 2012 World Energy Outlook (Birol et al., 2013), the combined shares of transportation and residential sectors in total primary energy consumption increased slightly from 60.8% in 1990 to 60.9% in 2008. The report also forecasts that these two sectors combined will remain dominant in energy demand, with a total share varying between 59.4% and 59.8% until 2035.

Our model, further, presumes that the price of energy input is growing at an exogenous rate.[32] Exogeneity in energy, especially oil, prices has recently become a debated issue in the literature. Barsky and Kilian (2004) was the first study to stress the bidirectional causality between oil prices and US macroeconomic performance. This reverse causality issue was later empirically quantified by Kilian (2009), who proposed a methodology to disentangle major oil price movements with respect to three determinant forces: (1) oil supply shocks, (2) demand shocks specific to oil market and (3) shocks due to the global demand for all industrial commodities. The author found evidence that global macroeconomic conditions have been the dominant factor in oil price movements for the post-1973 period. Similarly, more recent studies have suggested that the increase in oil prices between 2003-2008 was due to the global business cycle rather than to supply shortfall (Kilian and Hicks, 2013, Kilian and Murphy, 2014). Therefore, there

[32]Here we implicitly assumed that the energy source is non-renewable, because until recently global energy prices are driven mostly by fossil fuels such as oil, gas, and coal and the renewable energy sources still constitutes smaller portion of global primary energy supply/demand. For instance, in 2011, the share of fossil fuels and renewable energy sources in primary energy demand was 82% and 18%, respectively (Birol et al., 2013). Moreover, according to the Hotelling-based reasoning following Hotelling (1931), it is natural to expect that the price of nonrenewable energy sources would increase gradually in the long run due to the scarcity or depletion of resources, although the short-term verification of the rule may not be applicable.

seems to be a consensus in the literature that endogeneity is a problem in the empirical study of the relationship between oil prices and US macroeconomic indicators. Here, we propose a closed economy and use a broader definition of energy price, i.e. the price of energy services used in the consumption goods sector. While it is clearly possible to endogenize the energy prices in the model, with regards to our research objective, it is more convenient to keep it as an exogenous variable.[33]

The relationships derived in the theoretical part were tested empirically using an error-correction-based panel cointegration test and a panel Autoregressive Distributed Lag (ARDL hereafter) estimation for a group of countries, comprising Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, Japan, Luxemburg, the Netherlands, New Zealand, Portugal, Spain and Sweden.[34] The data on real GDP per capita, energy consumption per capita and composite energy prices cover the period from 1978 to 2011. The test reveals that energy prices have a significant cointegration relationship with real GDP per capita, as well as with energy consumption per capita. Moreover, we found that energy prices have negative and significant long-run effect on both variables. These results provide clear support for the derived theoretical relationships.

The contribution of this paper to the literature is two-fold. Firstly, there exist few studies on energy price-economic growth nexus in endogenous economic growth literature. For example, Van Zon and Yetkiner (2003) considering a three-sector model and embedding energy as an input in the intermediate goods sector, have already shown the negative impact of rising energy prices on economic growth.[35] In another study, Bretschger (2013), shows that decrease in energy consumption due to rise in energy prices would promote capital accumulation if the investment effect dominates the lower energy use effect. Thus, higher energy prices do not necessarily hamper the growth process. Secondly, to the best of the authors' knowledge, although a number of studies analyze the long-term relationship between energy consumption and economic growth, only few studies test the empirical regularity on the long-term relationship between energy price and economic growth. The majority of existing studies use error-correction based models (VECM or VAR) along with the cointegration tests to interpret the relationships for different countries (e.g., Asafu-Adjaye, 2000, Gardner and Joutz, 1996,

[33] In the Appendix A, we present the results of the model when energy price is a non-renewable and endogenous.

[34] Please see section 3.3 for the rationale for country selection.

[35] Van Zon and Yetkiner (2003), which is in fact based on Romer (1990), uses energy in intermediate goods sector. Yet, as commonly known, intermediate goods are capital good varieties, thus intermediate goods sector can be considered as investment goods sector.

Jiménez-Rodríguez and Sanchez, 2005, Stern, 1993).[36] Thus, this study explores an untapped area of potential research by applying panel cointegration tests and panel ARDL methodologies to the analysis of the long-term effects of energy prices on economic growth and energy consumption.

The set-up of this paper is as follows. In section 3.2 we present the basic model showing that endogenous growth is inversely affected by energy price growth. Section 3.3 presents the empirical analysis. A summary and some concluding remarks are provided in section 3.4.

3.2 A Two-Sector Endogenous Growth Model

The model developed in this article is based on a closed economy with no government. We define overall utility of the representative consumer in the economy as $U(C_t) = \int_0^\infty e^{-\rho t}\ u(C_t)\ dt$, where felicity function is $u(C) = \frac{C^{1-\theta}-1}{1-\theta}$, C is the consumption level ρ is the subjective rate of discount and $1/\theta$ represents intertemporal elasticity of substitution. We presume that there are two types of factor of production in the model: broader interpretation of physical capital, K, and energy, E. We further presume that there are also two sectors in the economy, namely investment goods sector and consumption goods sector. Following Rebelo (1991), we define production technology of the investment goods sector as follows:

$$Y_I = A \cdot K_I \tag{3.1}$$

In 3.1, Y_I represents output in investment goods sector, A is overall factor productivity, and K_I, a flow variable, is a broader interpretation of physical capital used in investment good production.

Consumption good is produced via flow variables physical capital (K_C) and energy (E) under constant returns to scale production technology defined as:

$$Y_C (\equiv C) = K_C^\alpha \cdot E^{1-\alpha} \tag{3.2}$$

We assume that total physical capital stock $K (= K_I + K_C)$ is fully employed.

[36]Ozturk (2010) provides an extensive survey of the literature on energy consumption-economic growth nexus since the seminal study of Kraft and Kraft (1978). Most recent studies mentioned in this survey either use ARDL approach to individual countries (e.g., Acaravci and Ozturk, 2010, Ocal and Aslan, 2013, Ozturk and Acaravci, 2010, Shahbaz et al., 2013a,b, Wang et al., 2011), or panel data error-correction models (e.g., Balke et al., 2002, Eggoh et al., 2011, Lee, 2005, Lee and Chang, 2008, Mahadevan and Asafu-Adjaye, 2007).

Equilibrium process in the investment goods sector from profit equation, $\Pi_I = p_I \cdot A \cdot K_I - R_I \cdot K_I$, leads to

$$p_I \cdot A = R_I \tag{3.3}$$

where, R_I is nominal rental rate (user cost) of physical capital in investment good production and p_I is the price of investment goods. For any K_I, condition in 3.3 must be satisfied. Profit maximization of the consumption goods sector yields inverse demand functions for physical capital (employed in the sector) and energy. In particular, the nominal profit equation $\Pi_C = p_c \cdot K_C^{\alpha} \cdot E^{1-\alpha} - R_C \cdot K_C - R_E \cdot E$ yields

$$p_c \cdot \alpha \cdot K_C^{\alpha-1} \cdot E^{1-\alpha} = R_C \tag{3.4a}$$

$$p_c \cdot (1-\alpha) \cdot K_C^{\alpha} \cdot E^{-\alpha} = R_E \tag{3.4b}$$

In equations 3.4a and 3.4b, R_C is the nominal rental rate (user cost) of physical capital in consumption good production, R_E is the nominal price of energy and p_C is the price of consumption goods. Real energy price is defined as $q = \frac{R_E}{p_C}$, and à la Van Zon and Yetkiner (2003), it was considered as growing at a constant rate, $\hat{q} > 0$, and that energy supply is infinite at the given energy price.

No arbitrage condition implies that rental rate of capital in both sectors must be equal. Hence,

$$R_I \equiv R_C \Rightarrow p_I \cdot A = p_c \cdot \alpha \cdot K_C^{\alpha-1} \cdot E^{1-\alpha} \Rightarrow p \cdot A = \alpha \cdot K_C^{\alpha-1} \cdot E^{1-\alpha} \tag{3.5}$$

In 3.5, $p = \frac{p_I}{p_C}$ is the relative price of investment goods in terms of consumption goods. Then, real user cost of capital (i.e. rental rate) is $RR = p \cdot A = \alpha \cdot K_C^{\alpha-1} \cdot E^{1-\alpha}$. One clear implication of equation 3.5 is that $\hat{p} = (\alpha - 1) \cdot \hat{K}_C + (1-\alpha) \cdot \hat{E}$, where $\hat{p}$, $\hat{K}_C$ and $\hat{E}$ represent the growth rates of relative price of investment goods (p) and capital (K_C) and energy (E) used by consumption goods sector, respectively. Recall that standard definition of user cost of capital is as follows:

$$RR \equiv (r + \delta - \hat{p}) \cdot p \tag{3.6}$$

In 3.6 r is real interest rate in terms of consumption good price, δ is capital depreciation rate and $\hat{p}$ is the capital loss due to changes in price.

For competitive equilibrium, we also need to examine the representative consumer's optimization problem. To this end, under the assumptions provided so far, the present value Hamiltonian would be as follows:

$$\mathcal{H} = e^{-\rho \cdot t} \cdot \frac{c^{1-\theta} - 1}{1-\theta} + \lambda\{r \cdot Assets + q \cdot E - C\} \tag{3.7}$$

In 3.7, *Assets* represents financial stock of the consumer and r is the real interest rate. We hereby assumed that the consumers receive $q \cdot E$ since they are treated as the owner of the energy resource stocks. First order optimization conditions are as follows:

$$\frac{\partial \mathcal{H}}{\partial C} = 0 \Rightarrow e^{-\rho \cdot t} \cdot C^{-\theta} = \lambda \tag{3.8a}$$

$$\dot{\lambda} = -\frac{\partial \mathcal{H}}{\partial Assets} \Rightarrow \dot{\lambda} = -\lambda \cdot r \tag{3.8b}$$

$$\dot{Assets} = \frac{\partial \mathcal{H}}{\partial \lambda} \Rightarrow \dot{Assets} = r \cdot Assets + q \cdot E - C \tag{3.8c}$$

In addition to these conditions, transversality condition, $\lim_{t \to \infty} \lambda(t) \cdot Assets = 0$, must be satisfied. Equations 3.8a and 3.8b yield:

$$\frac{\dot{C}}{C} = \frac{1}{\theta} \cdot (r - \rho) \tag{3.9}$$

At equilibrium, financial assets must be equal to physical capital under a closed economy with no government assumption; $Assets = p(t) \cdot K(t)$. Using this information, we may transform the representative consumer's budget constraint. Firstly, $\dot{Assets} = \dot{p} \cdot K + p \cdot \dot{K}$. Moreover, from 3.4b, real energy price is $q = (1-\alpha) \cdot K_C^{\alpha} \cdot E^{-\alpha}$, and from 3.5 and 3.6 we have $r = A - \delta + \hat{p}$. Hence,

$$\dot{p} \cdot K + p \cdot \dot{K} = p \cdot K \cdot (A - \delta + \hat{p}) + (1-\alpha) \cdot K_C^{\alpha} \cdot E^{1-\alpha} - K_C^{\alpha} \cdot E^{1-\alpha} \Rightarrow$$

$$p \cdot \dot{K} = p \cdot K \cdot (A - \delta) - \alpha \cdot K_C^{\alpha} \cdot E^{1-\alpha}$$

If one substitutes $A \cdot p$ for $\alpha \cdot K_C^{\alpha-1} \cdot E^{1-\alpha}$ due to 3.5 and divide both sides by p, we end up with:

$$\dot{K} = (A - \delta) \cdot K - A \cdot K_C \tag{3.10}$$

Hence, the optimization problem of representative consumer yields 3.9 and 3.10.

The model can be solved via the first order conditions derived from the optimization problems of representative firms and consumer. Firstly, if we use $r = A - \delta + \hat{p}$ obtained from equation 3.6 in 3.9, we get $\frac{\dot{C}}{C} = \frac{1}{\theta} \cdot (A - \delta + \hat{p} - \rho)$. Substituting $\hat{p} = (\alpha - 1) \cdot \hat{K}_C + (1 - \alpha) \cdot \hat{E}$ from 3.5 instead of $\hat{p}$, we find $\frac{\dot{C}}{C} = \frac{1}{\theta} \cdot (A - \delta + (\alpha - 1) \cdot \hat{K}_C + (1 - \alpha) \cdot \hat{E} - \rho)$. As $\hat{C} = \hat{Y}_C = \alpha \cdot \hat{K}_C + (1 - \alpha) \cdot \hat{E}$ due to equation 3.2,

$$\alpha \cdot \hat{K}_C + (1 - \alpha) \cdot \hat{E} = \frac{1}{\theta} \cdot (A - \delta + (\alpha - 1) \cdot \hat{K}_C + (1 - \alpha) \cdot \hat{E} - \rho) \Rightarrow$$
$$(1 - \alpha + \alpha\theta)\hat{K}_C + (1 - \alpha)(\theta - 1)\hat{E} = A - \delta - \rho$$

Finally, as $\alpha\hat{K}_C - \alpha\hat{E} = \hat{q}$ due to 3.4b, we obtain

$$\hat{E} = \frac{1}{\theta}(A - \delta - \rho - \frac{(1 - \alpha + \alpha\theta)}{\alpha}\hat{q}) \equiv g' \tag{3.11a}$$
$$\hat{K}_C = \frac{1}{\theta}(A - \delta - \rho - \frac{(1 - \alpha)(1 - \theta)}{\alpha}\hat{q}) \equiv g \tag{3.11b}$$
$$\hat{C} = \hat{Y}_C = \frac{1}{\theta}(A - \delta - \rho - \frac{(1 - \alpha)}{\alpha}\hat{q}) \equiv \alpha g + (1 - \alpha)g' \tag{3.11c}$$

where $\hat{q}$ is the growth rate of energy prices. Equations 3.11a – 3.11c imply that energy price growth has negative impact on the growth rate of energy use, as also shown by Van Zon and Yetkiner (2003). Note that $\frac{(1-\alpha+\alpha\theta)}{\alpha} > \frac{(1-\alpha)(1-\theta)}{\alpha}$ and that $\frac{(1-\alpha+\alpha\theta)}{\alpha} > \frac{(1-\alpha)}{\alpha}$. We will assume that the condition; $A - \delta - \rho > \frac{(1-\alpha+\alpha\theta)}{\alpha}$ holds, hence all growth rates above are positive. We may now solve the rest of the model under this assumption. First of all, using $\hat{p} = (\alpha - 1) \cdot \hat{K}_C + (1 - \alpha) \cdot \hat{E}$ equality, one can easily show that

$$\hat{p} = -(\frac{1 - \alpha}{\alpha})\hat{q}$$

This result can also be expressed as $p(t) = p(0) \cdot e^{-(\frac{1-\alpha}{\alpha})\hat{q}.t}$.[37] As long as growth rate of energy price is positive, relative price of investment goods in terms of consumption goods $p(t)$ approaches zero. From the equality of $r = A - \delta + \hat{p}$, we may show

$$r = A - \delta - (\frac{1 - \alpha}{\alpha})\hat{q}$$

[37]Recall that growth rate of energy price is exogenously given. Note that we may write the result also as $p(t) = p'(0) \cdot (q(t))^{-(1-\alpha)}$, $p'(0) = p(0)(q(0))^{-(1-\alpha)}$

Obviously, real interest rate and hence growth rate of consumption level, $\hat{C}$, are positive if and only if $A-\delta > (\frac{1-\alpha}{\alpha})\hat{q}$. Moreover from equation 3.8b we get,

$$\hat{\lambda} = -\{A - \delta - (\frac{1-\alpha}{\alpha})\hat{q}\}$$

As $r > 0$, λ must be approaching to zero. If we solve equation 3.10 via integrating factor method, we get

$$K(t) = \frac{A \cdot K_C(0)}{A-\delta-g} \cdot e^{g \cdot t} + const \cdot e^{(A-\delta) \cdot t}$$

where, *const* stands for constant term. We may easily determine the value of the constant term via the transversality condition. In particular, substituting respective values of λ and $Assets = p \cdot K$ in transversality condition $\lim_{t\to\infty}\{\lambda(t) \cdot Assets\} = 0$ yields that *const* must be zero. In addition to this, the condition $A - \delta - g > 0$ must hold for the transversality condition converges to zero at limit.[38] In conclusion, total capital stock path is given by,

$$K(t) = \frac{A \cdot K_C(0)}{A-\delta-g} \cdot e^{g \cdot t} \tag{3.12}$$

Hence, total capital stock is growing at rate g. Given that initial capital stock is defined exogenously as, $K(0) \equiv K_0 = \frac{A \cdot K_C(0)}{A-\delta-g}$, to the model, we can determine initial values of flow variables, i.e. $K_C(0)$, $K_I(0)$, $E(0)$.[39]

Finally, let us determine the time path of Real GDP. To this end, note that nominal GDP ($NGDP$) and real GDP in terms of consumption goods (Y) would be defined as:

$$NGDP = p_I \cdot Y_I + p_c \cdot Y_C \Rightarrow$$

$$Y = p.Y_I + Y_C$$

One can easily show that real GDP is:

$$Y = const' \cdot e^{[\alpha g + (1-\alpha)g'] \cdot t} \tag{3.13}$$

[38]For $\theta > 1$, $\frac{(A-\delta)\alpha(\theta-1)+\rho}{\alpha\theta+1-\alpha}$ is certainly positive. If $\theta < 1$, $\rho > (A-\delta)\alpha(\theta-1)$ must hold.

[39]It is straightforward to show that $E(0) = (1-\alpha)^{\frac{1}{\alpha}} \frac{A-\delta-g}{A} \cdot K_0 \cdot (q_0)^{-\frac{1}{\alpha}}$, $K_C(0) = \frac{A-\delta-g}{A} \cdot K_0$, $K_I(0) = \frac{\delta+g}{A} \cdot K_0$ and $p(0) = (1-\alpha)^{\frac{1-\alpha}{\alpha}} \cdot \frac{\alpha}{A} \cdot (q_0)^{-\frac{1-\alpha}{\alpha}}$.

