Oil Prices, Volatility, and Shocks: A Survey

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Abstract This paper surveys the literature on the economic effects of oil market developments. It assesses the economic theory behind oil price impacts and presents how the existing literature has analysed the link between oil markets—oil prices, oil price shocks, and oil price volatility—and economic outcomes. This review documents the general consensus amongst economists that the significance of moderate oil price movements is low if not inexistent, with clear impacts only present on financial markets. However, the evidence for significant macroeconomic effects of energy price shocks is strong, although methodological challenges such as causality and endogeneity remain an issue.

Keywords Oil price · Oil price shocks · Oil price volatility

1 Introduction

In the last decade, the oil price has returned to the political agenda. Against the background of price hikes and strong price volatility, international fora such as the energy consumer organization International Energy Agency (IEA), the producer-consumer-dialogue organization International Energy Forum (IEF) as well as G8 and G20 have been dealing intensively with oil market issues. Due to growing evidence that trading activities may foster significant oil price volatility, energy policy makers around the globe have been discussing whether and how stricter oil market regulation can limit excessive oil price fluctuations.

The implicit assumption underlying the policy makers' strong efforts is the economic significance of oil prices and their variations. To put it in simple terms: Oil prices are the focus of global policy because of their economic importance. In this context and in the public debate in general, the emotional scientific dispute on

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the economic significance of oil prices has been ignored, however. Few economic questions have been tackled empirically with such a variety of approaches regarding measurement as well as period, region or market of analysis, leading to numerous research articles, comments and replies—and to very different results with regard to the estimated economic relevance of the oil price.

This paper surveys the broad literature available in the field. It assesses the economic reasoning behind oil price impacts and presents how the existing literature has analyzed the relationship between oil market developments and economic outcomes. *Oil price shocks* and *oil price volatility* are the buzzwords with regard to such energy market developments. Definitions and measurement approaches of those phenomena are presented in the paper. The focus on the economic side of the *oil to macroeconomy-relationship* has been given to standard macroeconomic indicators such as production, GDP and (un-) employment, as well as to financial market developments.

The remainder of the paper is structured as follows: Sect. 2 presents popular definitions of oil market—price, price shock and volatility—measures. Section 3 summarizes the theoretical background as well as empirical findings regarding the oil-to-macroeconomy relationship, while Sect. 4 tackles theoretical and empirical findings regarding the role of the oil price in financial markets. Section 5 concludes.

2 Oil Market Measures

2.1 Oil Prices and Oil Price Shocks

Previous literature has noted that the nature of the movements of oil prices must be adequately addressed in order to accurately measure the economic effects of these prices (e.g., Löschel and Oberndorfer 2009). In his pioneering work on the oil-to-macroeconomy relationship, Hamilton (1983) makes use of an *oil price series in 1st differences*.[1] This approach is still common today, often in a log-differenced form in order to avoid non-stationarity problems by differencing and to receive easily interpretable estimation results (elasticities) by using logs. This series is constructed as

$$dloil_t = \log(oil_t) - \log(oil_{t-1}). \tag{1}$$

Here, the price of oil at time t is denoted oil_t.[2] In the search for more adequate and economically relevant oil price measures, Mork (1989) introduces the use of an *asymmetric oil price variable* that is defined as

[1] For the analysis of certain periods Hamilton (1983) makes use of detrended oil price change variables.

[2] Most authors use real oil prices, i.e., deflated nominal oil prices, in their analyses. In this sense, I refer to oil_t as a real oil price series throughout this paper.

$$dloilpos_t = max(0, \log(oil_t) - \log(oil_{t-1})). \tag{2}$$

$dloilpos_t$ gives the value of 0 if the oil price has decreased at time t compared to $t-1$. In contrast, if the oil price increased within this period, $dloilpos_t$ gives the first differenced logged oil price series ($dloil_t$).

Hamilton (1996) proposes the *net oil price increase* (*nopi*) as a further definition of an oil price variable. It compares the current price of oil with the maximum value of the previous year rather than its value at $t - 1$ (i.e., at the previous quarter, month, etc.) alone. If the current value of the oil price exceeds the previous year's maximum, the value of $nopi_t$ is assigned to the change of the current value over the previous year's maximum. If the price of oil at the current point in time is lower than it had been at any point during the previous year, the series is assigned the value of zero.

$$nopi_t = max(0,\ \log(oil_t) - max(\log(oil_{t-1}), \log(oil_{t-2}), \ldots, \log(oil_{t-m}))), \tag{3}$$

m gives the number of observed periods per year (i.e., in case of quarterly data, $m = 4$, in case of monthly data, $m = 12$).

In the following, these three oil price variables are presented in real terms on a monthly basis for the period 10/1973–01/2008. They give the oil price variables from a German perspective, with the oil import cost data published by the EIA deflated using the German consumer price index, and converted to domestic currency using exchange rates from the time series database of Deutsche Bundesbank (German Central Bank; based on data from the German Federal Statistical Office). The graphs (Figs. 1−3) are based on the dataset used by Löschel and Oberndorfer (2009).

The graphs illustrate the measurement differences between the three oil price variables. Both the oil price increase and the net oil price increase exclude oil price decreases. In particular, the net oil price increase series, takes the value of 0 for many points in time.

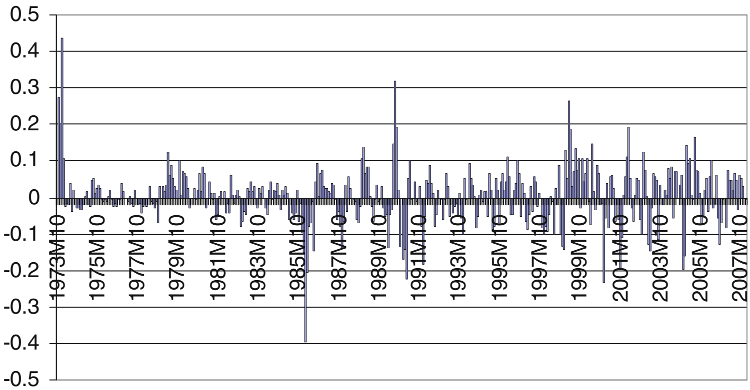

Fig. 1 Oil price change (dloil)

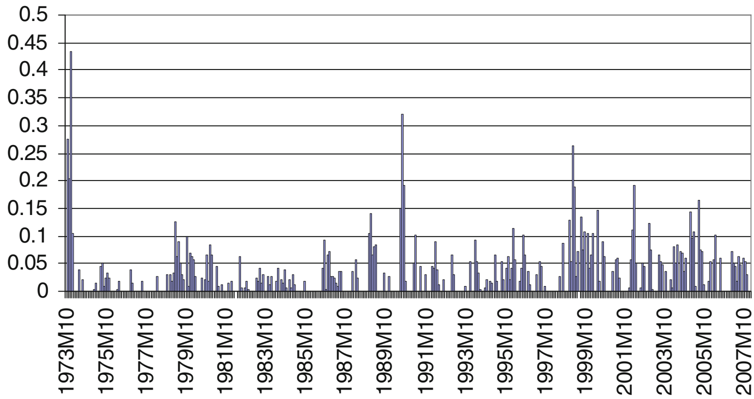

Fig. 2 Oil price increase (dloilpos)

The notion of oil price shocks is not very well defined. It is obvious though that a simple oil price change series includes all price changes in the sample period, whether or not they are shocks. If—as often argued—the economic effect of the oil price varies, depending on whether the oil price is rising or falling, or whether it is changing moderately or substantially in a shock-like manner, the inclusion of a simple oil price change series in an empirical analysis may not accurately reflect the effects of an oil shock.

As the term of a price shock is associated with the idea of rising prices, the definition of the asymmetric oil price increase variable comes closer to the phenomenon of an oil price shock. Finally, the net oil price increase may be the natural empirical implementation of the oil price shock idea, although seen rather arbitrary by some scholars. Only shock-like oil price increases, defined as one-year highs, are considered. Accordingly, Hooker (1996) criticises *nopi* definitions as being ad hoc,