In 3.13, $const' = p(0) \cdot Y_I(0) + (K_C(0))^{\alpha} \cdot (E(0))^{1-\alpha}$, a collection of initial values of the model. In conclusion, total physical capital stock, investment capital and consumption capital all grow at rate g. On the other hand, energy demand grows at rate g' and real GDP and consumption grow at rate $\alpha g + (1-\alpha)g'$, which is the weighted growth rate of energy and physical capital. Energy price growth rate has a negative effect on all growth rates.

3.3 Testing the Long-run Effects of Energy Prices

In this section, we attempted to test the long-run relationship between energy prices, economic growth and energy consumption, that we have derived in theoretical part, cf., equations 3.11a and 3.11c. For empirical purposes, these equations can, respectively, be reformulated as:[40]

$$\hat{E} = \beta_{10} + \beta_1 \hat{q} \tag{3.14a}$$

$$\hat{Y}_C = \beta_{20} + \beta_2 \hat{q} \tag{3.14b}$$

where, $\beta_{10} = \beta_{20} = \frac{1}{\theta}(A - \delta - \rho)$, $\beta_1 = -\frac{1}{\theta}\frac{(1-\alpha+\alpha\theta)}{\alpha}$ and $\beta_2 = -\frac{1}{\theta}\frac{(1-\alpha)}{\alpha}$. The growth rates $\hat{Y}_C$, $\hat{q}$ and $\hat{E}$ can further be defined as $\frac{d}{dt}\ln(E)$,$\frac{d}{dt}\ln(Y_C)$ and $\frac{d}{dt}\ln(q)$, respectively. Therefore, integrating both sides of 3.14a and 3.14b will lead to:

$$\ln(E) = \alpha_{10} + \beta_{10}t + \beta_1 \ln(q) \tag{3.15a}$$

$$\ln(Y_C) = \alpha_{20} + \beta_{20}t + \beta_2 \ln(q) \tag{3.15b}$$

where, α_{10} and α_{20} are the constant terms emerged from the integration procedure and t is the time trend component. The equations 3.15a and 3.15b are the long-run relationships to be tested. To this end, error-correction based panel cointegration test (Westerlund, 2007) and panel ARDL methodology (Pesaran et al., 1995, 1999) are applied on balanced panel data, consisting of real GDP per capita (Y), composite energy prices (q) and energy consumption per capita (E), covering the period between 1978 and 2011 for sixteen countries; namely Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, Japan, Luxemburg, the Netherlands, New Zealand, Portugal, Spain and Sweden.[41]

[40]Please note that, the growth rates of output in the consumption goods sector and of composite GDP are the same, i.e. $\hat{Y}_C = \hat{Y}$

[41]Although the theoretical model assumes closed economy, for empirical applications we use open economies. Yet, since we are dealing with long-run equilibrium, it is rational to expect that those countries have to end up with trade balance thus energy import would be met by export of consumption and service goods.

The countries have been chosen regarding the data availability. Historical data on composite energy prices for each country, defined as real index for households and industry (2005=100), have been taken from the International Energy Agency's (IEA) statistics database (IEA, 2013).[42] This data set has been provided for OECD countries. Out of these countries we have eliminated the ones, which have been net energy exporters in the subjected period as our main consideration is for imported energy. We, moreover, excluded the United States following the concerns on the endogeneity problem (please see Barsky and Kilian (2004)) and some other OECD countries due to data restrictions on other variables; i.e. GDP per capita and energy consumption per capita which have been taken from WDI (The World Bank Group, 2013). All three variables are used in natural logarithms and indexed taking 2005 as the base year. Table 3.1 provides the descriptive statistics for all three variables.

Table 3.1: Descriptive Statistics of variables (in natural logarithms) over 1978–2011

Statistics\Variables	$\ln(Y)$	$\ln(E)$	$\ln(q)$
Mean	4.368	4.487	4.509
Std. Dev.	0.238	0.173	0.186
Minimum	3.492	3.598	3.804
Maximum	4.711	4.785	5.006
# of Countries	16	16	16
# of Observations	544	544	544

As for panels with time dimension larger than the cross-sectional dimension, usual time series problems would emerge. To this end we have tested the variables for unit root using Levin-Li-Chu (LLC) and Im-Pesaran-Shin (IPS) tests proposed by Levin et al. (2002) and Im et al. (2003), respectively. Table 3.2 provides the results of the unit root tests. According to these results, the first differences of all three variables are stationary, i.e. all variables are integrated of order one, I(1). We proceed further with panel cointegration test and panel ARDL as both methodologies are convenient to be applied on I(1) variables.

We have applied error-correction based panel cointegration test proposed by Westerlund (2007). As correctly noted by Pesaran et al. (1995), this approach is more advantageous than other panel cointegration tests, such as the one proposed by Pedroni (1999), as it avoids the problem of common factor restriction. Persyn and Westerlund (2008) describes the data generating process assumed by this error-correction test as follows:

[42] The composite energy price in IEA (2013) is defined as a weighted average of oil products, coal, natural gas and electricity consumed by households and industry.

Table 3.2: Panel Unit Root Test Results

Variable	LLC (adjusted t-stat.) Level	LLC (adjusted t-stat.) First Difference	IPS (z-stat.) Level	IPS (z-stat.) First Difference
lny	1.3440	-6.6046***	3.3643	-8.9687***
lne	2.9221	-2.8324***	-0.8323	-12.8586***
lnq	1.5540	-8.1549***	0.6028	-10.5024***

Notes: Tests conducted with constant and trend components. *** represents significance at 1% level.

$$\Delta y_{i,t} = \delta_i' d_t + \alpha_i y_{i,t-1} + \lambda_i' x_{i,t-1} + \sum_{j=1}^{p_i} \alpha_{i,j} \Delta y_{i,t-j} + \sum_{j=-q_i}^{p_i} \gamma_{i,j} \Delta x_{i,t-j} + \varepsilon_{i,t} \qquad (3.16)$$

where, $y_{i,t}$ is the dependent variable, which in our case is either $\ln(Y)$ or $\ln(E)$ and $x_{i,t}$ is the independent variable, which is $\ln(q)$ for our case, for country i in year t. Moreover, while d_t represents the deterministic component, λ_i is defined as $-\alpha_i\beta_i'$ with α_i capturing the seed at which the system $y_{i,t-1} - \beta_i' x_{i,t-1}$ adjusts back to the equilibrium after an unexpected shock. Therefore, if $\alpha_i < 0$ model implies a cointegration between variables and thus the null hypothesis tested is $H_0 : \alpha_i = 0$ for all i. Westerlund (2007) proposes four different tests; two of these, namely the group mean tests G_τ and G_a, use alternative hypothesis of $H_A : \alpha_i < 0$ for at least one i. The remaining two, namely, the panel tests P_τ and P_a, use the alternative hypothesis of $H_A : \alpha_i = \alpha < 0$ for all i. The optimal lag and lead lengths of the variables have been chosen via Akaike Information Criteria (AIC). Moreover, following Persyn and Westerlund (2008) the Kernel width has been set as $4(T/100)^{2/9}$, where T is the number of observations in time series dimension.

We further proceed with the estimation of equation 3.16 and following the procedure described above; we have presented the results of the four-cointegration tests on Table 3.3. All test statistics, except for P_τ test on $\ln(Y)$ vs. $\ln(q)$, lead us to reject the null hypothesis of no cointegration between $\ln(Y)$ vs. $\ln(q)$, as well as between $\ln(E)$ vs. $\ln(q)$ at 1% significance level.

Table 3.3: Panel Cointegration Test Results

Relationship Tested	G_τ	G_a	P_τ	P_a
$\ln(Y)$ vs. $\ln(q)$	-2.842***	-30.345***	-8.820	-17.103***
$\ln(E)$ vs. $\ln(q)$	-2.852***	-20.312***	-12.088***	-18.806***

Notes: Optimal lag and lead lengths selected via AIC are both 1 and optimal Bartlett kernel window width is set to be 3. *** represents significance at 1% level.

Having concluded that two cointegrating relationships exist, we have, subsequently, applied Pooled Mean Group (PMG hereafter) and Mean Group (MG hereafter) estimators (i.e., panel ARDL methodology) proposed by Pesaran et al. (1995, 1999). While MG estimator is based on estimating N times time-series regressions and averaging the coefficients, PMG estimator reveals pooled coefficients. Pesaran et al. (1999) suggests that PMG estimator is more efficient, yet this is only consistent when the model is homogenous in the long run, i.e. the long-run coefficients are equal across countries. MG estimator is advantageous because it is consistent even when the panel data exhibits heterogeneous characteristics, which is common in cross-country studies. As proposed by Pesaran et al. (1999), these estimators lead consistent estimates in larger time dimensional heterogenous panels even when the assumption of strict exogeneity in the regressors is violated. Therefore, although we have accounted for the endogeneity issue when selecting countries to be analyzed, panel ARDL methodology is appropriate with regards to the possible doubts on the endogeneity of composite energy prices with respect to the macroeconomic conditions in the corresponding countries.

Following Blackburne and Frank (2009), we have defined ARDL(1,1) dynamic panel specification of equations 3.15a and 3.15b as:

$$y_{i,t} = \lambda_i y_{i,t-1} + \delta_{10,i} x_{i,t} + \delta_{11,i} x_{i,t-1} + \delta_{20,i} t + \mu_i + \varepsilon_{i,t} \tag{3.17}$$

and the error-correction parameterization as:

$$\Delta y_{i,t} = \phi_i (y_{i,t-1} - \theta_{0,i} - \theta_{1,i} x_{i,t} - \theta_{2,i} t) + \delta_{11,i} \Delta x_{i,t} + \varepsilon_{i,t} \tag{3.18}$$

where; $\phi_i = -(1-\lambda_i)$ is the error-correction term (ECT) speed of adjustment, $\theta_{0,i} = \frac{\mu_i}{1-\lambda_i}$ is the non-zero mean of cointegration relationship, $\theta_{2,i} = \frac{\delta_{20,i}}{1-\lambda_i}$ and $\theta_{1,i} = \frac{\delta_{10,i}+\delta_{11,i}}{1-\lambda_i}$ are the coefficients of interest, i.e. long-run estimates of elasticity (β_{10}, β_1) and (β_{20}, β_2) in equations 3.15a and 3.15b, respectively. Obviously, for our case, negative and significant ϕ_i and $\theta_{1,i}$ should be expected for both two relationships under consideration, i.e. $\ln Y$ vs. $\ln q$ and $\ln E$ vs. $\ln q$. The estimation results for both relationships and for both estimators (MG and PMG) have been provided on Table 3.4.

The results are in accordance with the expectations on the coefficients; $\beta_1 < 0$ and $\beta_2 < 0$. MG and PMG estimators estimate negative and highly significant long-run impact of energy price on both GDP per capita and energy consumption per capita. Estimation results reveal also that the effect on GDP per capita (-0.76 for MG estimator and -0.59 for PMG estimator) is slightly higher than that of energy consumption per capita (-0.73

Table 3.4: Panel ARDL Long Run and ECT Estimates

Long-Run Estimates	$\ln(Y)$ MG	$\ln(Y)$ PMG	$\ln(E)$ MG	$\ln(E)$ PMG
$\ln(q)$	-0.7595***	-0.5865***	-0.7308***	-0.5417***
	(0.2826)	(0.1277)	(0.1887)	(0.0479)
t	0.0246***	0.0098***	0.0119***	0.0059***
	(0.0073)	(0.0020)	(0.0041)	(0.0007)
ECT	-0.1831***	-0.0649***	-0.3830***	-0.2067***
	(0.0281)	(0.0105)	(0.0521)	(0.0329)

Notes: Figures in parenthesis are standard errors. *** represents significance at 1% level.

for MG estimator and -0.54 for PMG estimator). These results are consistent with the theory proposed in this article, as well as with the empirical literature. For instance, Kilian (2008b) has estimated the price elasticity of US total energy demand as -0.45 with error bounds of -0.27 and -0.66, moreover, Greene and Leiby (2006) suggested a range between -0.03 and -0.56 for price elasticity of oil demand for different countries. Although our estimates of effect on GDP per capita appears to be higher than that of the literature (e.g., Brown and Yücel, 1999, Greene and Leiby, 2006), they are reasonable as the prior studies mostly concentrated only on the effects of oil prices in the short-run. Moreover, negative and significant ECT terms indicate that the deviations from the long-run path are corrected each period, thus all variables return to their long-run equilibrium.

3.4 Conclusions and Policy Implications

In this paper we have presented a two-sector endogenous growth model, following Rebelo (1991). By including energy as an input in the consumption good sector, we have been able to show that the endogenous growth rate of both output and energy consumption depends negatively on the rate of growth of energy price. These findings are consistent with Van Zon and Yetkiner (2003), who use precisely this argument in a study of a three-sector model in which energy is identified as an input in the intermediate-good sector. By testing the theoretical relationships derived by employing error-correction based panel cointegration and panel ARDL methodologies, we found that energy prices have negative and significant impact on both real GDP per capita and energy consumption per capita in the long-run. Thus, both the theoretical and empirical findings suggest significant long-term welfare losses due to the fact that increasing energy prices leads to “under-capacity” or “below-capacity” economic growth.

One policy implication that clearly emerges from this result is the need for policy makers to prevent or at least restrict energy price increases in order to sustain higher long-term economic growth. Yet, this policy recommendation would be superfluous without the introduction of the appropriate channels for the achievement of this policy goal. Recall the energy price variable in the theoretical part is assumed to follow the Hotelling rule (Hotelling, 1931), which suggests that the price of nonrenewable energy sources would increase gradually due to scarcity or depletion of resources. This assumption is based on the fact that current global consumer energy prices are largely driven by scarce fossil fuels, such as oil, natural gas, and coal, which constitute 82% of global primary energy demand (Birol et al., 2013). Correspondingly, the composite energy prices, used in the empirical part, are also driven by fossil fuels. As defined by IEA (2013), these prices are determined as the weighted average of oil products, coal, natural gas, and electricity consumed by households and industry. Therefore, in order to prevent long-term welfare losses due to the rise in composite energy prices, and the consequent below-capacity growth rates, governments should subsidize renewable rather than non-renewable energy sources, as the prices of the latter tend to increase by their very nature in the long run.

There has been extensive literature on the profound positive impacts of renewable energy sources on sustainable development. It has been found previously that the dominance of renewable energy- in energy systems would increase public welfare not only by overcoming environmental constraints and by providing sustainable energy supply (e.g., Dincer, 2000, Lund, 2007, Omer, 2008, Panwar et al., 2011, among others), but also by job creation (e.g., Frondel et al., 2010, Lehr et al., 2012, Mathiesen et al., 2011, among others). To the authors' best knowledge, this stream of literature has so far neglected an additional important channel through which renewable energy sources have the potential to contribute to countries' long-term welfare. We suggest that increasing the share of renewable energy sources would directly serve to prevent permanent long-term increases in consumer energy prices, which would lead to increased economic growth. This potential benefit is confirmed by several empirical studies investigating the direct effect of increasing renewable energy consumption on economic growth (e.g., Apergis and Payne, 2010, Awerbuch and Sauter, 2006, Chien and Hu, 2007, Ewing et al., 2007, Fang, 2011, Sadorsky, 2009, among others).

Chapter 4

Two-period resource duopoly with endogenous intertemporal capacity constraints

4.1 Introduction

One of the most important aspects of strategic firm behavior in oligopolistic non-renewable or exhaustible resource markets is the allocation of a finite resource stock over time. The problem of resource allocation becomes more complicated once firms seize the opportunity to increase the resource base. In this case, in addition to the production decisions, firms also need to choose the optimal amount of resource additions over time.

In order to address the question of how firms would react under endogenous capacity constraints, we study a resource duopoly model with two firms, competing in quantity for two consecutive periods. At the beginning of the first period, each firm is endowed with a fixed amount of exhaustible resource stock and is then allowed to invest in capacity in between the two periods of production in order to increase its resource stock. Thus, their 2^{nd} period capacity constraints become endogenous. With this setup, we find that the equilibrium price weakly decreases over time. Moreover, asymmetric distribution of initial resource stocks leads to a significant change in equilibrium outcome, provided that firms do not have the same cost structure in capacity additions. It is also verified that if only one company is capable of investment in capacity, the market moves to a more concentrated structure in the second period.

Apart from the mainstream economic growth literature dealing with the optimal depletion of exhaustible resources following Hotelling (1931)[43], there has been a plethora of works that deal with the microeconomic structure of resource markets. Salant (1976) proposes a cartel with a competitive fringe model to explain the world oil market and suggests that a cartel would restrict its supply, leading to a monotonic increase in prices, until it takes over the whole market and the competitive fringe exhausts its resources. Gilbert (1978) extends the study of Salant (1976) with a Stackelberg model under the price and quantity leadership of the cartel and confirms that the price would increase until the reserves of the fringe firms are exhausted. Another dynamic oligopolistic market is examined by the study of Lewis and Schmalensee (1980), which proposes that any firm having a greater initial resource endowment will produce more at each period of the game. Eswaran and Lewis (1984) extend the oligopoly model such that each firm has an initial share of the common reserve. The authors find that given uneven distribution of the shares among firms, industry extraction is inefficient as it is not cost minimizing.