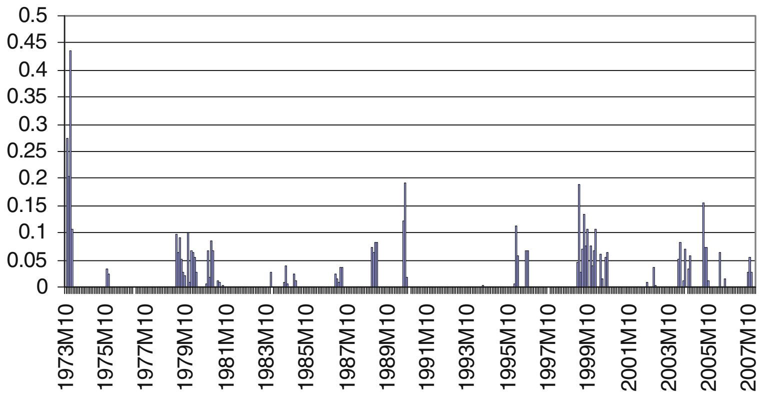

Fig. 3 Net oil index increase (nopi)

although he admits being “sympathetic to the argument that oil price increases which cancel out recent decreases have different effects than those which occur in a relatively stable environment”.

2.2 Oil Price Volatility

The standard measure of oil price volatility at time (period) t, denoted as $oilvol_t$, is the estimation of the *standard deviation of the oil price* in a given period (cp., e.g., Ferderer 1996).

$$oilvol_t = \left[(1/(n-1)) \sum_{p=1}^{q} \left(oil_{t,p} - \mu_t \right)^2 \right]^{0.5}, \tag{4}$$

Here, μ_t is the mean of the oil price $oil_{t,p}$ in time (period) t. n gives the number of observations. t can be divided into subperiods from $p = 1$ to q, i.e., $\mu_t = (1/q) \sum_{p=1}^{q} oil_{t,p}$. E.g., in case $oilvol_t$ refers to monthly oil price volatility as in Ferderer’s (1996) analysis, $oil_{t,p}$ could give daily oil prices. In this case, $oil_{t,q}$ would refer to the oil price on last day q of the month t.

However, this standard estimation approach not only requires values for the oil price to be available for period t (i.e., oil_t), but also for shorter subperiods p (i.e., $oil_{t,p}$). Depending on the choice of period and subperiod, this may prove to be difficult, i.e., if period t represents days/daily observations. In such a case, it is not possible to estimate the standard deviation unless intraday prices are available.

In order to cope with this data challenge, Oberndorfer (2009a) uses *squared oil price changes* as an oil price volatility proxy variable.

$$oilsp_t = \left(oil_t - oil_{t-1} \right)^2. \tag{5}$$

Squared price changes can be seen as good indicators of market volatility as they give the deviation of the changes of the respective price from its mean (which is often 0). However, volatility terms defined as squared changes, such as $oilsp_t$, are positive by definition and therefore often exhibit highly significant positive means. This means that these volatility variables do not indicate volatility surprises (or unexpected volatility), i.e., volatility innovation, and they can be predicted to a certain extent.[3]

This may be problematic in financial market analyses: If capital markets work efficiently, only innovations, i.e., unexpected movements of selected systematic variables, can affect them. The use of these volatility variables that at least partly

[3] This is illustrated by the success of estimators of the ARCH-class (cp., e.g., Engle 2001) that model volatility by dynamic processes.

represent expected volatility could therefore induce an errors-in-variables problem in financial market analyses (Chen et al. 1986).

In order to cope with this problem, Oberndorfer (2009a) additionally proposes using errors of AR(K) processes of squared oil price changes as *oil volatility innovations* ($oilvi_t$). This is done by estimating an AR(K) model for the squared oil price change series.

$$oilsp_t = a + \sum_{k=1}^{K} b_k oilsp_{t-k} + e_t. \tag{6}$$

e_t is the noise disturbance with zero mean and variance v_t^2. a and the b_k, besides v_t^2 are the unknown parameters that have to be estimated by OLS. The lag lengths (K) of the respective regressions can be determined according to information criteria such as the Bayesian Schwarz Information Criterion. e_t is the estimated error term of the model and therefore the oil volatility innovation that can be used as an explanatory variable within a regression analysis.

$$oilvi_t = e_t.$$

According to Pagan (1984), the use of current levels of "generated regressors" such as $oilvi_t$ within a two-step analysis should yield consistent and efficient estimates in an empirical analysis.

3 Oil Prices and the Macroeconomy

3.1 Theoretical Background

The theory on the macroeconomic role of oil prices is complex. Numerous channels have been proposed and several survey articles exist. This section can only briefly summarize the main channels of the oil-to-macroeconomy-relationship. An excellent and extensive review is provided by Brown and Yücel (2002); I would like to refer the interested reader to that manuscript for further information and references. If not designated otherwise, the argumentation in this subsection is based on Brown and Yücel (2002).