In his famous work entitled "A Theory of 'Oil'igopoly: Cournot Equilibrium in Exhaustible Resource Markets with Fixed Supplies", Loury (1986) proposes a non-cooperative Cournot oligopoly model. He finds that marginal returns on resource stocks are inversely related to players' initial resource endowments and that aggregate production decreases over time. He also suggests that firms with smaller resource stock exhaust their stocks at the same time as larger stock firms. Polasky (1992) extends the model of Loury (1986) by introducing different extraction costs among the firms and empirically testing the model. Gaudet and Long (1994) criticize the assumptions thought to be necessary by Loury (1986) in order to achieve a unique equilibrium for the game with uneven distribution of initial resource stocks among players. Contrary to Loury (1986), they suggest that exhaustion of resources in finite time is not a necessary condition for equilibrium. Later, Salo and Tahvonen (2001) contributed to this stream of literature by considering the economic depletion of resources instead of the physical depletion. They find, contrary to the literature, that the degree of concentration in supply would decline such that the market would head in the direction of more competitive rather than monopolistic. On the other hand, more recently Benchekroun et al. (2009) and Benchekroun et al. (2010) suggest, in accordance with Loury (1986), that the oligopolistic market, in which players have different initial resource stocks and different cost structures, would move towards a cartel with a competitive fringe structure as low-cost deposits are exhausted.

This article also relates to the literature on strategic firm behavior under capacity constraints. Pioneering works in this stream are Levitan and Shubik (1972) and Osborne

[43]Seminal works in this stream of literature are as follows: Solow (1974b), Dasgupta and Heal (1974), Stiglitz (1974), Loury (1978), Pindyck (1978).

and Pitchik (1986), both of which are based on price competition under exogenous capacity constraints. Important contributions are made, among others, by Bikhchandani and Mamer (1993), Gabszewicz and Poddar (1997), Besanko and Doraszelski (2004) and Laye and Laye (2008). Moreover, Saloner (1987) introduces intertemporal production decisions with a two-period Cournot duopoly, which is later extended by Pal (1991) with the inclusion of cost differences.

The primary contribution of this paper is that it is among the firsts to subject dynamic duopoly markets to endogenous intertemporal capacity constraints. In fact, the author is only aware of two papers that address the strategic firm decisions under a two-period duopoly with exogenous intertemporal capacity constraints, namely Biglaiser and Vettas (2004) and van den Berg et al. (2012), examining price and quantity competition, respectively. We extend the model of van den Berg et al. (2012), which most resembles the current study, by relaxing the assumption of exogenous capacity constraints. Thus, in our setting, besides the quantity competition firms also enter into a rivalry in capacity investments, which leads to endogenous capacity constraints. In contrast to van den Berg et al. (2012)'s main finding that the price weakly increases over time, we are able to show that the price decreases with endogenous capacity constraints. This would explain the temporary downward price trends experienced occasionally in most exhaustible resource markets. Thus, the author believes that the model presented in this study better explains the stylized characteristics of such markets.

The organization of the current paper is as follows: Section 4.2 introduces the model. Section 4.3 solves the model using the Subgame Perfect Nash Equilibrium concept and provides major results. Section 4.4 presents oil market interpretation of the model. Welfare analysis is conducted in Section 4.5. Finally, Section 4.6 concludes.

4.2 Model

This article proposes a resource duopoly model with two firms, $i = 1, 2$, competing in quantity for two consecutive periods, $t = 1, 2$. At the beginning of the first period ($t = 0$), each firm is endowed with a fixed amount of exhaustible resource, $R_{i,0} \geq 0$, which can be increased to a cumulative recoverable resource, $(R_{i,0} + R_{add,i}) \in [R_{i,0}, R_{max}]$, where $R_{add,i}$ is the additions to the resource base (capacity additions) of firm i and R_{max} is finite. Thus, firms can endogenize their 2^{nd} period capacity by simultaneously choosing $R_{add,i}$ in the interim period at a cost of x_i, i.e., capacity investment. This creates a three-stage game as depicted in Figure 4.1.

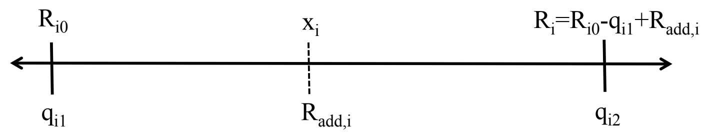


FIGURE 4.1: Structure of the Game

In Figure 4.1, $q_{i,1}$ is the quantity decision of firm i in the first stage (1^{st} period of production) subject to its initial resource endowment ($R_{i,0}$), $R_{add,i}$ is the decision made on capacity addition in the second stage (in between the two periods of production) at a cost of x_i, and finally $q_{i,2}$ is the quantity decision of firm i in the third stage (2^{nd} period of production) subject to its remaining endogenous capacity defined by the following equation:

$$R_i = R_{i,0} - q_{i,1} + R_{add,i}. \tag{4.1}$$

Assumption 1. *Initial resource endowment for each firm lies in the following range:*[44]

$$\frac{\alpha_1 A + \alpha_3 R_{j,0}}{\alpha_4 - \alpha_2} < R_{i,0} < \frac{(\alpha_4 - 3\alpha_8)A - 3\alpha_{10} R_{j,0}}{3\alpha_9} \quad for \quad i,j \in 1,2 \quad and \quad i \neq j$$

The upper bound of the interval provided by Assumption 1 guarantees that the second period capacity constraint for each firm is binding; thus, at equilibrium firms invest in capacity $R_{add,i} > 0$ for $i \in \{1,2\}$. If this part of the assumption is violated, the problem becomes less interesting as it reduces to the typical dynamic Cournot game with exogenous intertemporal constraints, in which equilibrium is achieved without positive capacity investments. This case is in fact already considered in van den Berg et al. (2012). The lower bound, moreover, guarantees that each firm would carry some of its initial resource endowment over to the second period. If violated, the capacity constraints are no longer intertemporal. In this case, each firm uses up all of its initial capacity in the first period, generates new capacity in the interim period and uses it again in the second period. Since the focus of this paper is the intertemporal allocation of the endogenous resource, a lower bound of Assumption 1 is also necessary.

We, furthermore, assume that the costs of exploring initial resource stock and resource extraction are sunk and therefore do not have a role in the model. The inverse demand

[44] The α's are defined on page 59 by Proposition 1.

function for each period is as follows:

$$P_t = P_t(Q_t) = A - Q_t,$$

where A captures the market size and $Q_t = q_{i,t} + q_{j,t}$ for $i, j \in \{1, 2\}$ and $i \neq j$. Moreover, we define the capacity addition cost function as:

$$x_i = a_i \times {R_{add,i}}^2, \tag{4.2}$$

where a_i ($\in \mathbb{N}_+$) is a finite constant that captures the "reverse efficiency" (or the cost) of capacity investments such that, as it becomes larger, capacity additions become more costly.[45]

4.3 Subgame Perfect Nash Equilibrium

We employ the Subgame Perfect Nash Equilibrium (SPNE, hereafter) concept, which suggests that the strategy of each player at each instant of time is a function of the prior decisions made by both itself and its rival. Therefore, for any state of the game at the beginning of the 2^{nd} period $z(q_{i,1}, q_{j,1}, R_{add,i}, R_{add,j})$, which is the result of the 1^{st} and interim period decisions, firm i will solve the following maximization problem given firm j's production decision:

$$\begin{aligned}
&\max_{q_{i,2}} \ \pi_{i,2} = q_{i,2} \ P_2(q_{i,2}, q_{j,2}) - x_i(R_{add,i}) \\
&\text{subject to} \\
&0 \leq q_{i,2} \leq R_i,
\end{aligned}$$

where, recall that, R_i is the 2^{nd} period capacity constraint defined by Equation 4.1. The resulting best response correspondence for firm i in the 2^{nd} period, $\sigma_{i,2}(z) : [0, R_j] \rightarrow [0, R_i]$, will be as follows:

$$\sigma_{i,2}(q_{j,2}) = \begin{cases} R_i & \text{if} \quad 0 \leq R_i \leq \frac{A - q_{j,2}}{2} \\ \max\left(0, \frac{A - q_{j,2}}{2}\right) & \quad \text{otherwise.} \end{cases}$$

[45] We would have assumed a general functional form for capacity addition cost, x_i, that is convex in $R_{add,i}$, yet the functional form provided is tractable as its first derivative is linear.

Equilibrium strategies for firm i are given by the function $f_i^*(z)$ and defined as follows:

$$f_i^*(z) = \begin{cases} \frac{A}{3} & \text{if} \quad R_i, R_j > \frac{A}{3} \\ \frac{A-R_j}{2} & \text{if} \quad R_i > \frac{A-R_j}{2} \text{ and } R_j \leq \frac{A}{3} \\ R_i & \text{if either } R_i \leq \frac{A}{3} \text{ and } R_j > \frac{A-R_1}{2} \text{ or } R_i \leq \frac{A-R_j}{2} \text{ and } R_j \leq \frac{A-R_i}{2}. \end{cases} \tag{4.3}$$

Region	$q_{1,2}^*$	$q_{2,2}^*$	R_1	R_2
I	A/3	A/3	$> A/3$	$> A/3$
II	R_1	$\frac{A-R_1}{2}$	$\leq A/3$	$> \frac{A-R_1}{2}$
III	$\frac{A-R_2}{2}$	R_2	$> \frac{A-R_2}{2}$	$\leq A/3$
IV	R_1	R_2	$\leq \frac{A-R_2}{2}$	$\leq \frac{A-R_1}{2}$

TABLE 4.1: Second Period Possible Equilibrium Outcomes

There may exist four possible Nash equilibria for the second-period subgame $(q_{1,2}^*, q_{2,2}^*)$, which satisfy both $\sigma_{1,2}(q_{2,2}^*) = q_{1,2}^*$ and $\sigma_{2,2}(q_{1,2}^*) = q_{2,2}^*$ as provided in Table 4.1. Since in Region I the 2^{nd} period capacities of both firms are non-binding, each firm chooses the Cournot outcomes and ends up with a residual amount left 'unproduced' in the resource base. Regions II and III correspond to the outcomes when only one firm has a binding capacity, firm 1 and firm 2, respectively. And, finally, in Region IV both firms have binding capacities, thus producing whatever their capacity allows. Given Assumption 1, the equilibrium can not occur in Regions I, II and III (See Lemma 1).

Lemma 1. *Given Assumption 1, each firm chooses the second period equilibrium quantity to be:*

$$\begin{gathered} q_{i,2}^* = R_i = R_{i,0} - q_{i,1} + R_{add,i} \\ \textit{for} \quad i = 1,2 \quad \textit{where} \quad R_i, R_j \leq A/3 \end{gathered} \tag{4.4}$$

Proof. Firms would deviate from this equilibrium if and only if at least one of them, say firm 1, has non-binding capacity in the second period. Given Assumption 1, this can arise due to either the firm investing too much in the capacity in the interim period and thus generating more capacity addition than it needs, or the firm producing too little in the first period thus saving the capacity for the second period in order to end up with the Cournot outcome. Let us analyze these two cases:

i. Let us assume that firm 1 chooses to over-invest in capacity in the interim period to end up with the non-binding second period capacity constraint and thus produce the Cournot quantity. Since the capacity addition cost function is strictly increasing in $R_{add,1}$, the firm can decrease the capacity addition, and hence the cost, until the second period capacity reaches the threshold value of $\overline{R}_1 = A/3$, without changing the second period equilibrium strategy of $q^*_{1,2} = A/3$. Once the second period capacity equalizes to $\overline{R}_1$, the firm is in Region IV. Note that the capacity addition decisions in the interim period are being made simultaneously. Thus, there is no first-mover advantage in the game. If this was the case, the outcome may have been different than that proposed here.

ii. Let us assume that firm 1 chooses to produce too little –strictly lower than the Cournot quantity– in the first period to assure non-binding capacity for the second period, i.e., $q_{1,1} < A/3$. This implies that it would not add further capacity in the interim period since it has already ensured the Cournot outcome for the second period, i.e., $R_{add,1} = 0$. First of all, one must note that firm 1 will affect firm 2's decision at this stage of the game if and only if it has a binding capacity. If its capacity constraint is not binding, then firm 2's behavior is left unaltered (firm 2 chooses the optimal quantity given firm 1's production not the capacity). Hence, firm 1 could deviate from this strategy by producing one marginal unit more at the first stage instead of having left over at the third stage. This reallocation continues until the second period capacity of firm 1 becomes binding, i.e., $R_1 \leq \overline{R}_1$.

Moreover, the firm would not choose an equilibrium quantity of zero for the second period, i.e., $q^*_{i,2} = 0$, because it would always have the incentive to generate additional capacity for the second period. ■

Given the 2^{nd} period equilibrium provided in Equation (4.4), firm i will subsequently choose the capacity additions with the following maximization problem:

$$\max_{R_{add,i}} \; \pi_{i,2} = q^*_{i,2} \; P_2(q^*_{i,2}, q^*_{j,2}) - x_i(R_{add,i}), \tag{4.5}$$

where $q^*_{i,2}$ and $q^*_{j,2}$ represent the 2^{nd} period equilibrium quantities of firms i and j, respectively. Following the maximization problem in Equation (4.5), the best response correspondence for the interim period capacity addition decision, γ_i, for firm i is as follows:

$$\gamma_i(R_{add,j}) = \begin{cases} 0 & \text{if} \quad R_{add,j} > A + 2q_{i,1} + q_{j,1} - 2R_{i,0} - R_{j,0} \\ \frac{A+2q_{i,1}+q_{j,1}-2R_{i,0}-R_{j,0}-R_{add,j}}{2+2a_i} & \quad \text{otherwise.} \end{cases}$$

The corresponding possible Nash equilibria, which satisfy $\gamma_1(R^*_{add,2}) = R^*_{add,1}$ and $\gamma_2(R^*_{add,1}) = R^*_{add,2}$, for the subgame at the interim period are provided in Table 4.2. Region A corresponds to the equilibrium in which none of the firms generate additional capacities for the second period. Regions B and C are the regions in which firm 1 and

Region	$R^*_{add,1}$	$R^*_{add,2}$
A	0	0
B	$\frac{A+2q_{1,1}+q_{2,1}-2R_{1,0}-R_{2,0}}{2+2a_1}$	0
C	0	$\frac{A+2q_{2,1}+q_{1,1}-2R_{2,0}-R_{1,0}}{2+2a_2}$
D	$\frac{A(1+2a_2)+(3+4a_2)q_{1,1}+2a_2q_{2,1}-(4a_2+3)R_{1,0}-2a_2R_{2,0}}{4a_1a_2+4a_1+4a_2+3}$	$\frac{A(1+2a_1)+(3+4a_1)q_{2,1}+2a_1q_{1,1}-(4a_1+3)R_{2,0}-2a_1R_{1,0}}{4a_1a_2+4a_1+4a_2+3}$

Region	Parameter Conditions
A	$A + 2q_{1,1} + q_{2,1} < 2R_{1,0} + R_{2,0}$ $A + 2q_{2,1} + q_{1,1} < 2R_{2,0} + R_{1,0}$
B	$A + 2q_{1,1} + q_{2,1} \geq 2R_{1,0} + R_{2,0}$ $(1 + 2a_2)A + (3 + 4a_2)q_{1,1} + 2a_2q_{2,1} < (3 + 4a_2)R_{1,0} + 2a_2R_{2,0}$
C	$(1 + 2a_1)A + (3 + 4a_1)q_{2,1} + 2a_2q_{1,1} < (3 + 4a_1)R_{2,0} + 2a_1R_{1,0}$ $A + 2q_{2,1} + q_{1,1} \geq 2R_{2,0} + R_{1,0}$
D	$(1 + 2a_2)A + (3 + 4a_2)q_{1,1} + 2a_2q_{2,1} \geq (3 + 4a_2)R_{1,0} + 2a_2R_{2,0}$ $(1 + 2a_1)A + (3 + 4a_1)q_{2,1} + 2a_1q_{1,1} \geq (3 + 4a_1)R_{2,0} + 2a_1R_{1,0}$

TABLE 4.2: Interim Period Possible Equilibrium Outcomes

firm 2, respectively, choose not to add capacity. Finally, Region D represents the equilibrium with positive amount of capacity additions for both firms. Given Assumption 1 and Lemma 1, Lemma 2 will rule out the equilibria in regions A, B and C (See Lemma 2).

Lemma 2. *Interim period equilibrium capacity addition for each firm, $i = 1, 2$, is as follows:*

$$R^*_{add,i} = \frac{A(1 + 2a_j) + (3 + 4a_j)q_{i,1} + 2a_jq_{j,1} - (3 + 4a_j)R_{i,0} - 2a_jR_{j,0}}{4a_ia_j + 4a_i + 4a_j + 3}$$
$$\textit{where} \quad (3 + 4a_j + 2a_i)(R_{i,0} - q_{i,1}) + (3 + 4a_i + 2a_j)(R_{j,0} - q_{j,1}) \leq (2 + 2a_i + 2a_j)A. \tag{4.6}$$

Proof. Given the best response correspondence, we have 4 different equilibria for the interim period subgame as provided in Table 4.2. The equilibrium can not occur in Regions A, B and C because:

i. Parameter conditions in Region A together suggest the following:

$$\frac{2A}{3} < (R_{1,0} - q_{1,2}) + (R_{2,0} - q_{2,2})$$

since the capacity addition for each firm in this region is zero, which, given Lemma 1, follows directly as:

$$q_{1,2}^* + q_{2,2}^* > \frac{2A}{3}.$$

This inequilibrium can occur only if at least one of the firms has non-binding capacity in the second period and produces an amount larger then the Cournot outcome. This contradicts Assumption 1.

ii. The equilibrium outcomes in Regions B and C suggest that one firm chooses not to invest in capacity additions in the interim period. Recall that the decisions at this stage are held simultaneously. Thus, this case can occur only if the firm ensures the Cournot quantity for the second period. Given Assumption 1, this can arise if and only if its first period supply is strictly lower than the Cournot quantity. This case has already been eliminated by Lemma 1.