The traditional and most common explanation for macroeconomic oil price impacts is the *supply-side effect*. It describes rising oil prices as an indicator of the reduced availability of a basic input—oil—for production (e.g., Brown and Yücel 2000). As a consequence of this increased scarcity, prices rise in general, creating inflationary pressure. Moreover, the growth of output and productivity are slowed down. The decline in productivity growth lessens real wage growth, and increases unemployment. Negative effects can be expected to be stronger if wages are nominally sticky downward and therefore cannot fully adjust. Consumption smoothing on behalf of the consumers—decreased savings, increased borrowings—together with lower output growth, may increase the real interest rate and, consequently, the inflation rate. This effect can add to the direct inflationary impact of rising oil prices. Thus, the supply-side effect is the best explanation for a double negative macroeconomic effect of rising oil prices: slowed economic growth and increasing inflation. *The real balance effec*t is in some way related to the aspect of consumption smoothing, suggesting that an oil price rise increases the demand for money, leading to higher interest rates and, consequently, to lower GDP growth. Additionally, the *income transfer channel* describes the shift in purchasing power from oil importing countries to oil exporting countries when oil prices rise. A reduction in demand for goods produced in oil-importing countries can be the net effects.

Going beyond these simple mechanisms, at least four channels suggest oil prices have an *asymmetric effect* on the economy. Accordingly, whereas oil price rises would harm the economy, comparable oil price decreases would not (fully) compensate for those effects, respectively. Firstly, it is argued that monetary policy that fails to hold GDP constant can constitute such a channel if wages are nominally sticky downward. Secondly, adjustment costs that occur within a sectoral shift in the economic production or structure in general from energy-intensive to energy-extensive sectors can play a role in this respect. Thirdly, asymmetric cost pass-through in the oil-intensive production chain can be responsible or such asymmetric effects. Finally, authors like Hamilton (1996) argue that historical oil crises have been characterized by widespread *concern about the price and availability of energy*, potentially causing irreversible investment decisions to be postponed in case of oil price appreciations. This argument is referred to and is particularly relevant in cases where the oil prices rise significantly, i.e., in so-called oil shock situations (see also previous section). A similar channel is put forward by Bernanke (1983), who argues that investment will be postponed in a situation of oil price increases as firms attempt to find out whether or not the observed price rise is permanent.

Similarly, Sauter and Awerbuch (2003) argue that since the 1980s *oil price volatility* has had a more significant effect on economic activity than the oil price level. In their assessment, however, no clear definitory distinction is made between notions such as oil price volatility, oil price increases and oil price shocks. However, Sauter and Awerbuch's (2003) claim seems to be motivated by the reasoning of negative economic implications of oil shocks or asymmetric oil price effects. They identify two different negative implications of oil price volatility, uncertainty in investment and sectoral shift, which other authors also associate to oil price increases or shocks (see above).

Generally, it is obvious that the above mentioned effects strongly depend on *fiscal and monetary policy* reactions to oil price increases. Both can contribute to a demand stimulation, e.g., in oil shock situations. However, there are good reasons to believe in Brown and Yücel's (2002) claim that oil price shocks "increase the potential for errors in monetary policy", as well as in fiscal policy. From a theoretical standpoint, it is crucial in this respect whether money illusion is present or not.

If so, an accommodative monetary policy has the potential to offset, at least partly, losses in GDP growth that are due to oil price rises. A restrictive monetary policy can aggravate negative macroeconomic oil price effects in such a setting. In the absence of a money illusion, on the other hand, monetary policy is simply mirrored by inflation without having real effects, apart from—potentially negative—impacts of the inflation caused by monetary policy. Wage policy is a further aspect to be observed in this regard; in contrast to the mechanism of the supply-side effect described above, a so-called *wage-price-spiral* implying inflationary pressure can evolve if nominal wages are set in line with observed (oil) price increases and if prices in general reflect past wage increases (Barsky and Kilian 2004).