■

Using equilibrium outcomes in the 2^{nd} and the interim periods, $q_{i,2}^*$ and $R_{add,i}^*$ defined by Equations (4.4) and (4.6), the game to a one-period optimization in which firm i only chooses the 1^{st} period quantity. The maximization problem is defined as follows:

$$\begin{aligned} &\max_{q_{i,1}} \ \Pi_i = \pi_{i,1}(q_{i,1}, q_{j,1}) + \pi_{i,2}(q_{i,2}^*, q_{j,2}^*, x_i(R_{add,i}^*)) \\ &\text{subject to} \quad q_{i,1} + q_{i,2}^* \le R_{i,0} + R_{add,i}^*, \end{aligned} \tag{4.7}$$

where $\pi_{i,1}$ and Π_i are firm i's first period profit and reduced profit functions, respectively.[46] Consequently, given Lemma 1 and Lemma 2, the best response correspondence for firm i in the 1^{st} period, $\sigma_{i,1} : [0, R_{j,0}] \to [0, R_{i,0}]$, will be as follows:

$$\sigma_{i,1} = \begin{cases} \frac{\beta_1 A - \beta_2 q_{j,1} + \beta_3 R_{i,0} + \beta_4 R_{j,0}}{\beta_5} & \text{if } max\left\{ \frac{-\beta_6 A + \beta_7 q_{j,1} - \beta_8 R_{j,0}}{\beta_9}, \frac{\beta_6 A - \beta_7 q_{j,1} + \beta_8 R_{j,0}}{\beta_{10}}, \frac{\beta_{11} A - \beta_{12} q_{j,1} + \beta_{13} R_{j,0}}{\beta_{14}} \right\} \\ & \qquad \le R_{i,0} \le \frac{\beta_{15} A + \beta_{16} q_{j,1} - \beta_{17} R_{j,0}}{\beta_{10}} \\ R_{i,0} & \text{if} \quad R_{i,0} < \frac{\beta_6 A - \beta_7 q_{j,1} + \beta_8 R_{j,0}}{\beta_{10}} \\ 0 & \text{if} \quad q_{j,1} > \frac{\beta_6 A + \beta_9 R_{i,0} + \beta_8 R_{j,0}}{\beta_7}, \end{cases}$$

[46] Please note that discount factor assumed to be unity for simplicity.

$$
\begin{aligned}
& \text{where} \\
\beta_1 &= 8a_i^2(1+a_j)+16a_i(1+a_j)^2+(3+4a_j)^2 \\
\beta_2 &= 24a_i(1+a_j)(1+2a_j)+16a_i^2(1+a_j)(1+2a_j)+(3+4a_j)^2 \\
\beta_3 &= 16a_i^2(1+a_j)(1+2a_j)+(3+4a_j)^2 \\
\beta_4 &= 8(1+a_i)a_j(1+a_j) \\
\beta_5 &= 2(1+a_i)(3+4a_j)(3+4a_j+8a_i(1+a_j)) \\
\beta_6 &= 8a_i^2(1+a_j)+16a_i(1+a_j)^2+(3+4a_j)^2 \\
\beta_7 &= (3+4a_i)^2+24a_j(1+a_i)(1+2a_i)+16a_j^2(1+a_i)(1+2a_i) \\
\beta_8 &= 16a_ia_j(1+a_i)(1+2a_i) \\
\beta_9 &= 2a_i(8a_i(1+a_j)(1+2_aj)+(3+4a_j)^2) \\
\beta_{10} &= 2a_i(3+4a_j+4a_i(1+a_j))^2 \\
\beta_{11} &= 3a_i(5+6a_i)-4a_j(1+a_i)(3+2a_i)-16a_j^2(1+a_i)(1+2a_i) \\
\beta_{12} &= 3(a_i(3+4a_i)+4a_j(1+a_i)(3+8a_i)+16a_j^2(1+a_i)(1+2a_i)) \\
\beta_{13} &= 12a_j(1+a_j)(3+4a_j+a_i(7+8a_j)) \\
\beta_{14} &= 6a_i(3+4a_j+4a_i(1+a_j)) \\
\beta_{15} &= 3+4a_j+2a_i(8+10a_j+a_i(7+8a_j))) \\
\beta_{16} &= 9+12a_j+2a_i(3+2a_i)(5+6a_j) \\
\beta_{17} &= (1+a_i)(9+12a_j4a_i(6+7a_j)).
\end{aligned}
$$

The quantities $(q^*_{i,1}, q^*_{j,1})$ are the Nash equilibrium of the reduced game if and only if $q^*_{i,1} \in \sigma_{i,1}(q^*_{j,1})$ and $q^*_{j,1} \in \sigma_{j,1}(q^*_{i,1})$. Lemma 3 provides the unique Subgame Perfect Nash Equilbrium of the reduced game.

Lemma 3. *Nash equilibrium of the reduced game for firm i is as follows:*

$$
\begin{aligned}
q^*_{i,1} &= \tfrac{\alpha_1 A+\alpha_2 R_{i,0}+\alpha_3 R_{j,0}}{\alpha_4} \quad \textit{for} \quad R_{i,0} > \tfrac{\alpha_1 A+\alpha_3 R_{j,0}}{\alpha_4-\alpha_2} \\
& \textit{where;} \\
\alpha_1 &= 32a_i^2(1+a_j)(1+6a_j+6a_j^2)+4a_i(1+a_j)(15+88a_j+88a_j^2) \\
& \quad +(3+4a_j)(9+50a_j+40a_j^2) \\
\alpha_2 &= 4a_i(1+a_j)(27+60a_i+32a_i^2+16(1+a_i)(6+7a_i)a_j+16a_j^2(5+11a_i+6a_i^2)) \\
\alpha_3 &= -2a_j(3+4a_i+4a_j+4a_ia_j)(9+8a_i+8a_j+8a_ia_j) \\
\alpha_4 &= 64a_i^3(1+a_j)(1+2a_j)(5+6a_j)+48a_i(1+a_j)(9+34a_j+28a_j^2) \\
& \quad +32a_i^2(1+a_j)\big(21+8a_j(9+7a_j)\big)+(3+4a_j)\big(27+4a_j(27+20a_j)\big).
\end{aligned}
\tag{4.8}
$$

Proof. The other two possible equilibrium strategies for firm i at this stage are [i] $q^*_{i,1} = 0$ and [ii] $q^*_{i,1} = R_{i,0}$. Let us explain why the firm would not choose these two strategies:

i. Let us assume that in the first period the firm chooses to produce 0 and save all of its initial resource for the second period. Choosing zero production quantity leads to monopoly prices since the only supplier will be the rival. It is a fact that in the second period the firm will not be a monopoly because even if the rival supplies all its initial resource endowment in the first period, it still has an incentive to invest in capacity and to generate new capacity for the second period. Thus, the second period price will be less than the monopoly price. In this case, the firm would enjoy monopoly prices in the first period by reallocating its capacity such that it would increase the production in the first period without changing the production in the second period.

ii. Firm i will choose the first period quantity to be equal to its initial resource endowment if and only if $R_{i,0} \leq \frac{\alpha_1 A+\alpha_3 R_{j,0}}{\alpha_4-\alpha_2}$. Yet, Assumption 1 excludes this.

■

Following Lemma 1 and Lemma 2, the Nash equilibrium of the reduced game $(q^*_{i,1}, q^*_{j,1})$, defined by Lemma 3, leads to the Sub-game Perfect Nash Equilibrium of the entire game, which is defined by Proposition 1.

Proposition 1. *The Sub-game Perfect Nash Equilibrium of the entire game is unique and defined as follows:*

$$
\begin{aligned}
(q^*_{i,1}, R^*_{add,i}, q^*_{i,2}) \quad &= \left(\tfrac{\alpha_1 A+\alpha_2 R_{i,0}+\alpha_3 R_{j,0}}{\alpha_4}, \tfrac{\alpha_5 A+\alpha_6 R_{i,0}+\alpha_7 R_{j,0}}{\alpha_4}, \tfrac{\alpha_8 A+\alpha_9 R_{i,0}+\alpha_{10} R_{j,0}}{\alpha_4}\right), \\
&\quad \textit{where} \\
\alpha_1 &= 32a_i^2(1+a_j)(1+6a_j+6a_j^2)+4a_i(1+a_j)(15+88a_j+88a_j^2) \\
&\quad +(3+4a_j)(9+50a_j+40a_j^2) \\
\alpha_2 &= 4a_i(1+a_j)(27+60a_i+32a_i^2+16(1+a_i)(6+7a_i)a_j+16a_j^2(5+11a_i+6a_i^2)) \\
\alpha_3 &= -2a_j(3+4a_i+4a_j+4a_ia_j)(9+8a_i+8a_j+8a_ia_j) \\
\alpha_4 &= 64a_i^3(1+a_j)(1+2a_j)(5+6a_j)+48a_i(1+a_j)(9+34a_j+28a_j^2) \\
&\quad +32a_i^2(1+a_j)\big(21+8a_j(9+7a_j)\big)+(3+4a_j)\big(27+4a_j(27+20a_j)\big) \\
\alpha_5 &= 2\big[8a_i^2(1+a_j)(1+4a_j)(5+6a_j)+(1+a_j)(3+4a_j)(9+40a_j) \\
&\quad +a_i\big(66+4a_j(107+2a_j(89+44a_j))\big)\big] \\
\alpha_6 &= -\big(3+4a_j+4a_i(1+a_j)\big)\big(27+4a_j(27+20a_j)+4a_i(9+8a_2(4+3a_j))\big) \\
\alpha_7 &= -\big(3+4a_j+4a_i(1+a_j)\big)\big(4a_j(9+10a_j+2a_i(5+6a_j))\big) \\
\alpha_8 &= \big(3+4a_j+4a_i(1+a_j)\big)\big(9+8a_j(6+5a_j)+4a_i(3+2a_j(7+6a_j))\big) \\
\alpha_9 &= \big(3+4a_j+4a_i(1+a_j)\big)\big(4a_i\big(9+12a_i(1+a_j)(1+2a_j)+10a_j(3+2a_j)\big)\big) \\
\alpha_{10} &= -(3+4a_j+a_i(1+a_j))(2(3+4a_i)a_j(3+4a_j))
\end{aligned}
\tag{4.9}
$$

for

$$\frac{\alpha_1 A+\alpha_3 R_{j,0}}{\alpha_4-\alpha_2} < R_{i,0} < \frac{(\alpha_4-3\alpha_8)A-3\alpha_{10}R_{j,0}}{3\alpha_9}.$$

Proof. Nash equilibrium of the reduced game, provided by Lemma 3, corresponds one-to-one with the SPNE of the entire game. Moreover, the parameter constraints provided by Lemma 1, Lemma 2 and Lemma 3 restrict our attention to only one region, which is disjoint to the other excluded regions. Thus, given the interval for the initial resource endowments of each firm, the SPNE defined by Proposition 1 is unique. ■

Note that the equilibrium in Proposition 1 is valid only for the initial resource endowments that lie in the provided interval. With this interval, we restrict our attention to the equilibrium in which both firms would have positive capacity additions and positive supplies in both periods. As the upper bound of this range is approached, the second period reduces to the unconstrained Cournot game in which the equilibrium is achieved without capacity additions, since the capacity constraints become non-binding.

Proposition 2. *The equilibrium price, P_t^*, weakly decreases over time.*

Proof. Given the interval for initial resource endowments of each firm, we can verify for any combination of (a_i, a_j) that $Q_1^* \leq Q_2^*$, where $Q_t^* = q_{1,t}^* + q_{2,t}^*$. Since the inverse demand function does not change over time, i.e., $P_t = A - Q_t$, the equilibrium price in the first period is larger than or equal to the second period price, $P_1^* \geq P_2^*$. ■

Proposition 2 contradicts Hotelling-based reasoning, which states that the scarcity rent of the exhaustible resources would cause the prices to increase gradually (Hotelling, 1931). Yet, this reasoning is based on the assumption of a fixed amount of initial resource endowments. Thus, the result proposed by Proposition 2 is due to the endogenous capacity constraints. This result, in fact, captures the short-term stylized characteristics of exhaustible resource markets in which price drops are observed from time to time. For instance, exploration of new oil reserves would lead to declining prices as a result of supply enhancements. Proposition 2 may not be applicable if this model is extended to an infinite time horizon since in this case, the capacity addition cost function should have a different structure, capturing the fact that it gets harder to add capacity as the cumulative capacity addition increases.

Proposition 3. *Given a fixed aggregate initial resource endowment, $S_0 = R_{i,0} + R_{j,0}$:*

i. if $a_i = a_j$, an increase or decrease in $|R_{i,0} - R_{j,0}|$ leads to no change in equilibrium price.

ii. if $a_i > a_j$, the equilibrium price in both periods increases (decreases) as the share of $R_{j,0}$ relative to $R_{i,0}$ increases (decreases).

Proof. Let us assume a fixed amount of aggregate initial resource, $S_0 = R_{i,0} + R_{j,0}$. For $a_i = a_j$, total amount of supply in both periods will be a function of only the aggregate initial resource endowment, i.e., $Q_t^*(S_0)$. Thus, given a fixed S_0, a change in

$|R_{i,0} - R_{j,0}|$ would not affect the outcome. Yet, when $a_i \neq a_j$, we can verify that an uneven distribution of the fixed aggregate initial resource stock among firms would lead to a significant change in equilibrium supply. More specifically, we can verify that for $a_i > a_j$, an increase in $R_{j,0}$ relative to $R_{i,0}$ leads to a decrease in equilibrium supply in both periods, Q_1^* and Q_2^*. ■

Proposition 3 suggests that if the firms are symmetric in their cost functions, any asymmetric distribution in reserves do not affect the equilibrium outcomes. Moreover, if firms have different cost parameters, $a_i \neq a_j$, equilibrium price increases due to a decrease in equilibrium quantity when the distribution is altered in favor of the more efficient firm, i.e., the one with lower a. The equilibrium price, on the other hand, would decline if the asymmetry is in favor of the less efficient firm, i.e., the one with higher a. This is an expected result since if one firm is more efficient in capacity addition, it would become more dominant in the second period, leading to a more concentrated market structure and eventually to an increase in prices. On the other hand, distribution of initial resource stock in favor of the less efficient firm would offset the advantage of a more efficient firm leading to a more competitive market structure.

Proposition 4. *At equilibrium,*

i. if $R_{i,0} > R_{j,0}$, then, ceteris paribus, $q^*_{i,t} > q^*_{j,t}$ and $R^*_{add,i} < R^*_{add,j}$ for $i, j \in \{1, 2\}$, $i \neq j$ and $t \in \{1, 2\}$.

ii. $\frac{\partial q^*_{i,t}}{\partial R_{i,0}} > 0$, $\frac{\partial q^*_{j,t}}{\partial R_{i,0}} < 0$, $\frac{\partial R^*_{add,i}}{\partial R_{i,0}} < 0$ and $\frac{\partial R^*_{add,j}}{\partial R_{i,0}} > 0$ for $i, j \in \{1, 2\}$, $i \neq j$ and $t \in \{1, 2\}$.

Proof. The proof follows directly from the first derivatives of the corresponding continuous functions, i.e. $q^*(.)$ and $R^*_{add}(.)$, with respect to the initial resource endowments. ■

Proposition 4 implies, not surprisingly, that the firm with a greater initial resource endowment would supply more in both periods and generate smaller additional capacity, all else being equal. Moreover, initial resource endowment of a firm has a positive effect on its supplies and a negative effect on the supplies of rival firm in both periods. Finally, initial endowment has negative and positive effects on the capacity additions of the firm itself and its rival, respectively.

Proposition 5. *At equilibrium,*

i. *if* $a_i < a_j$ *then, ceteris paribus,* $q^*_{i,t} > q^*_{j,t}$ *and* $R^*_{add,i} > R^*_{add,j}$*for* $i, j \in \{1, 2\}$*,* $i \neq j$ *and* $t \in \{1, 2\}$*.*

ii. $\frac{\partial q^*_{i,t}}{\partial a_i} < 0$*,* $\frac{\partial q^*_{j,t}}{\partial a_i} > 0$*,* $\frac{\partial R^*_{add,i}}{\partial a_i} < 0$ *and* $\frac{\partial R^*_{add,j}}{\partial a_i} > 0$ *for* $i, j \in \{1, 2\}$*,* $i \neq j$ *and* $t \in \{1, 2\}$*.*

Proof. The proof follows directly from the first derivatives of the corresponding continuous functions, i.e., $q^*(.)$ and $R^*_{add}(.)$, with respect to the cost parameters. ■

Proposition 5 implies that the firm with higher efficiency, or lower cost parameter, will supply more output in both periods and generate larger capacity addition. Moreover, a_i has negative effects on both supply and investment decisions of firm i and positive effects on those of firm j.

4.4 Oil Market Interpretation: Oil Field Service (OFS) Companies

One of the most important resource markets is, without a doubt, the oil market. The model presented in Section 4.2 would, therefore, be applicable to this specific market. The initial resource stock of the firms and the investment in capacity additions could refer to the initial recoverable reserves and the reserve growth investments in the oil market, respectively. As is commonly known, the upstream petroleum industry represents a highly concentrated market structure. For instance, in 2004, 81% of the world's proved reserves was controlled by the major National Oil Companies (NOCs) including Saudi Aramco, National Iranian Oil Company, Iraq National Oil Company, Kuwait Petroleum Corporation, Abu Dhabi National Oil Company, PDVSA (National Oil Company of Venezeula) and National Oil Company of Libya (PWC, 2005). Moreover, according to the US Energy Information Administration, in 2011, NOCs accounted for around 55% of global oil supply, while major International Oil Companies (IOCs) were responsible for 27% (EIA, 2013). Thus, it is a reasonable simplification to assume that the current upstream oil industry is dominated by two blocks of companies, i.e., IOCs and NOCs.

Over the last few years, high oil prices, fluctuating around 100$/bbl (well above the maximum marginal costs for producing a barrel of conventional (around 60$) and of unconventional (around 80$) crude oil), have encouraged upstream petroleum companies to increase production. However, in addition to other factors, substantial risks and costs associated with upstream activities, especially exploration and development operations, remain as the main obstacles facing supply enhancements. The excessive profits that the IOCs can extract create an incentive to face these risks and costs; yet NOCs would not be able to invest further in these activities as they may not have the required know-how or may be required to consider other factors, such as maximizing social welfare in the host country. In this respect, Oil Field Service (OFS, hereafter) companies, which specialize in development activities, emerge as business partners for NOCs.

Increasing recoverability of the reserves is one of the main objectives of development activities in the upstream petroleum industry. Reserve growth technologies, such as enhanced or improved oil recovery techniques, would lead to enhancement in supply via increasing the recoverability ratios of the reserves. Therefore, investment in such technologies is of great importance for upstream petroleum companies as well as for the future market structure of the petroleum industry.

In the general model presented in Section 4.2, we suggest that both firms can generate additional capacity for the second period. The reality, however, may differ. In fact, as previously mentioned, we implicitly assume that one of the firms, i.e., NOC, may not have the necessary know-how or funding opportunity to invest further into increasing the recoverable reserve and instead employs an OFS company, which is specialized in reserve growth technologies. Now let us assume that there are no OFS companies existing in the upstream oil market and that the NOC, which is represented by firm 2, is not capable of capacity investment. This means that for the NOC, the cost parameter is infinitely large and they can not generate additional capacity for the second period. We call this new case “no-OFS”.

Proposition 6. *The Nash equilibrium for the no-OFS case is as follows:*

$$\begin{aligned}(q^*_{1,1}, R^*_{add,1}, q^*_{1,2})_{noOFS} &= \Bigg(\frac{(5+6a_1)A+2a_1(5+6a_1)R_{1,0}-(2+2a_1)R_{2,0}}{2(1+a_1)(5+6a_1)}, \frac{2A-R_{2,0}-2R_{1,0}}{2(1+2a_1)}, \\ &\qquad \frac{(5+6a_1)A+2a_1(5+6a_1)R_{1,0}-(3+4a_1)R_{2,0}}{2(1+a_1)(5+6a_1)}\Bigg) \\ (q^*_{2,1}, R^*_{add,2}, q^*_{2,2})_{noOFS} &= \left(\frac{(2+3a_1)R_{2,0}}{5+6a_1},\ 0,\ \frac{(3+3a_1)R_{2,0}}{5+6a_1}\right).\end{aligned} \tag{4.10}$$

Proof. The proof follows directly from the fact that as the cost parameter for the NOC, a_2, approaches infinity, the Nash equilibrium given in Equation (4.9) will approach the one represented in Equation (4.10):

$$\lim_{a_2\to\infty}(q^*_{i,1}, R^*_{add,i}, q^*_{i,2})_{General} \to (q^*_{i,1}, R^*_{add,i}, q^*_{i,2})_{noOFS}.$$

Note that given the cost function in Equation (4.2), $R_{add,i} = (\frac{x_i}{a_i})^{1/2}$ (which satisfies Inada conditions) we make sure that as a_2 approaches infinity, $R_{add,2}$ approaches zero and not a negative value, i.e., $\lim_{a_2 \to +\infty} R_{add,2} = 0$ ■

In order to investigate the effects of OFS companies on the market dynamics, we compare the Nash equilibria of both the General and no-OFS cases, represented by Equations (4.9) and (4.10), respectively. Let us assume that in the General case each firm has exactly the same capacity addition cost structure, i.e., $a_1 = a_2 = a$. In the no-OFS case, the cost parameter of firm 1, a_1, stays at the same level, while the cost parameter of firm 2, a_2, approaches infinity.

Proposition 7. *The effect of OFS companies on equilibrium supply and capacity additions for $a_1 = a$ and $a_2 \to \infty$:*

i. The quantity supplied by the capable firm, firm 1 (IOC) in our setup, is greater at each instant of time in the no-OFS case:
$q_{1,1,General} \leq q_{1,1,noOFS}$ *and* $q_{1,2,General} \leq q_{1,2,noOFS}$.

ii. The quantity supplied by the incapable firm, firm 2 (NOC) in our setup, is lower at each instant of time in the no-OFS case:
$q_{2,1,General} \geq q_{2,1,noOFS}$ *and* $q_{2,2,General} \geq q_{2,2,noOFS}$.

iii. Total quantity supplied to the market is greater at each instant of time in the General Case:
$Q_{t,General} \geq Q_{t,noOFS}$ *where* $Q_t = q_{1,t} + q_{2,t}$ *and* $t = 1, 2$.

iv. Total capacity addition in the General case is greater:
$R_{add,total,General} \geq R_{add,total,noOFS}$ *where* $R_{add,total} = R_{add,1} + R_{add,2}$.

v. The additional capacity generated by the capable firm is greater in the no-OFS case:
$R_{add,1,General} \leq R_{add,1,noOFS}$.

Proof. The proofs for [*i.*], [*ii.*], [*iii.*], [*iv.*] and [*v.*] follow directly from Proposition 1 and Proposition 6. ■

Proposition 7 implies that the existence of OFS companies leads to a more competitive market structure in the upstream oil industry. The market would move to a more concentrated structure if we only allow for one firm to invest in reserve growth technologies or, in other words, if there were no OFS companies in the market, because the capable firm would supply more and increase its supply periodically. Existence of OFS firms, moreover, has a significant effect on reserve growth investments and, thus, equilibrium capacity additions. As expected, due to the rivalry between firms, total additional capacity generated in the General case is greater than that in no-OFS case. Yet, the additional capacity generated by the capable firm is greater in the no-OFS case. This result emerges possibly due to the fact that in the no-OFS case, capable firm would enjoy higher profits in the 2^{nd} period by increasing its capacity even more.

4.5 Welfare Analysis

In the previous sections, we derived the Nash equilibrium for the General case (Section 4.3) and the no-OFS case (Section 4.4). In this section, we conduct a welfare analysis. At equilibrium, the consumer surplus (CS) is defined as follows:

$$\text{CS}^* = \frac{1}{2}\left[(Q_1^*)^2 + (Q_2^*)^2\right],$$

where Q_1^* and Q_2^* are the equilibrium aggregate supplies in periods 1 and 2, respectively.

Proposition 8. *In both the General and the no-OFS cases, an increase in the initial resource endowment for at least one of the firms leads to a weak increase in consumer surplus.*

Proof. The proof follows directly from the first derivatives of the equilibrium outcomes with respect to $R_{i,0}$ for $i \in 1, 2$. ■

Proposition 8 suggests, not surprisingly, that consumers would benefit from an increase in the availability of the exhaustible resource. This result is in accordance with the previous findings in the literature, such as Gaudet and Long (1994), and with the stylized characteristics of exhaustible resource markets.

Proposition 9. *Given fixed aggregate initial resource endowment,* $S_0 = R_{i,0} + R_{j,0}$,

1. *in the General Case,*
   - i. *if* $a_i = a_j$, *an increase or decrease in* $|R_{i,0} - R_{j,0}|$ *leads to no change in consumer surplus.*
   - ii. *if* $a_i > a_j$, *the consumer surplus increases (decreases) as the share of* $R_{j,0}$ *relative to* $R_{i,0}$ *decreases (increases).*
2. *in the no-OFS Case,*
   for any a_1, *the consumer surplus increases (decreases) as the share of* $R_{1,0}$ *relative*

to $R_{2,0}$ decreases (increases) or as the share of $R_{2,0}$ relative to $R_{1,0}$ increases (decreases).

Proof. The proof follows directly using the same reasoning provided in the proof of Proposition 3. ■

Proposition 9 implies, in line with Proposition 3, that if one firm is slightly more efficient than the other, consumer welfare tends to change with the asymmetric distribution of initial resource endowment. Consumer welfare decreases if the asymmetry is in favor of the more efficient firm. On the other hand, if the initial resource distribution is in favor of the less efficient firm, the consumer welfare increases.

The total welfare function in our setting can be defined as follows:

$$\mathrm{W} = \mathrm{TS}_1 + \mathrm{TS}_2 - X = A\big(Q_1^* + Q_2^*\big) - \frac{1}{2}\big[(Q_1^*)^2 + (Q_2^*)^2\big] - \big(a_1 R_{add,1}^2 + a_2 R_{add,2}^2\big),$$

where TS_1 and TS_2 are total surpluses in periods 1 and 2, respectively, and X is the aggregate amount of capacity addition costs. The first-best decisions made on total quantity and capacity addition, which maximize total welfare, are as follows:

$$\begin{aligned} Q_{1,FB} = Q_{2,FB} &= \tfrac{A(a_1+a_2)+2a_1a_2(R_{1,0}+R_{2,0})}{a_1+a_2+4a_1a_2} \\ R_{add,FB} &= \tfrac{(a_1+a_2)(A-R_{1,0}-R_{2,0})}{a_1+a_2+4a_1a_2}. \end{aligned} \tag{4.11}$$

Proposition 10. *The equilibria in the General case defined by Proposition 1, in the no-OFS case by Proposition 6 and first-best case by Equation 4.11 reveal the following:*

i. $W_{FB} > W_{General} > W_{noOFS}$,

ii. $Q_{t,FB} > Q_{t,General} > Q_{t,noOFS} \quad for \quad t \in \{1,2\}$,

iii. $R_{add,FB} > R_{add,General} > R_{add,noOFS}$.

Proof. The proof follows directly from the equilibria defined by equations (4.9), (4.10) and (4.11). ■

According to Proposition 10, the total welfare and all three decision variables are the largest in the first-best calculation and smallest in the no-OFS case. We confirm, in line with Proposition 7, that the General case, in which both firms are capable of capacity addition is superior to the no-OFS case.

4.6 Conclusion

This paper analyzes the strategic firm behavior within the context of a two-period resource duopoly model in which firms face endogenous intertemporal capacity constraints. We find that the equilibrium price weakly decreases over the two periods. This result captures the short-term stylized characteristics of exhaustible resources markets, in which price drops are occasionally observed. For instance, exploration of new oil reserves may lead to declining prices as a result of supply enhancements. Moreover, we show that asymmetric distribution of initial resource stocks leads to a significant change in equilibrium outcome, provided that firms do not have the same cost structure in capacity additions. It is also verified that if only one company is capable of investment in capacity, the market moves to a more concentrated structure in the second period.

We also conduct an oil market interpretation of the general model. For this purpose, we assume that the NOC does not have the necessary know-how or funding opportunities for reserve growth investments. Yet, it can employ an OFS company to compete with the IOC in capacity addition. We find that under the absence of OFS companies, only one firm is capable of increasing the capacity for the second period, thus moving the market towards a more concentrated structure. Therefore, the OFS companies carry significant importance in the upstream petroleum industry. Although the integrated structure of the companies, mostly IOCs, increases the profitability, the increasing role of small independent firms that are specialized only in exploration and production is sustainable only if these small firms are supported by OFS companies in development activities. Hence, promoting specialization in these activities, especially reserve growth technologies, would not only serve as a useful tool to increase the competition but also lead to more recoverable resources.

A possible extension of the model could be the introduction of stochasticity in capacity generation such that the capacity additions would be a result of R&D activity held at a prior stage of the game. Another extension would be to analyze the first-mover advantages in the game. However, these extensions could only be made if one could find a model specification that is sufficiently general but also analytically tractable.

Chapter 5

The effects of the CFTC's regulatory announcements on US oil- and gas-related stocks during the 2008 Credit Crunch

5.1 Introduction

The surge in crude oil prices during the commodity boom of the 2000s raised concerns of possible speculation and manipulation in oil markets. Although the prices have declined after a trend reversal that occurred due to the credit crunch in 2008, the issue has remained a priority among policy makers and regulatory authorities. The common view was that the price boom in crude oil markets was not driven by economic and physical market fundamentals but rather by speculation. However, mainstream energy economics literature has recently provided evidence that speculation and market manipulation were not responsible for the 2008 price spikes and that economic fundamentals were the major cause.[47] Nevertheless, the increasing volume of non-commercial trading in the crude oil futures market stimulated the Commodity Futures Trading Commission (CFTC, hereafter) to take action against possible market manipulation in commodity futures markets (Masters (2008)).

The CFTC is the main regulatory authority in commodity futures markets. It has closely monitored the crude oil futures market, one of the most liquid commodity markets in

[47]Seminal works in this stream of literature are as follows: Sanders et al. (2004); Hamilton (2009a,b); Kilian (2009); Büyüksahin and Harris (2011); Kilian and Murphy (2012); Fattouh et al. (2013); Alquist and Gervais (2013); Elder et al. (2013); Kilian and Hicks (2013).

the USA, since the surge in oil prices in the early 2000s, which was followed by record levels in summer 2008. Regulation, in order to avoid speculation in futures markets, can in general affect the commodity markets through two channels. Firstly, speculators might benefit from rising or declining prices depending on their positions, i.e., long or short respectively. Thus, any deviation of the futures price of the commodity from its fundamental value needs to be corrected by the regulatory authorities. Yet, this was not the case for the oil market during the 2008 financial crisis because, as already mentioned, the recent energy economics literature provided evidence against the role of speculation in driving the oil prices. Secondly, during periods of high uncertainty, regulation is meant to decrease the riskiness of the commodity markets through suppressing the volatility. Although there exists little evidence in the literature that speculation was responsible for the increases in oil price volatility, as correctly noted by Fattouh et al. (2013), the aim of regulatory efforts in oil markets has so far been to reduce volatility. Thus, during the credit crunch period, this second channel might explain how the CFTC interventions affected the oil market.

Moreover, there has been an extensive literature on the relationship between the oil price and the stock market activity since Hamilton (1983) showed that crude oil price shocks affect macroeconomic indicators and company stock prices by influencing companies' operational costs and hence their income.[48] This consequently affects the firms' stock returns. Several papers confirm the significant impact of oil price changes on aggregate stock markets. For example, Jones and Kaul (1996) show the sensitivity of the aggregate stock markets of several countries (USA, Canada, Japan and the UK) to oil price shocks. Huang et al. (2005) show that stock market returns in the US, Canada and Japan can be affected by oil price changes and volatility. Aside from aggregate stock market returns, the relationship between the oil price and the stock price of individual firms and sectors has been analyzed in previous studies. For our research, the effect of oil price changes on companies from the energy sector is of particular importance. Al-Mudhaf and Goodwin (1993) show that oil price shocks can affect the returns of NYSE-listed oil companies. Faff and Brailsford (1999) analyze Australian oil and gas companies and find a significant degree of oil price sensitivity for these firms. Sadorsky (2001) and Boyer and Filion (2007) show a positive sensitivity of Canadian oil and gas companies' stock returns to oil prices. Hence, we observe that changes in the oil price and its volatility can affect the stock returns of oil and gas-related firms as well as the aggregate stock markets. Therefore, in the event that CFTC announcements are found to affect the crude oil markets, there should also be a relationship between these announcements and the oil and gas companies' stock returns.

[48]Refer to Section 2.2 for a comprehensive literature review on the relationship between the oil prices and stock market activity.

This paper investigates the effects of CFTC announcements, which are released in order to prevent manipulation and excess speculation in energy markets (particularly oil and gas), on oil and gas related stocks listed in the New York Stock Exchange (NYSE, hereafter) around the credit crunch period surrounding the financial crisis of 2008. Given the relationship between the oil prices and the stock market activity, the theoretical linkage between CFTC announcements and oil related stocks should be through the crude oil prices. The announcements may serve as a signal for the CFTC's willingness to reduce speculation in the commodity markets. If, for example, the CFTC were to announce substantial fines against speculation and manipulation in the oil futures market, potential manipulators might be prevented from engaging in these activities. Well functioning regulatory interventions can decrease the volatility of oil prices and hence make the oil market less risky. Given that the stock market activity is generally driven by the expectations and perceptions of traders, decreasing riskiness would lead to increasing investments in oil related financial stocks. Hence, we suggest that the CFTC's regulatory announcements have a direct effect on the stock prices of firms from the oil and gas sector.

Furthermore, we focus our analysis on the credit crunch period surrounding the financial crisis of 2008. We expect the CFTC's regulatory interventions to have a stronger impact during this time of high manipulation, as their regulatory measures might be more appreciated during this period. Investors of oil and gas firms should advocate the implementation of tighter regulation and higher sanctions against manipulators given rumors about severe market manipulation in the oil and gas sector.

Hence, two questions, which are of significant importance, arise: (1) Do the CFTC announcements affect the stock returns at all? (2) If so, is the sign of the effect systematically the same during the financial crisis of 2008? In order to address these questions we employ event study methodology and analyze the effects of CFTC announcements on daily returns of oil related stocks listed in the NYSE for the period between 2007 and 2009. We identify 35 CFTC announcements related to energy futures commodities, specifically oil and gas.[49] The companies whose stocks are analyzed are chosen from the following indices: Dow Jones US Oil & Gas Index, PHLX Oil Service Sector Index, SIG Oil Exploration & Production Index, NYSE ARCA Oil Index, NYSE ARCA Natural Gas Index S&P Global Oil Index and NYSE Energy Index. We employ the methodology both on individual companies and overall industry, which is compiled as the weighted average of all companies included in the analysis, as well as on the aforementioned indices.

[49] The announcements are collected from CFTC's official website by searching keywords including: "oil", "gas", "WTI" and "energy". All announcements are provided in Table B.1. Please see section 5.2.2 for more detailed explanation of the announcements.

Regarding the effects of sector-specific announcements and the consequences for the oil sector, a vast amount of literature investigates the effects of OPEC meetings on oil markets since Draper (1984).[50] For instance, recently, Lin and Tamvakis (2010) examine three types of decisions made by OPEC (quota cut, quota increase and quota unchanged) and find the decision 'quota cut" to stimulate significant feedback via the increase in prices of different grades of petroleum. They also distinguish between price regimes as they suggest the effects may differ for different price ranges. Demirer and Kutan (2010) examine the informational efficiency of crude oil spot and futures markets with respect to OPEC conference and U.S. Strategic Petroleum Reserve announcements. They find asymmetry in the response of oil prices to the OPEC announcements. They also conclude that Strategic Petroleum Reserve announcements have short-term effects. Moreover, Guidi et al. (2006) find significant responses of the US and the UK stock markets to the outcomes of OPEC meetings for the period between 1986 and 2004. This result is of higher importance for our analysis as it takes the stock market responses to sectoral announcements into account.