Several authors argue that macroeconomic oil price effects have diminished in recent years, an occurrence that is difficult to describe with any of the above mentioned channels at hand. It is perceivable, though, that (monetary and/or fiscal) policy makers have drawn lessons from past oil crises and consequently improved their responses to oil shocks. Moreover, as recent world oil consumption is particularly boosted by the dramatic gains in oil consumption outside the advanced economies of the OECD, with the strongest gains in emerging (mostly Asian) economies, the predominance of *oil demand rather than supply shocks* in recent years can offer an explanation in this regard. The boost in oil consumption seems to be driven, as well as accompanied by, an economically beneficial general rise in demand for goods and services on the world markets.[4] Such a stimulating effect can at least partly offset the negative impacts of oil price rises.

A further reason why the oil price effect on employment could have diminished over the past decades is the decline in *energy intensity* observed almost all over the world (e.g., IEA 2011a),[5] which could go hand in hand with a reduced oil price impact on the economy (e.g., Barsky and Kilian 2004, or Schmidt and Zimmermann 2007). (Differences in) Energy efficiency could indeed constitute a central factor for the specific macroeconomic effects in respective countries or regions and over time, with efficiency improvements being a potential tool to diminish the economic vulnerability to oil prices.

3.2 Insights from Empirical Analyses

Different empirical analyses tell different stories about how (much) the oil price matters to economic development. Interestingly, this is also true for the available literature reviews. In their prominent survey paper, Barsky and Kilian (2004) argue that there was little evidence that the oil price significantly affected the

[4] In this respect, e.g., Lin (2008) emphasizes the role of recently rising Chinese demand for increases in the oil price.

[5] However, recent energy efficiency data provided by the IEA suggest that this global trend towards energy efficiency halted or at least paused in 2008 and 2009.

macroeconomic performance in the United States. Their findings suggest that oil price shocks are neither necessary nor sufficient to explain the weak macroeconomic performance in the US and generally conclude that the economic influence of oil prices changes was rather small or even nonexistent. In contrast, the review provided by Sauter and Awerbuch (2003) states that the "idea that rising oil prices and price volatility serve to stifle economic activity … has by now become widely accepted in the literature and seems virtually axiomatic". Making reference to influential studies using US data for the post-WW II-period, Sauter and Awerbuch (2003) argue that oil price increases of 10 % could be followed by GDP decreases of around 1.5 %.

The academic discussion about the robustness of an oil-to-macroeconomy-relationship has led to the development of different measures representing oil shocks. This term is rather vague, but implies oil price increases that are greater than usual variations. Accordingly, apart from the discussion about channels or transmission mechanisms of oil price shocks on the economy, the available literature suggests that the actual nature of oil price movements has to be adequately addressed in empirical analyses in order to correctly measure the effects of oil price shocks (Löschel and Oberndorfer 2009; see above).

While Hamilton (1983) establishes that oil prices have a linear negative effect on GDP, subsequent research has called this result into question on the grounds that the 1973 oil crisis included in Hamilton's (1983) data set would be an outlier and impact his results. Going beyond the linear oil-to-macroeconomy relationship, Mork (1989) makes use of asymmetric oil price variables. This research shows that the negative relationship between GDP growth and oil prices found by Hamilton (1983) was robust in the case of *oil price increases*, but that the correlation between the change in GDP and *oil price decreases* was significantly different or even zero, indicating an asymmetric relationship between oil prices and economic activity. In response to further scepticism with regard to the oil-to-macroeconomy relationship, expressed particularly by Hooker (1996), Hamilton (1996) goes beyond the simple asymmetric oil price effect as applied by Mork (1989). The net oil price increase proposed by Hamilton (1996) gives values different from zero only if current oil prices exceed the previous year's maximum (for definitions, see Sect. 2) and outperforms other oil price measures in causality tests provided by Hamilton (1996).

Subsequently to Hamilton's (1996) work, the net oil price increase has been widely used as an oil shock variable. Net oil price increases have been shown to have a significant impact on economic performance for markets outside the US (e.g., for Germany, see Löschel and Oberndorfer 2009, for other European countries, see Cuñado and Pérez de Gracia 2003, and for Asian economies, see Cuñado and Pérez de Gracia 2005). According to Du et al. (2010), a complex asymmetric relationship between oil price and the macroeconomy is also present in China; moreover, reforms of the national oil pricing mechanism need to be taken into account here. All in all, evidence for economic effects of oil shocks seems therefore convincing.

As mentioned above, critics of the empirical finding of a significant oil-to-macroeconomy-relationship are nevertheless widespread (see, e.g., Barsky and Kilian 2004, for the US and Schmidt and Zimmermann 2007, for Germany). Apart from the theoretical reasoning elaborated above, empirical arguments against a strong economic role of the oil price include the empirically challenging questions about the exogeneity of oil prices: Do oil prices move the economy or does the economy move the oil price? They also address causality. In the past, oil price shocks have often occurred in times of geopolitical crises in the Middle East. This raises the question whether oil price hikes or respective geopolitical crises themselves affect the economy (Barsky and Kilian 2004).

4 Oil Prices and Financial Markets

4.1 Theoretical Background

Based on the common representation of stock prices of corporation *i* (p_i) as expected future cash flows of the corporation ($E(cf_i)$) that are discounted by the discount rate δ, the argument that oil prices may affect the respective corporation's stock returns is straightforward. Such representation is proposed in a general context regarding the *systematic effect of macroeconomic variables on stock returns* by Chen et al. (1986). They accordingly define stock prices as

$$p_i = E(cf_i)/\delta, \tag{7}$$

implying stock returns of corporation *i* of

$$dp_i/p_i = d[E(cf_i)]/E(cf_i) - d\delta/\delta.$$

Within this framework, Chen et al. (1986) argue that both changes in the discount rate δ and in the expected future cash flows $E(cf_i)$ determine the stock returns of corporation *i*. Following Oberndorfer (2009a), this suggests in particular that *stock returns of companies directly involved in the oil business* or dealing with oil products and services are affected by oil price changes. Rising oil prices would upvalue the resource stocks of companies related to the oil business or their products and services. Consequently, their expected future cash flows should rise. Stock returns of utilities and other companies that use fossils fuels as an input, e.g., for electricity generation, would be negatively affected, as the price of their most important input for production rises, with an ex-ante unclear ability to pass through those cost increases to consumers.

However, based on the framework presented above, the *impact of oil price changes on stock returns can be generalized* to corporations from other sectors if it is assumed that the oil price has a direct or indirect effect on their cash flows. Given the role oil prices play for the macroeconomy as such—as set out above from a theoretical perspective—, the channels include induced changes of prices of oil intensive goods, interest rates, production and wages. Oil price effects on stock returns are therefore perceivable for corporations stemming from practically any sector. In particular, a negative relationship between oil prices and stock prices is expected for corporations outside of the energy sector, given the general negative oil-to-macroeconomy-relationship.

As described above, Sauter and Awerbuch (2003) allege that, *oil price volatility* has had a more significant effect on economic activity than the oil price level since the 1980s. Based on this claim, and against the background that the energy industry is strongly exposed to energy price risks even though option trading is available (Hampton 1995), it may not only be appreciations and depreciations in oil price levels that, to the market developments of energy stocks but also oil price volatility. Oberndorfer (2009a) argues that oil market volatility can lead to augmented expenditures for affected corporations, and may for example induce hedging costs. Moreover, following Pindyck (2004), an increase in price volatility may decrease the production of the respective commodity. Therefore, Oberndorfer (2009a) concludes that oil market volatility may equally impact the discounted expected future cash flows of corporations and therefore affect stock prices as shown above in the theoretical framework based on Chen et al. (1986).

4.2 Insights from Empirical Analyses

A number of authors have made an in-depth analysis of the role of oil prices for financial markets, but the available literature is not as broad as in the field of the oil-to-macroeconomy relationship. The—more intuitive—relationship between *oil prices and energy corporations' stock prices* has received more scientific attention than possible oil price effects on corporations from other sectors (or on stock prices in general, as measured by stock indexes).

The main result with regard to oil prices and oil corporations' stocks is that they are—as expected—positively related. This result has for example been produced for the UK oil industry by Manning (1991), who also shows that the effect is largest for corporations purely engaged in oil exploration and production. Faff and Brailsford (1999) reproduce the general positive relationship for the Australian oil and gas sector, Sadorsky (2001) for Canadian, and Oberndorfer (2009a) for Eurozone oil and gas firms.