The current paper contributes to the literature in two regards. Firstly, to the authors' best knowledge, we are not aware of any study investigating the effects of CFTC announcements on oil and gas related stocks. For oil companies, understanding of their reaction towards CFTC announcements may provide valuable knowledge regarding their stock price exposure. This is particularly relevant in times of high volatility in the oil market, since the announcements may be published more frequently and may contain more drastic punishments or significant regulatory amendments, which in turn may strongly affect the firms' stock prices. As discussed above, several arguments can be found that these announcements affect stock prices positively, but also negative reactions can be explained. Our paper is the first to address the question how investors of oil and gas related stocks perceive the CFTC announcements with respect to the oil and gas firms' stock prices in reality. Secondly, although there exists extensive literature on whether speculation is a driving force in the oil market, the impacts of regulatory efforts have not yet been investigated entirely. Given that a huge amount of speculation is assumed to have occurred during the rise in oil prices prior to the financial crisis of 2008, the period around the crisis provides an interesting opportunity to assess the CFTC's regulatory influence. We, therefore, contribute to the existing literature by employing event study analysis on a firm-level database with a unique set of announcements to explain the effects of regulatory efforts by the CFTC on the oil market and thus oil related stocks.

Our results indicate that, depending on the content and the importance, the CFTC announcements can affect the oil and gas companies' stock prices. This holds particularly

[50] See, for example, Deaves and Krinsky (1992), Horan et al. (2004), Wirl and Kujundzic (2004).

true for announcements during the peak of the financial crisis, i.e., period following Lehman Brothers failure, hence indicating a strong regulatory influence in times of high speculation, market manipulation and market turmoil, which cause higher volatility in oil prices. Although the firms' stock prices are affected positively for most events during this period, we cannot identify a clear pattern with respect to the direction of the effect, as the positive effects alternate with two negative effects in our analyses. Unfortunately, a basic weakness of the event study methodology is that results may be driven by confounding events. When analyzing possible confounding events, we find convincing explanations that the two negative stock price reactions may have been driven by alternative events that occurred within the same event window and potentially dominating the effect of the CFTC announcements.[51] With respect to the different types of companies operating in different branches of the industry (e.g., upstream, downstream), we could not find any statistical differences in responses to the CFTC announcements. This shows that traders in general perceive the CTFC's interventions same (either positive or negative) for all companies regardless of their sub-branch. Furthermore, given their economic importance, we closely examine the stock price movements of the 5 biggest oil and gas companies, finding significant stock market reactions and high co-movements around the time of the announcements.

The rest of the paper is organized as follows: Section 5.2 describes the methodology and the data used in detail. Section 5.3 provides the major results. Finally, Section 5.4 concludes.

5.2 Data and Methodology

5.2.1 Data

We use publicly available daily stock price returns for all companies included in the following indices: Dow Jones US Oil & Gas Index, PHLX Oil Service Sector Index, SIG Oil Exploration & Production Index, NYSE ARCA Oil Index, NYSE ARCA Natural Gas Index S&P Global Oil Index and NYSE Energy Index. Our observation period covers the years 2007–2009, i.e., the announcements during the year of the financial crisis in 2008 and the years directly preceding and following it. We exclude firms if the stock prices are not available on the date of the announcements, the event window and the estimation period. The stock prices are adjusted for stock splits. Our analysis includes 122 firms and 35 announcements.

[51] Clearly, we can never exclude the possibility that the positive effects are also caused by confounding events. Yet, we could not find suitable candidates that would lead to positive effects for most of the announcements.

5.2.2 CFTC Announcements

The announcements are collected from CFTC's official website by searching keywords including: "oil", "gas", "WTI" and "energy". All announcements are listed in Table B.1 of the Appendix. The CFTC announcements are not standardized, thus our analysis contains a set of heterogeneous events. Most announcements contain fines against manipulation in the energy sector, while others contain announcements on the CFTC's staff. The announcements also differ regarding their relevance for the stock prices of oil and gas related firms in our analysis. While the announcement of a major fine should significantly affect the energy firms, pure information on the CFTC's staff should have a negligible effect. However, judging their importance ex ante and deleting announcements that we consider unimportant might bias our results, as this decision would represent our subjective opinion, while investors could still perceive these announcements as important. Hence, we include all announcements in our analysis, irrespective of our opinion on their importance, and discuss potentially unimportant events in more detail while interpreting our results.

Initially, our search yielded 40 announcements, but some of them occurred in quick succession and hence led to a problem of confounding events.[52] As a result, we deleted 5 events that occurred on the same date as another event or within two days before or after the event. We kept the announcement that we regarded to be of greater importance when two announcements overlapped. Moreover, confounding events might explain an unexpected stock price reaction during some events. In case a CFTC announcement does not contain relevant information, but still triggers significant abnormal stock market returns (or a reaction in another direction as expected), the reaction might rather be driven by other events that occurred on the same date, e.g., news related specific to the oil market. Hence, these events and not the CFTC announcements might cause the abnormal returns in this case. Thus, we carefully check the event windows in our analysis for confounding, oil markets related news that might affect the oil firms' stock market response instead or in addition to the CFTC announcements. This is, in particular, of high importance in case the CFTC announcements contain relatively unimportant news that should not trigger abnormal returns, but the firms still react significantly. When analyzing the results, we carefully examine if our results are driven by confounding events and mention this if necessary.

[52]Please refer to McWilliams and Siegel (1997) for the problem of confounding events in event study methodologies. They suggest that the effects of two events are hard to differentiate if they take place on the same date or follow each other within a short period of time.

5.2.3 Methodology

For our analysis, we use event study methodology following, e.g., Brown and Warner (1980, 1985). In order to examine the impact of the CFTC announcements on the firms, we consider the firms' cumulated abnormal return (AR), i.e., the firms' ex post stock return minus the firms' normal return during the event window. The event window is defined as the time period several days after the respective CFTC announcement (the event) in order to fully incorporate all relevant information associated with the event and several days prior to the event to account for the possibility that some information leaks out prior to the announcement. However, the use of long event windows can violate the assumption of market efficiency (McWilliams and Siegel (1997)). Hence, we use event windows of 2 days before ($\tau_- = 2$) and 2 days after ($\tau_+ = 2$) the CFTC announcement for our analysis.[53] The company's normal returns are estimated based on the individual stocks' betas (β's), estimated by a market model (Brown and Warner (1980)) using a period from 280 to 30 trading days (250 trading days) before the event (estimation window). We use the S&P 500 index for our calculation as market beta, given that we analyze companies listed in the US. Finally, we calculate the firms' abnormal returns by subtracting the normal return for each firm from its actual stock return during the event window. Hence, we estimate the following model:

$$r_i = \alpha + \beta_i \cdot r_{S\&P} + \varepsilon_i \tag{5.1}$$

where $r_{S\&P}$ is the daily return on the S&P 500, r_i is the daily stock return for each company and β_i is the firm's beta coefficient. Next, for each CFTC announcement we calculate the abnormal return for each company (i.e., the difference between the predicted stock return based on our estimation and the actual stock return during the event window). Thus, the following model is estimated:

$$AR_i = \big(r_i - (\alpha + \beta_i \cdot r_{S\&P})\big) \tag{5.2}$$

[53]Given that our events are heterogeneous, they may require different event windows to incorporate all relevant information. Thus, the duration of our event window is crucial for our analysis as different event windows may include different information and thus lead to different stock price reactions. Hence, we use different event windows for robustness in our analysis. The results can be seen in Table B.4. It can be seen that the results are comparable and similar. In particular, the stock price reactions are strongly pronounced during the financial crisis and less pronounced after and before the crisis. Given that all event windows provide highly similar results, we restrict our analysis to the standard event window, i.e., 2 days before ($\tau_- = 2$) and 2 days after ($\tau_+ = 2$) the CFTC announcement.

Finally, we calculate the cumulative abnormal returns (CAR) by summing up the firm's abnormal returns over the event window for each firm individually,

$$CAR_i = \sum_{t=-2}^{+2} AR_{it} \tag{5.3}$$

Moreover, we test whether the announcements significantly affect the individual companies' stock returns and the overall sector's stock returns by determining the significance of their stock price impact. In doing so, we examine the significance of the individual firms' CARs and the overall industry's CAR, i.e., the mean of the CAR of all firms in our sample for a given event. Following Angbazo and Narayanan (1996), the sample mean of the abnormal return for an event on a given event day t is calculated by:

$$\overline{AR}_t = \frac{1}{N}\sum_{i=1}^{N} AR_{it} \tag{5.4}$$

Its significance can be tested by the following statistic:

$$\frac{\overline{AR}_t}{\hat{S}(\overline{AR}_t)} \tag{5.5}$$

with $\hat{S}(\overline{AR}_t)$ equal to the estimation of the standard deviation of $\overline{AR}_t$ calculated during the estimation window (trading days ranging from 280 to 30 days prior to the event) as follows:

$$\hat{S}(\overline{AR}_t) = \sqrt{\frac{1}{250}\sum_{t=-280}^{-30}(\overline{AR}_t - \overline{\overline{AR}})^2} \tag{5.6}$$

where $\overline{\overline{AR}} = \frac{1}{250}\sum_{t=-280}^{-30}(\overline{AR}_t)$. We test the significance of $\overline{AR}_t$ using a student's t-distribution, assuming independent and identical distributions.

The significance of the average CAR across all companies over the event window is tested by examining the significance of

$$\overline{CAR} = \sum_{t=-2}^{+2} \overline{AR}_t \tag{5.7}$$

The test statistic for the overall CAR is given by

$$\frac{\sum_{t=\tau_-}^{\tau_+}[\overline{AR}_t/(\tau_+ - \tau_- + 1)]}{\sum_{t=\tau_-}^{\tau_+}[\sigma\left[\overline{AR}_t/(\tau_+ - \tau_- + 1)\right]]} = \frac{\sum_{t=\tau_-}^{\tau_+}\overline{AR}_t}{\sqrt{\tau_+ - \tau_- + 1}} = \frac{\sum_{t=-2}^{+2}\overline{AR}_t}{\sqrt{5}} \tag{5.8}$$

distributed as standard normal under the null hypothesis of $CAR = 0$. Thus, we are able to examine whether CFTC announcements have significant overall CARs, indicating a significant effect on the overall industry.[54]

After analyzing the consequences of the announcements for the overall oil and gas industry and the individual indices, we extend our analysis by focusing on the impact of CFTC announcements on the 5 biggest companies in our sample: BP, Chevron, Exxon, Shell and Total. Given the size of these companies and their importance for the global economy, a closer examination of these companies will yield valuable information for shareholders, regulators and executives. Thus, we follow the approach described above and examine the consequences of the CFTC's announcements on these 5 firms individually. Moreover, we create an index containing only these 5 firms (Major 5 index) and analyze its stock price reaction to the announcements.

Additionally, we analyze whether the firms' stock price reactions depend on their geographic location and therefore test to see whether the effects of the CFTC's announcements are more pronounced for firms that are based in the US and Canada (North America) than for firms that are located in other countries (Non-North American). This will provide evidence on the CFTC's ability to reach firms that are not located in North America but are listed on a US stock index. Moreover, we examine whether companies from different business segments react differently to the CFTC's announcements. We subdivide the firms with respect to their business model into three subcategories: Upstream, Mid & Downstream and Oil field service.[55] Given the differences across business models (e.g., upstream–related firms should benefit from rising oil prices while downstream–related firms should suffer), an examination of the reaction to CFTC announcements may provide valuable findings for regulators and shareholders. However, as stated above, the CFTC's regulatory efforts would cause an overall increase in stock market activity due to decrease in riskiness of oil market investments by deterring speculative efforts. Hence, the stock price reactions of the firms from the different subcategories may also follow the overall market trend and may therefore be similar for all types of firms in the oil and gas sector.

[54]We did not adjust our analysis as described in Boehmer et al. (1991), who suggest using the cross-sectional variance for testing procedures. Since some of our indices contain a small amount of firms, this would lead to biased cross-sectional variances.

[55]As most companies in the US are engaged in both midstream and downstream activities, we combine these two segments of the sector.

5.3 Results

As previously mentioned, we use stock price data of 122 companies listed in the NYSE and quoted by seven different indices, i.e., Dow Jones US Oil & Gas Index, PHLX Oil Service Sector Index, SIG Oil Exploration & Production Index, NYSE ARCA Oil Index, NYSE ARCA Natural Gas Index S&P Global Oil Index and NYSE Energy Index. Out of these seven indices, the most comprehensives are NYSE Energy Index with 113 companies and S&P Global Oil Index with 62 companies.

The results of our event study for the overall oil and gas industry and the individual indices are summarized in Table B.2. The overall industry (the weighted average of all 122 companies quoted by those 7 different indices) responded significantly to 16 out of 35 events. Thus, it can be seen that CFTC announcements can in general affect the stock returns of oil and gas companies, depending on their content. However, as mentioned above, some of the announcements do not have important consequences or contain relevant information for the stock markets and thus should not affect the companies' stock prices.[56] Regarding our research questions, we find that most of the announcements, specifically just around the credit crunch period, affect the stock returns of oil and gas companies significantly, indicating a strong regulatory influence of the CFTC in times of high speculation, market manipulation and market turmoil, which cause higher volatility in oil prices. However, our results do not indicate a clear pattern regarding the direction of the firms' stock price reaction. Given the sample of heterogeneous events in our analysis, this finding is not surprising as the announcements strongly differ with respect to their content and importance. Nevertheless, our results show that during the peak of the financial crisis, e.g., after the Lehman Brothers failure, the CFTC announcements mostly trigger significantly positive stock market responses, hence indicating that the CFTC could indeed fulfill its duty in times of market turmoil, as the investors perceived their interventions positively. However, some of the announcements negatively affected the oil and gas firms' stock prices, hence casting doubt on the overall positive effect of the CFTC's regulatory efforts. We will discuss selected events that triggered negative stock reactions in the oil and gas sector in order to evaluate this finding.

Of all the events, the most significant responses of the companies, of the overall industry returns and of the indices are to announcements number 10 (46 companies responded significantly), number 15 (42 companies responded significantly) and number 21 (50 companies responded significantly). The largest CARs occurred during these events. Hence, we examine these events and the sector's reaction in more detail.

[56]For example, event number 26 is simply the information that the CFTC will publish a new monthly report. An announcement like this should not affect the sector significantly. Our results show that in this case, the CAR is very close to zero and insignificant. However, we also included these types of announcements in our analysis for the sake of completeness.

Event number 10 contains the information that a broker has been fined $10 million by the CFTC due to manipulation of the natural gas market. The overall sector's CAR amounted to –5.66% (significant at the 1%-level), and almost all other indices responded negatively as well. A possible explanation for this finding is that the sector interpreted the CFTC's announcement as a warning signal and proof of its willingness to enforce severe sanctions in times of high (suspected) manipulation, but the majority of the firms might have considered the potential of benefiting from rising oil prices higher than the positive aspects of stable (less volatile) oil markets, even though the price increase might have been driven by speculation and manipulation.[57] In times of lower (assumed) manipulation, these types of announcements have fewer consequences, as seen for example in the weaker reactions towards announcements 30 and 35. Hence, our results indicate that severe punishments are perceived as signals against market manipulation in times of high (assumed) speculation, but lose their deterrent effect if speculation is not present in the energy sector at a given time.

Announcements number 15 and 21[58] both include the information that the sector will be subject to tighter regulation. The (significant) CARs amount to 5.52% and 10.01%, respectively. Both events took place closely around the peak of the financial crisis in 2008 and thus during a period of high (assumed) market manipulation. Again, this indicates that the CFTC's regulatory interventions have a strong positive impact during times of high manipulation, proving their regulatory efficiency. Regarding the results, the firms appear to appreciate the implementation of tighter regulation given rumors about severe market manipulation in the oil and gas sector.

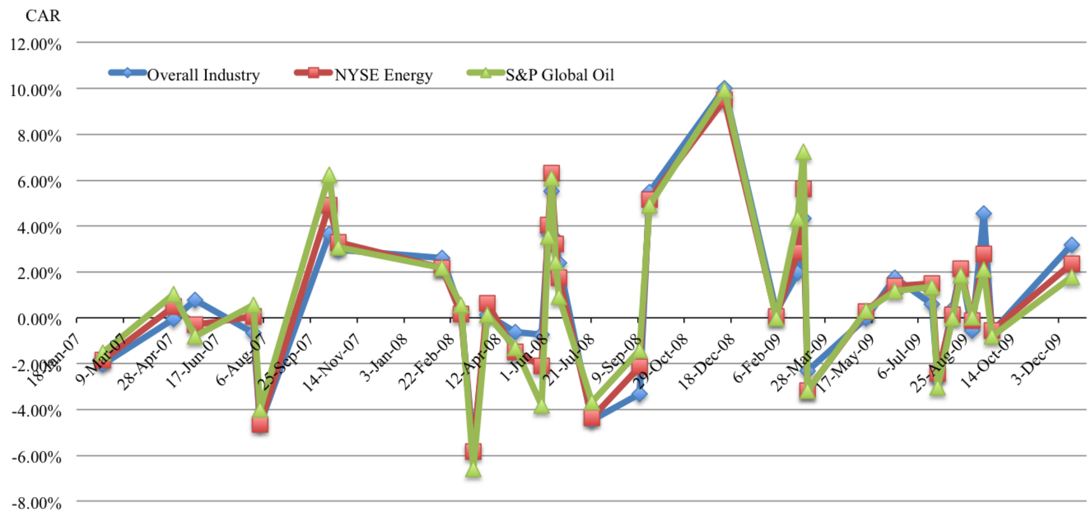
To further analyze the effects of the announcements, we plot the CARs for the overall index and the two biggest indices (NYSE Energy Index and S&P Global Oil Index). Figure 5.1 shows the curves during our observation period in chronological order. It can be seen that these curves tend to move together, even though they do not comprise identical companies. More importantly, one can see that the CARs (and thus the firm's reaction to the CFTC's announcements) are more pronounced around the financial crisis

[57] This explanation would be consistent with the negative, yet insignificant stock market reaction for event number 1, while the announcements of fines after the period of high-assumed speculation and manipulation (announcements 35 and 30) affect the stock prices positively. For instance, the sanctions against BP (announcement 7) triggered positive responses prior to the peak of the crisis, potentially owing to the large size of the fine (US$ 303).

[58] The effect of the announcement number 21 appeared to be relatively strong, as the announcement contained only the information that the CFTC is seeking for public support to expand its regulatory activities. In general, related literature indicates that these types of meetings can strongly affect the stock markets in case they contain relevant information on future regulatory activities, but might also be likely to just contain information of minor importance. To ensure that the stock response in our analysis is driven by the meeting and not by confounding events, we searched for oil and gas related events or news around the announcement day. We did not find major events or relevant news at the event date and the days surrounding the event day, hence finding evidence that the stock markets responses in our analysis are indeed driven by CFTC announcement number 21.

(and thus during times of high speculation). In particular, one can see strong positive reactions in particular between June 2008 and February 2009. Prior to this period, the reactions are less severe, hence, our results indicate, once more, that the CFTC's announcements have a greater effect on the stock returns during times of high market volatility.

FIGURE 5.1: CAR of Overall Industry, NYSE Energy Index and S&P Global Oil Index over all events



During the mentioned period, i.e., months covering the financial credit crunch, all but two announcements caused positive CARs. Only announcement numbers 18 and 19 lead to negative CARs. Hence, we examine possible reasons for their negative effects. Both announcements took place at the exact dates of two natural catastrophic events, namely Hurricane Dolly (on July 22, 2008) and Hurricane Ike (September 11, 2008) coinciding with events 18 and 19, respectively. The US oil market suffered directly from these hurricanes, which threatened the offshore fields in Gulf of Mexico.[59] Major companies that are operating in the region needed to evacuate their personnel and to shut down the rigs, which eventually caused a decline in the oil stocks. The output cut-off is followed by the decline in their revenues. Hence, both hurricanes affected negatively the oil related stocks in the USA.[60]

[59]For instance, according to the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), Hurricane Dolly caused 4.66% decline in the US oil production. Refer to the official website of the BOEMRE, formerly known as Mineral Management Service of the USA; http://www.boemre.gov.

[60]Given that the issue of confounding events is a general problem in the event study methodology (McWilliams and Siegel, 1997), the positive stock price reactions in our analysis might have also been caused by alternative events and not by the announcements. Hence, we carefully examined the oil market-related news during the event windows in our study. Even though we cannot rule out the possibility that some of these events affected the stock prices of oil firms, for most announcements we could not identify alternative events that would have direct positive effects on US oil related stocks. Hence, regarding the overall picture of our results, we conclude that CFTC announcements might indeed have positive effects on the stock prices of oil and gas firms, at least during the mentioned period.

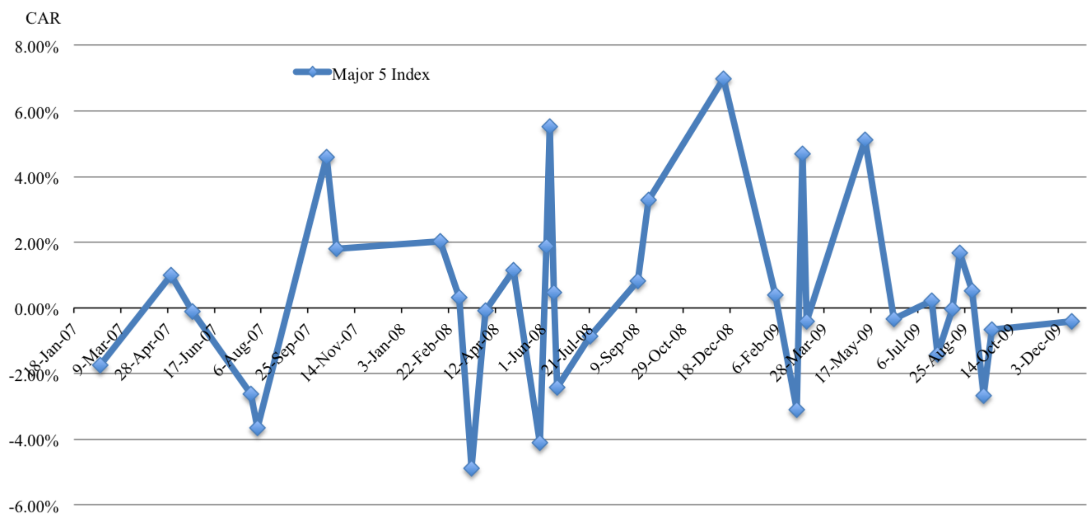
As described earlier, we extend our analysis to focus on the impact of CFTC announcements on the 5 biggest companies (Major 5 index) in our sample: BP, Chevron, Exxon, Shell and Total. Given the size of these companies as well as their importance for the global economy, a closer examination of these companies in addition to the overall sector will yield valuable information for shareholders, regulators and executives. The results of the event study for these 5 companies can be found in Table B.3.

The findings are mostly in line with the results from the previous analysis. Again, we find highly significant CARs for announcements number 10 and 21. In addition, we find a particularly strong reaction after announcement number 6 (content: "First International Commodity Market Manipulation Conference to be hosted by the CFTC"). This is interesting as the returns are significantly positive. We assume that the big companies regarded this announcement as positive news because their businesses are strongly related to the oil price. In the event that the CFTC announces measures against speculation, this may directly affect these firms' expected returns. Hence, even major companies appear to appreciate the CFTC's role as a regulator against market manipulation in times of high uncertainty and volatility, indicating its importance and effectiveness as a regulatory body.

Furthermore, we follow our previous analysis and plot the CAR for the Major 5 index to further analyze the effects of the announcements during our observation period in chronological order. The plots can be found in Figure 5.2. The results are once again comparable to the results for the overall sector. We find that the CARs (and thus the firms' reaction to the CFTC's announcements) are more distinctive during and before the financial crisis (and thus during times of high uncertainty). Similar to before, we see high CARs (positive and negative) in particular between June 2008 and February 2009. Consistent with the findings for the overall sector, the reactions are less severe prior to this period, but still more pronounced than after this period. Thus, we find evidence that the CFTC's announcements can affect the firms' stock returns more effectively during times of high volatility, indicating that the CFTC is able to reduce manipulation and speculation in the energy sector when the level of speculation and manipulation appears to be highest.

Moreover, Table B.5 provides insights for different reactions of companies with different geographical locations, i.e., North America based companies and Non-North America based companies. The results indicate that the firms from different regions react very similar to each other. In most cases, positive (negative) stock market reactions of North American companies are accompanied by positive (negative) stock market reactions of Non-North American companies. Furthermore, we find additional evidence for the significance of events number 10, 15 and 21 as these events trigger strong reactions for

Figure 5.2: CAR of Major 5 Index over all events



both types of firms (except the missing reaction of Non-North American based companies for event number 15). Similarly, the stock price reaction of the different subcategories of firms in the oil and gas sector (Upstream, Mid-downstream and Oil field service) confirm these findings. Table B.6 indicates a strong co-movement of the CARs for all industry subcategories, as most announcements either trigger positive or negative stock price reactions for all firms. Once again, we find that announcements number 10, 15 and 21 trigger particularly strong reactions for all firms, indicating that the firms follow a general, overall market trend after the announcements are made rather than exhibiting firm-specific reactions. Hence, the CFTC announcements lead to comparable effects for all types of firms in the oil and gas sector, irrespective of the firms' geographic location or industry subcategory.

Overall, our results indicate that the CFTC announcements are indeed associated with significant stock market responses of oil and gas-related firms. This finding also holds for several subsamples that we analyze in our study, i.e., the major 5 oil firms, North America based companies and Non-North America based companies and the different subcategories of firms in the oil and gas sector (Upstream, Mid-downstream and Oil field service). The direction of the effect is ambiguous, as some announcements trigger positive stock reactions while others lead to negative reactions. However, for the negative reactions, we find confounding events that might explain this unexpected reaction, while we could not find such alternative events for most events that triggered positive stock price reactions. Hence, our results indicate that the CFTC announcements might indeed affect the oil and gas companies' stock prices. In particular, this is the case for announcements during the peak of the financial crisis, hence indicating a strong regulatory influence in times of high speculation, market manipulation and market turmoil, which cause higher volatility in oil prices. Our results do not claim to prove that these announcements exclusively caused the stock price reactions but rather indicate at least a positive effect of the CFTC's regulatory interventions on the oil firms' stock prices.

5.4 Conclusions

We analyze the effects of the announcements of the Commodity Futures Trading Commission's (CFTC), the main regulatory authority in commodity futures market, on the stock returns of companies from the US oil and gas industry around the credit crunch period surrounding the financial crisis of 2008. Hence, we examine whether the CFTC is able to fulfill its purpose as a regulatory authority and affect the reaction of these firms in periods of high uncertainty in the oil market. We employ event study methodology in order to identify the effects of CFTC announcements on daily returns of oil related stocks listed in the NYSE for a set of 35 CFTC announcements and 122 companies.

The theoretical linkage between the CFTC announcements and oil related stocks should be reflected through the crude oil futures market. The CFTC's regulatory interventions are meant to decrease the riskiness of the crude oil futures market by suppressing the volatility through deterring the speculation and market manipulation. Moreover, decreasing riskiness would have profound effects on US oil and gas related stocks, as the investment decisions in stock markets are generally driven by the expectations and perceptions of the traders. Hence, the CFTC's regulatory announcements would have direct effects on the US oil and gas stock returns.

Our results indicate that CFTC announcements can in general affect the stock returns of oil and gas companies, depending on their content. We find significant abnormal returns for several CFTC announcements during our observation period. In particular, we find strong stock price responses for announcements that include highly relevant content (e.g., announcing tighter regulation in oil and gas markets) or high fines against speculators. The effects are stronger during the period of high volatility, which is caused by high-assumed speculation and market manipulation in the energy sector. We find particularly strong stock price reactions during the peak of credit crunch, i.e., Lehman Brothers failure. During this period most of the announcements have positive effects on the stock returns of oil and gas companies. Yet, during the same period, we also identified some negative stock reactions, which might be explained by alternative confounding events that took place simultaneously. Hence, our overall results could not prove that the CFTC's announcements exclusively caused positive stock price reactions, yet they at least indicate that the CFTC could reach to the stock markets as the regulatory authority in times of high uncertainty. In addition, we examine the effects of the CFTC announcements on several subsamples, i.e., the five major oil companies, companies based on different geographical locations and the different subcategories of firms in the oil and gas sector. The results are consistent with our prior findings, showing that the CFTC can also affect the individual companies' stock returns in times of high volatility.

One of the most important drawbacks of the event study analyses is the selection of the events. The events that are used in this study, i.e. the CFTC announcements, are heterogenous and, hence, their effects cannot be clearly anticipated. Moreover other sectoral confounding events can also affect the oil and gas related stocks. Although, the results of the current paper are useful to interpret the CFTC's regulatory effects, the work can be extended by analyzing these confounding events more clearly.

Appendix A

Supplementary Material for Chapter 3

Solution of the Model under Endogenous Energy Price

Suppose now that the energy is a non-renewable one. The non-arbitrage condition would then involve that the real price of energy must increase at the real interest rate:[61]

$$\hat{q} = r(t) \tag{A.1}$$

Equation A.1 is the well-known Hotelling's rule in its the simplest form. Now let us use this information in the model. One may recall that we obtained $\alpha\hat{K}_C - \alpha\hat{E} = \hat{q}$ from the equation 3.4b, $r = A - \delta + \hat{p}$ and $\hat{p} = (\alpha - 1)\hat{K}_C + (1 - \alpha)\hat{E}$ from equations 3.5 and 3.6. Therefore

$$\alpha \cdot \hat{K}_C - \alpha \cdot \hat{E} = \hat{q} = r = A - \delta + \hat{p} \Rightarrow$$

$$\alpha \cdot \hat{K}_C - \alpha \cdot \hat{E} = A - \delta(\alpha - 1)\hat{K}_C + (1 - \alpha)\hat{E} \Rightarrow$$

[61]Suppose that the energy market is a perfectly competitive one and that extraction is costless. Under these assumptions, the representative firm would solve the following maximization problem (cf., Gaitan et al., 2004, Yetkiner and van Zon, 2009):

$$\max \int_0^\infty q(t) \cdot E(t) \cdot e^{-\int_0^t r(\tau)d\tau} dt$$
$$\text{s.t.} \int_0^\infty E(t)dt \leq S_0$$
$$\lim_{t\to\infty} \{q(t) \cdot E(t) \cdot e^{-\int_0^t r(\tau)d\tau}\} = 0$$

where S_0 is the initial stock of the nonrenewable energy. The solution of the isoperimetric calculus of variations problem leads to the equation A.1.

$$\hat{K}_C = A - \delta + \hat{E}$$

If this information is used in equation 3.9, we obtain:

$$\frac{\dot{C}}{C} = \frac{1}{\theta} \cdot (A - \delta + \hat{p} - \rho) \Rightarrow$$

$$\frac{\dot{C}}{C} = \frac{1}{\theta} \cdot (A - \delta + (1 - \alpha)(\hat{E} - \hat{K}_C) - \rho) \Rightarrow$$

$$\frac{\dot{C}}{C} = \frac{1}{\theta} \cdot (\alpha(A - \delta) - \rho)$$

Hence,

$$\hat{p} = -(1 - \alpha)(A - \delta)$$

$$r = \hat{q} = \alpha(A - \delta)$$

$$\hat{E} = \frac{1}{\theta}[\alpha(A - \delta)(1 - \theta) - \rho] \equiv g'$$

$$\hat{K}_C = \frac{1}{\theta}[(A - \delta)(\theta + \alpha(1 - \theta)) - \rho] \equiv g$$

Interestingly, given that $A - \delta > 0$ for a positive real interest rate and energy price growth rate, θ must be less than one. Otherwise, energy demand would be decreasing in time. As, $\theta + \alpha(1 - \theta)$ is always true, growth rate of physical stock employed in consumption good sector is positive as long as $(A - \delta)(\theta + \alpha(1 - \theta) > \rho$.

Appendix B

Supplementary Material for Chapter 5

Table B.1: Description of CFTC announcements

CFTC event	calender_day	Number	Title
1	15-Feb-07	PR5292-07	United States Commodity Futures Trading Commission Settles Action Charging NRG Energy Inc. with Falsely Reporting Natural Gas Trades
2	2-May-07	pr5287-07	CFTC's Office of the Chief Economist Releases Study on "Market Growth, Trader Participation and Pricing in Energy Futures Markets"
3	25-May-07	pr5339-07	CFTC Grants Relief to NYMEX in Connection with Clearing Contracts Traded on the Dubai Mercantile Exchange Trading System to be avail. in U.S.
4	26-Jul-07	PR5360-07	U.S. CFTC Alleges that Energy Transfer Partners and Its Subsidiaries Used the Intercontinental Exc. in attempted manipulation of Nat. Gas Market
5	2-Aug-07	pr5368-07	CFTC Announces September Hearing to Examine Trading on Regulated Exchanges and Exempt Commercial Markets
6	15-Oct-07	pr5400-07	First International Commodity Market Manipulation Conference to be Hosted by the CFTC
7	25-Oct-07	PR5405-07	BP Agrees to Pay a Total of $303 Million in Sanctions to Settle Charges of Manipulation and Attempted Manipulation in the Propane Market
8	13-Feb-08	PR5455-08	CFTC Establishes New Energy Markets Advisory Committee
9	4-Mar-08	PR5463-08	CFTC Approves Program Designed to Allow for Increased Capital Efficiency and Transparency
10	17-Mar-08	PR5471-08	Energy Transfer Partners and Its Subsidiaries to Pay a $10 M. Penalty to Settle CFTC Action Alleging Attempted Manipulation of Nat. Gas Prices
11	1-Apr-08	PR5477-08	CFTC Seeks Public Comment on NYMEX Exemption Request Involving Three New Contracts to be Traded on the Dubai Mercantile Exchange
12	1-May-08	PR5495-08	CFTC Grants Exemption to NYMEX in Connection with Three New Contracts to be Traded on the Dubai Mercantile Exchange
13	29-May-08	PR5503-08	CFTC Announces Multiple Energy Market Initiatives
14	5-Jun-08	PR5506-08	U.S. Commodity Futures Trading Commission Hosts International Energy Market Manipulation Conference
15	9-Jun-08	PR5507-08	CFTC Committee to Discuss Energy Markets
16	13-Jun-08	PR5509-08	U.S. Commodity Futures Trading Commission Held its Second International Manipulation Enforcement Conference, June 11-12, 2008
17	17-Jun-08	PR5511-08	CFTC Conditions Foreign Access on Adoption of Position Limits on London Crude Oil Contract
18	22-Jul-08	PR5520-08	Interagency Task Force on Commodity Markets Releases Interim Report on Crude Oil
19	11-Sep-08	PR5542-08	CFTC Releases Staff Report on Swap Dealers and Index Traders
20	22-Sep-08	PR5553-08	CFTC Statement Regarding Today's Trading in Crude Oil
21	11-Dec-08	PR5581-08	CFTC Seeks Public Comment on Proposed Rules to Expand Regulatory Authority Over Exempt Commercial Markets
22	4-Feb-09	PR5607-09	CFTC Launches New Monthly Report
23	27-Feb-09	CFTC Statement	CFTC Enforcement Statement Regarding Trading in Crude Oil and the Roll by United States Oil Fund on February 6, 2009
24	5-Mar-09	PR5627-09	CFTC and FSA Welcome IOSCO Proposals to Boost Regulation of Commodity Futures Markets
25	10-Mar-09	PR5630-09	Commissioner Bart Chilton appointed to Chair CFTC's Energy Markets Advisory Committee
26	11-May-09	RY051109	CFTC's Energy and Environmental Advisory Committee to Meet on May 13, 2009
27	11-Jun-09	RY061109	Green CAT Markets to be Largest in World Regulatory Reforms Also Needed, Chilton Says
28	21-Jul-09	PR5681-09	CFTC to Hold Three Open Hearings to Discuss Energy Position Limits and Hedge Exemptions
29	27-Jul-09	PR5683-09	CFTC Exercises Authority to Apply Regulations to Exempt Commercial Markets with Significant Price Discovery Contracts
30	12-Aug-09	PR5692-09	Amaranth Entities Ordered to Pay a $7.5 Million Civil Fine in CFTC Action Alleging Attempted Manipulation of Natural Gas Futures Prices
31	20-Aug-09	PR5698-09	CFTC and Financial Services Authority to Enhance Regulatory Cooperation and Cross-Border Surveillance of Oil Markets
32	2-Sep-09	PR5710-09	CFTC Implements New Transparency Efforts to Promote Market Integrity
33	14-Sep-09	PR5716-09	CFTC Advisory Committee to Discuss Energy and Environmental Markets
34	23-Sep-09	PR5720-09	Gensler Addresses International Energy Agency in Paris
35	17-Dec-09	PR5763-09	CFTC Sanctions MF Global Inc. $10 Million for Significant Supervision Violations between 2003 and 2008