Amongst that studies that have analyzed the energy sector from a broader perspective, interesting contributions include that of Henriques and Sadorsky (2008) who found that the stock prices of alternative energy companies are positively affected by oil prices (although this result shows only little significance). Their interpretation of this finding is that oil price movements are not as important as once thought with regard to alternative energy companies because investors may view the sector as similar to other high technology branches.[6] Oberndorfer (2009a) finds

[6] This result may also be explained by the fact that most renewable energy sources are not competitive in many energy markets and therefore profit from different kinds of public support.

that oil prices negatively impact stock returns of European utilities that use fossil fuels as a main input for electricity production. In their international analysis of the risk factors of the oil and gas industry, Ramos and Veiga (and Veiga 2011) conclude that the oil and gas sector in advanced countries responds more strongly to oil price changes than in emerging markets, and that oil and gas industry returns respond asymmetrically to oil price changes: Oil price rises have a greater impact than oil price drops.

Sadorsky's (1999) findings suggest that oil price movements are an important determinant of *stock returns in general*. Based on an analysis of stock return data for the S&P 500—i.e., the biggest US corporations—Sadorsky (1999) draws the conclusion that positive shocks to oil prices depress real stock returns. Similar results are produced by Nandha and Faff (2008) who analyze different industry indices. Their findings indicate that oil price rises have a negative impact on equity returns for all sectors except energy industries.

Very few authors have integrated *oil price volatility in empirical analyses of stock markets*. This is even more striking given the fact that at least two analyses have produced statistically significant results on this. Oberndorfer (2009a) finds that oil market volatility negatively affects European oil and gas stocks. He specifically shows that also for castable oil market volatility impacts the stock market, implying profit opportunities for strategic investors. According to Sadorsky (2003), technology stock return volatility is positively affected by oil price volatility. The analysis of Arouni et al. (2011) for the stock markets of the Gulf Cooperation Council countries suggests that there are both return and volatility spillovers between oil and stock markets.

5 Conclusion

The oil price is back on the political agenda. This makes it even more important to analyze the relevance of oil prices for the economy and financial markets. This paper intends to contribute to that debate—not by estimating the magnitude of oil price effects, but rather by shedding some light on the arguments, notions and definitions underlying the existing analyses.

Apart from these theoretical and technical aspects, this review documents the general consensus amongst economists that the economic significance of moderate oil price movements is low or even nonexistent. Even minor oil price changes affect financial markets, however: Stock prices of energy companies as well as those operating in other sectors are shown to be very sensitive to price movements and volatility of the oil market. As long as oil prices remain within a price floor,

(Footnote 6 continued)
Several renewable energy support schemes such as feed-in-tariffs applied in many countries eliminate price risks for renewable energy generation so that the prices of fossil fuels such as oil should have a minor impact—or no impact at all—on renewable companies' businesses.

macroeconomic indicators seem to be barely affected. However, there is strong evidence that energy price shocks, i.e., massive price movements, have significant economic effects. Macroeconomic impacts may depend on their own "nature"—the differentiation between supply and demand shocks provides an example in this regard—, on the national or regional particularities—such as the level of energy efficiency—, as well as on policy responses.

The debate about the oil-to-macroeconomy-relationship is not over. Methodological challenges such as causality and endogeneity remain an issue and the question about how strongly the oil price affects economic outcomes is far from being resolved.[7] These questions call for further empirical analysis, based on approaches presented in this paper as well as on modern econometric techniques. As oil prices are expected to continue rising in the mid- and long-term (e.g., IEA 2011b), the question about their economic implications will remain highly relevant.

The age of cheap oil may be over, as stated by both the IEA and the *peak oil hypothesis*. As a result, and in combination with the rise of shale gas and progress on renewable energy technologies, the world might be entering a *golden age of gas* as well as a period of *electrification*. This suggests the increasing importance of analyses that deal with non-oil energy market segments such as electricity and gas markets. The approaches presented in this paper should be well suited also for these kinds of assessments. For this analytical purpose, the integration of macroeconomic energy cost indicators (Oberndorfer 2012) could also be considered. Finally, carbon markets such as the European Union Emission Trading Scheme (EU ETS) as further evolving energy markets could be assessed (cp. Oberndorfer 2009b or Chevallier 2011).

Conflict of Interest This article represents the personal opinion of the author and does not reflect the official position of the institution he is affiliated with.

References

Arouni MEH, Lahani A, Nguyen DK (2011) Return and volatility transmission between world oil prices and stock markets of the GCC countries. Econ Model 28(4):1815–1825

Barsky RB, Kilian L (2004) Oil and the macroeconomy since the 1970s. J Econ Perspect 18 (4):115–134

Bernanke B (1983) Irreversibility, uncertainty, and cyclical investment. Quart J Econ 98(1):85–106

Brown SPA, Yücel MK (2002) Energy prices and aggregate economic activity: an interpretative study. Q Rev Econ Finan 42(2):193–208

Brown SPA, Yücel MK (2000) Oil prices and the economy. Southwest Econ 4:1–6

Chen N-F, Roll R, Ross SA (1986) Economic forces and the stock market. J Bus 59(3):383–403

Chevallier J (2011) Evaluating the carbon-macroeconomy relationship: evidence from threshold vector error-correction and Markov-switching VAR models. Econ Model 28(6):2634–2656

[7] Further methodological issues that can drive the results of oil-to-macroeconomy and oil-to-financial markets analyses are the choice of empirical approaches and specifications.

Cuñado J, Pérez de Gracia F (2005) Oil prices, economic activity and inflation: evidence for some Asian countries. Q Rev Econ Finan 45(1):65–83

Cuñado J, Pérez de Gracia F (2003) Do oil price shocks matter? evidence for some European countries. Energy Econ 25(2):137–154

Du L, Yanan H, Wei C (2010) The relationship between oil price shocks and China's macro-economy: an empirical analysis. Energy Policy 38(8):4142–4151

Engle RF (2001) GARCH 101: the use of ARCH/GARCH models in applied econometrics. J Econ Perspect 15(4):157–168

Faff RW, Brailsford TJ (1999) Oil price risk and the Australian stock market. J Energy Finan Dev 4(1):69–87

Ferderer JP (1996) Oil price volatility and the macroeconomy. J Macroecon 18(1):1–26

Hamilton JD (1996) This is what happened to the oil price-macroeconomy relationship. J Monetary Econ 38(2):215–220

Hamilton JD (1983) Oil and the macroeconomy since World War II. J Polit Econ 91(2):228–248

Hampton M (1995) Options. In: Jameson R (ed) Managing energy price risk. Risk Magazine Publications, London, pp 97–116

Henriques I, Sadorsky P (2008) Oil prices and the stock prices of alternative energy companies. Energy Econ 30(3):998–1010

Hooker MA (1996) What happened to the oil price-macroeconomy relationship? J Monetary Econ 38(2):195–213

IEA (2011a) IEA Scoreboard 2011: implementing energy efficiency policy: progress and challenges in IEA member countries, Paris

IEA (2011b) World energy outlook 2011, Paris

Lin SX (2008) Effect of Chinese oil consumption on world oil prices. Cass Business School, City University London

Löschel A, Oberndorfer U (2009) Oil and unemployment in Germany. J Econ Stat 229(2–3):146–162

Manning N (1991) The UK oil industry: Some inferences from the efficient market hypothesis. Scott J Polit Econ 38(4):324–334

Mork KA (1989) Oil and the macroeconomy when prices go up and down: an extension of Hamilton's results. J Polit Econ 97(3):740–744

Nandha M, Faff R (2008) Does oil move equity prices? A global view. Energy Econ 30(3):986–997

Oberndorfer U (2012) Developing macroeconomic energy cost indicators. Energy Policy 42:1–3

Oberndorfer U (2009a) Energy prices, volatility, and the stock market: evidence from the Eurozone. Energy Policy 37(12):5787–5795

Oberndorfer U (2009b) EU emissions allowances and the stock market: evidence from the electricity industry. Ecol Econ 68(4):1116–1129

Pagan A (1984) Econometric issues in the analysis of regressions with generated regressors. Int Econ Rev 25(1):221–247

Pindyck RS (2004) Volatility and commodity price dynamics. J Futures Markets 24(11):1029–1047

Ramos SB, Veiga H (2011) Risk factors in oil and gas industry returns: international evidence. Energy Econ 33(3):525–542

Sadorsky P (2003) The macroeconomic determinants of technology stock price volatility. Rev Financ Econ 12(2):191–205

Sadorsky P (2001) Risk factors in stock returns of Canadian oil and gas companies. Energy Econ 23(1):17–28

Sadorsky P (1999) Oil price shocks and stock market activity. Energy Econ 21(5):449–469

Sauter R, Awerbuch S (2003) Oil price volatility and economic activity: a survey and literature review. IEA Research Paper, Paris

Schmidt T, Zimmermann T (2007) Why are the effects of recent oil price shocks so small? Ruhr Economic Paper No. 21, Essen