TABLE B.2: CAR of Overall Industry and All Indices

Event Number	Overall Industry CAR	NYSE Energy CAR	S&P Global Oil CAR	Dow Jones Oil & Gas CAR	NYSE ARCA Oil CAR	NYSE ARCA Nat. Gas CAR	PHLX Oil Service CAR	SIG Oil CAR	# of sign. comp.
1	-2.01%	-1.83%	-1.53%	-1.70%	-1.56%	-0.98%	-3.15%	-1.13%	5
2	-0.05%	0.50%	1.03%	0.17%	0.60%	0.39%	0.41%	0.49%	3
3	0.77%	-0.30%	-0.82%	1.50%	1.30%	0.18%	1.67%	-4.96%	5
4	-0.66%	0.07%	0.56%	0.58%	-1.59%	-0.84%	2.42%	0.98%	16
5	-4.65%***	-4.63%*	-3.99%	-4.44%	-5.14%*	-1.04%	-5.25%	-2.43%	37
6	3.65%***	4.92%**	6.25%**	2.49%	3.87%	3.39%	0.46%	4.28%	18
7	2.98%***	3.28%	3.07%	2.63%	3.30%	3.13%	1.21%	4.25%	20
8	2.60%***	2.18%	2.18%	1.78%	1.45%	2.28%	3.01%	1.90%	9
9	0.30%	0.18%	0.57%	0.77%	0.14%	0.98%	1.22%	0.07%	6
10	-5.66%***	-5.84%***	-6.60%***	-4.98%**	-7.53%***	-5.63%**	-4.15%	-5.36%**	46
11	0.14%	0.62%	0.13%	0.15%	-0.56%	-1.27%	0.49%	-0.68%	10
12	-0.63%	-1.50%	-1.31%	-2.68%	0.29%	-1.88%	-2.84%	-1.92%	16
13	-0.72%	-2.08%	-3.82%	-0.87%	-1.95%	-1.63%	-4.23%	-0.98%	16
14	3.73%***	4.04%	3.53%	4.55%	1.46%	5.33%**	4.61%	5.96%*	25
15	5.52%***	6.29%**	6.08%**	6.54%**	6.22%**	6.67%**	6.17%*	8.42%***	42
16	3.43%***	3.23%	2.41%	3.40%	2.39%	2.42%	2.54%	3.69%	6
17	2.38%**	1.74%	0.91%	1.23%	-1.37%	-0.12%	2.25%	0.58%	7
18	-4.45%***	-4.37%	-3.69%	-4.52%	-2.41%	-5.77%*	-3.08%	-6.35%*	22
19	-3.31%**	-2.15%	-1.43%	-2.12%	-0.39%	-2.12%	-0.62%	-3.12%	15
20	5.46%***	5.17%	4.91%	3.89%	4.71%	3.56%	3.35%	5.13%	20
21	10.01%***	9.49%**	9.93%**	9.98%**	10.36%**	9.02%*	12.77%**	9.98%*	50
22	0.26%	0.07%	-0.02%	-0.37%	-0.68%	0.44%	1.10%	-0.71%	7
23	1.96%	2.86%	4.33%	4.02%	3.25%	4.89%	4.94%	5.64%	16
24	4.33%*	5.61%	7.23%	8.08%	6.59%	5.67%	5.30%	7.24%	27
25	-2.30%	-3.17%	-3.16%	-2.69%	-2.69%	-5.53%	-3.64%	-4.99%	9
26	-0.01%	0.26%	0.30%	-0.43%	1.99%	-1.62%	-0.73%	-2.28%	2
27	1.74%	1.37%	1.17%	2.07%	0.42%	2.92%	2.75%	2.65%	
28	0.59%	1.50%	1.34%	1.67%	0.22%	0.54%	1.15%	2.17%	1
29	-2.68%	-2.42%	-3.01%	-2.06%	-2.97%	-3.42%	-3.62%	-2.63%	
30	0.39%	0.14%	0.00%	0.37%	-0.07%	0.77%	0.44%	0.97%	3
31	2.14%	2.14%	1.87%	2.37%	1.70%	1.15%	3.88%	1.05%	
32	-0.54%	-0.14%	0.01%	-0.17%	0.30%	-1.34%	0.37%	-1.62%	
33	4.56%**	2.80%	2.11%	3.38%	-0.33%	3.65%	3.73%	5.81%	1
34	-0.64%	-0.55%	-0.81%	-0.92%	-0.22%	-1.10%	-0.84%	-0.97%	
35	3.17%*	2.36%	1.78%	3.16%	0.57%	4.03%	3.00%	5.24%	1

Notes: ***,**,* represent significance at 1%, 5% and 10% levels, respectively

Table B.3: CAR of Major 5 Index

Event Number	BP	Chevron	Exxon	Shell	Total
1	-1.46%	-4.90%*	-1.72%	-2.44%	1.37%
2	0.80%	0.54%	-0.72%	2.33%	1.58%
3	-1.00%	-0.61%	0.85%	-0.97%	0.20%
4	-2.01%	-3.14%	-4.17%*	-2.84%	-0.77%
5	-2.84%	-5.27%**	-2.92%	-2.39%	-4.75%**
6	7.49%***	2.43%	3.27%	4.87%**	5.63%***
7	3.76%*	1.86%	-0.25%	3.63%*	0.29%
8	0.74%	3.34%	2.38%	1.77%	1.50%
9	0.36%	3.37%	-0.58%	-2.04%	0.05%
10	-8.62%***	-5.23%**	-1.29%	-5.46%**	-4.87%*
11	0.01%	-0.10%	-1.78%	1.06%	0.68%
12	4.20%*	1.98%	-4.62%**	3.90%	1.46%
13	-6.13%**	-2.57%	-4.52%**	-3.70%	-4.16%
14	0.72%	3.04%	2.85%	2.05%	0.27%
15	5.79%**	6.01%*	6.14%*	5.62%**	4.03%
16	1.91%	1.57%	0.93%	0.22%	-2.38%
17	-2.88%	-1.93%	-2.04%	-3.40%	-2.09%
18	-0.73%	-4.38%*	0.90%	0.07%	0.18%
19	-0.48%	3.54%	0.64%	0.56%	-0.94%
20	2.44%	4.09%	1.17%	6.09%*	3.00%
21	8.26%*	4.79%	4.72%	9.24%**	10.38%**
22	1.80%	-0.49%	-1.14%	-0.67%	3.60%
23	-5.51%	-1.08%	-1.25%	-7.87%	-2.01%
24	6.27%	4.29%	2.24%	6.11%	6.41%
25	0.23%	-0.15%	-3.17%	1.24%	0.83%
26	3.61%	3.69%	5.00%	6.08%	7.37%
27	-1.28%	3.57%	0.74%	-2.80%	-3.44%
28	-0.37%	0.24%	0.50%	-0.69%	1.01%
29	-2.47%	-0.90%	-0.52%	0.33%	-3.96%
30	-0.77%	-0.60%	-1.47%	2.30%	0.84%
31	0.59%	0.93%	2.19%	1.26%	3.17%
32	3.35%	-1.42%	-0.53%	1.12%	0.87%
33	-4.24%	-1.04%	-3.87%	-2.54%	-2.09%
34	-1.32%	-0.47%	0.02%	0.50%	-2.27%
35	0.66%	0.42%	-1.51%	-0.87%	-0.83%

Notes: ***,**,* represent significance at 1%, 5% and 10% levels, respectively

TABLE B.4: Robustness: Different Event Windows

	Event Window [-2 ; +2]		Event Window [-2 ; +4]		Event Window [-4 ; +2]		Event Window [-4 ; +4]		Event Window [-6 ; +2]	
Event Number	Industry CAR	# sig. comp.	Industry CAR	# sig. comp.	Industry CAR	# sig. comp.	Industry CAR	# sig. comp.	Industry CAR	# sig. comp.
1	-0.0201	5	0.0014	3	-0.0192	5	0.0023	2	-0.019	3
2	-0.0005	3	-0.0018	5	0.0036	3	0.0023	3	0.0108	2
3	0.0077	5	0.0149	4	0.0143	6	0.0215*	8	0.0342***	8
4	-0.0066	16	-0.0066	13	-0.0076	13	-0.0076	14	0.0109	14
5	-0.0465***	37	-0.031***	27	-0.0458***	29	-0.0303***	27	-0.0422***	34
6	0.0365***	18	0.0335***	20	0.0512***	28	0.0481***	24	0.0414***	12
7	0.0298***	20	0.0314***	19	0.011	12	0.0126	13	0.021**	13
8	0.026***	9	0.0624***	35	0.0556***	25	0.092***	48	0.0419***	16
9	0.003	6	-0.0082	10	0.0131	19	0.0019	16	0.0356***	26
10	-0.0566***	46	-0.074***	59	-0.0569***	36	-0.0743***	55	-0.0684***	34
11	0.0014	10	0.0152*	12	0.0303***	17	0.0441***	17	0.0542***	28
12	-0.0063	16	0.0198**	18	0.0087	13	0.0348***	19	-0.0314***	21
13	-0.0072	16	-0.0259**	23	-0.024**	14	-0.0426***	27	0.0081	12
14	0.0373***	25	0.0358***	17	0.0688***	35	0.0673***	26	0.0582***	22
15	0.0552***	42	0.0293***	13	0.0368***	17	0.0108	9	0.0686***	26
16	0.0343***	6	0.026**	8	0.0237**	5	0.0154	6	0.0684***	27
17	0.0238**	7	0.0669***	29	0.0263**	7	0.0694***	22	0.0159	6
18	-0.0445***	22	-0.0244**	7	-0.1279***	73	-0.1079***	55	-0.1381***	71
19	-0.0331**	15	-0.0165	20	-0.0766***	29	-0.06***	26	-0.0895***	33
20	0.0546***	20	0.0253*	7	0.0718***	26	0.0425***	12	0.0679***	17
21	0.1001***	50	0.0968***	29	0.104***	39	0.1006***	25	0.0206	13
22	0.0026	7	0.0195	6	0.0199	7	0.0368	6	0.0026	9
23	0.0196	16	0.0458*	24	0.0001	11	0.0262	16	0.0012	11
24	0.0433*	27	0.0099	15	0.0189	19	-0.0144	12	0.052**	28
25	-0.023	9	-0.0225	6	0.0033	11	0.0038	11	-0.0214	13
26	-0.0001	2	-0.0149	2	0.0064	4	-0.0084	5	0.0572**	9
27	0.0174	0	-0.014	0	0.0055	0	-0.0259	1	-0.0106	2
28	0.0059	1	0.0159	1	0.006	1	0.016	1	0.0091	0
29	-0.0268	0	-0.0097	1	-0.0331	3	-0.0161	2	-0.0244	2
30	0.0039	3	0.0063	1	-0.0152	2	-0.0129	1	-0.0252	2
31	0.0214	0	-0.0011	0	0.0076	0	-0.0149	0	0.0149	0
32	-0.0054	0	0.014	0	-0.0123	0	0.0071	0	-0.0361*	0
33	0.0456**	1	0.0317	2	0.0652***	3	0.0513**	2	0.0696***	2
34	-0.0064	0	-0.0071	0	-0.0211	0	-0.0217	0	0.0025	0
35	0.0317*	1	0.0389**	1	0.043***	7	0.0502***	10	0.0376**	6

Notes: ***,**,* represent significance at 1%, 5% and 10% levels, respectively

Table B.5: Geographical Classification

Event Number	North American CAR	non-North American CAR
1	-0.0163	-0.021
2	0.0027	0.0189
3	-0.0016	-0.0076
4	0.0002	0.0017
5	-0.0459*	-0.043**
6	0.022	0.1628***
7	0.0302	0.038*
8	0.0215	0.0197
9	0.0065	-0.0103
10	**-0.0494****	**-0.1077*****
11	0.0024	0.0188
12	-0.0196	0.0137
13	-0.0122	-0.0594*
14	0.0476*	0.0001
15	**0.0665****	**0.0326**
16	0.0345	0.0107
17	0.0179	0.014
18	-0.0473	-0.0207
19	-0.0198	-0.0224
20	0.0447	0.0748*
21	**0.0932***	**0.0991***
22	-0.0018	0.0268
23	0.037	-0.0055
24	0.0551	0.0561
25	-0.0353	-0.0207
26	-0.0069	0.0346
27	0.0215	-0.0141
28	0.0129	0.0141
29	-0.0216	-0.0379
30	0.0035	-0.0113
31	0.0225	0.0089
32	-0.0052	0.0137
33	0.037	-0.016
34	-0.0048	-0.009
35	0.0346	-0.0305

Notes: ***,**,* represent significance at 1%, 5% and 10% levels, respectively

TABLE B.6: Industry Subcategories: Response of Different Business Segments

Event Number	Upstream CAR	Mid-downstream CAR	Oil field service CAR
1	-0.0155	-0.0014	-0.0233
2	0.0137	-0.0031	0.0005
3	0.0038	-0.0634	0.0132
4	0.0009	-0.0187	0.0223
5	-0.0365	-0.0554**	-0.0536
6	0.082***	0.0026	0.0043
7	0.0406	0.0318	0.0225
8	0.0225	0.0022	0.0333
9	-0.0014	0.001	0.0058
10	**-0.0634****	**-0.0513****	**-0.0401**
11	-0.0008	0.0103	0.0152
12	-0.0183	-0.0027	-0.0271
13	-0.0016	0.0036	-0.0222
14	0.0472	0.0007	0.0571*
15	**0.076****	**0.0182**	**0.0613****
16	0.0404	0.0202	0.0323
17	0.0173	0.0189	0.0277
18	-0.0629*	-0.0421*	-0.0339
19	-0.0381	-0.0066	-0.0099
20	0.0748*	0.0199	0.024
21	**0.0983***	**0.0865****	**0.0936***
22	-0.0014	0.0177	-0.002
23	0.0276	0.0351	0.0396
24	0.0596	0.0284	0.0662
25	-0.0426	-0.0384	-0.0247
26	0.0043	-0.0197	-0.0088
27	0.0166	0.0145	0.0226
28	0.0259	0.0053	0.0004
29	-0.0218	-0.021	-0.0318
30	0.0014	-0.0045	0.0001
31	0.0103	0.0139	0.039
32	-0.0153	0.0000	0.0118
33	0.0376	0.0146	0.0364
34	-0.0089	-0.0027	-0.0018
35	0.0330	-0.0015	0.0366

Notes: ***,**,* represent significance at 1%, 5% and 10% levels, respectively

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2010 – 2011	Executive Secretary, Scientific Research Projects, Izmir University of Economics, Izmir, Turkey.

Publications

Publications in Journals covered by SCI, SSCI and AHCI

2014	Ediger, V.Ş., Berk, I., Kösebalaban, A. Lignite Resources of Turkey: Geology, Reserves and Exploration. International Journal of Coal Geology, 132, 13–22.
2014	Berk, I., Yetkiner, I.H. Energy Prices and Economic Growth: Theory and Evidence in the Long Run. Renewable and Sustainable Energy Reviews, 36, 228–235.
2011	Ediger, V.Ş., Berk, I. Crude oil import policy of Turkey: Historical analysis of determinants and implications since 1968. Energy Policy, 39 (4), 2132–2142

Book Chapters

2008	Berk, I., Erdil, E., Yetkiner, I.H. The Competitive Power of Turkeys Downstream Petroleum Industry Relative to EU. in: Bekmez, S., ed., Turkey-European Union Industrial Competitiveness Analyses, Nobel Yayinevi, 357–382 (in Turkish)

Working Papers

2014	Berk, I. Two Period Resource Duopoly with Endogenous Intertemporal Capacity Constraints. EWI Working Paper Series No. 14/13
2012	Berk, I., Aydogan, B. Crude Oil Price Shocks and Stock Returns: Evidence from Turkish Stock Market under Global Liquidity Conditions. EWI Working Paper Series No. 12/15

Selected Conference Presentations

July & September 2014	Two Period Resource Duopoly with Endogenous Intertemporal Capacity Constraints. PhD students Workshop in Economics, Braga & Workshop on Behavioral Economics and Industrial Organization, Budapest.
October 2013	Reserve Growth Investments and Oil Market Structure: Two Period Resource Duopoly with Endogenous Intertemporal Capacity Constraints. Young Energy Economists and Engineers Seminar, Stockholm.
August 2013	Energy Prices and Economic Growth in the Long Run: Theory and Evidence. 13th IAEE European Conference, Düsseldorf.

Languages

Turkish	Native Speaker
English	Fluent
German	Intermediate