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Abstract

This paper deals with three aspects of spectacular oil price episodes such as the one witnessed in 2008. First, the concept of temporary explosiveness is proposed as an empirical method for capturing this type of behavior. The application of a recently proposed recursive unit root test shows that phases of explosive behavior occurred in 1990/1991, 2005/2006, and 2007/2008. Second, the underlying causes of the observed behavior are discussed. The prevailing opinion in the literature is that fundamental factors are the main explanation for the 2007/2008 oil price hike, but that in 1990/1991, speculative demand shocks also played a role. Third, it is shown that temporary oil price hikes influence economic decisions that are based on oil price information. For this purpose, a real options model on the oil field development decision is reconsidered. The mechanism behind this is an increase in the profitability of the oil field development project. In sum, the key contributions of this paper are to highlight a new empirical feature in oil prices and to show that economic effects of speculative demand shocks can emerge that to date appear to have been overlooked.

JEL-Code: C120, C580, D810, Q300.

Keywords: oil prices, explosiveness, uncertainty, real options, climate change, speculative demand shocks.

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1 Introduction

Heavy disruptions of the global oil market occur with considerable regularity. Among the manifold examples are the two oil crises, the OPEC collapse, the oil price hike associated with Gulf War II in 1990/1991 and, finally, the episode in July 2008 when oil prices reached a record level of more than 140 USD per barrel. Every one of these disruptions has led to heated debates in both the public and academic arenas. Considerable effort has been made to understand both the macroeconomics and the behavior of oil prices, and this work is well justified for at least two reasons. First, crude oil is still an important economic input factor and there is a widespread notion that virtually all economic recessions are associated with increases in oil prices. Second, crude oil is a fossil resource, the combustion of which is one of the main drivers of climate change.

The last two oil price hikes mentioned abovethe one that occurred in 1990/1991 and the one in 2008have striking empirical similarities. In both cases, the observed steep increase constitutes a break with previous behavior, but after prices returned to the previous level, the previous behavior also reemerged (see Figure 1). The overall behavior of oil prices is certainly subject to structural changes. The horizontal movement before and after the 1990/1991 oil price hike is equally apparent as the upward trending behavior before and after the 2007/2008 hike. Most recently, oil prices seem to have stabilized at about 100 USD. Existing oil price modeling at-tempts do not seem able to capture this type of behavior.

This paper deals with three dimensions of this type of behavior. First, it attempts to empirically capture this idiosyncratic behavior. The empirical concept employed for this purpose is temporary explosiveness. The procedure applied is based on the recursive application of a standard unit root test. The key result of this exercise is that there is evidence of temporary phases of explosiveness in 1990/1991 as well as in 2005/2006 and 2007/2008. This finding, standing alone, makes a contribution to the literature on oil price behavior. However, the paper goes further and addresses two other issues related to this empirical finding. First, the underlying causes of the identi-

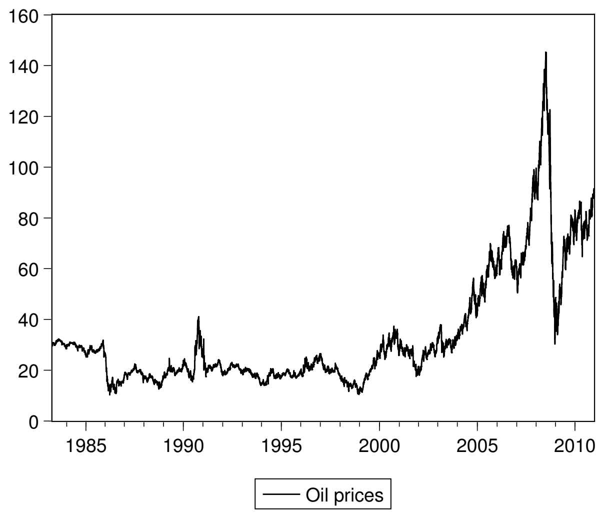

Figure 1: Oil prices

fied explosive phases are discussed. The key reference in this regard is the recent paper by Kilian and Murphy (2013), which shows that in both cases fundamental factors were important, but that, particularly in 1990/1991, speculative demand shocks also played a considerable role.[1] Second, this paper shows that important economic decisions are affected by explosive oil prices. This insight is arrived at based on reconsideration of a real option model on the oil field development decision under uncertain oil prices. The key mechanism in this model is that also temporary oil price hikes lead to an increase in the value of an oil field and thus influence the optimal moment of development. Thus, the paper highlights an effect of oil price affecting speculative demand shocks that has not, to date, been addressed.

The paper's empirical strategy consists of a forward recursive application of an augmented Dickey-Fuller unit root test. In each step, the null of a unit root is tested against the alternative of explosiveness. This procedure is borrowed from Phillips et al. (2011). Monthly as well as daily oil price

[1]Speculative demand shock is defined as proposed by Kilian and Murphy (2013). The precise definition is presented in Section 4.

data spanning 19862011 and 19822010, respectively, are used in the study.

Because of the significance of oil to the world economy, it is no surprise that the oil price hikes of 2008 generated a heated debate regarding its causes and consequences. Whether it contributed to the recession observed after 2008 (Hamilton, 2009), as well as whether it was due to speculative demand shocks or macroeconomic fundamentals (Kilian and Murphy, 2013), are among the topics discussed. As the oil price hike coincided with the so-called financialization of oil futures markets, many believe that this has to be viewed as a driving force behind the hike. Empirical support for this publicly popular claim, however, is practically nonexistent (see, e.g., Fattouh et al., 2013). This finding is also the main outcome of Kilian and Murphy (2013). However, these authors do show that influences of speculative demand shocks were present in earlier oil price episodes, particularly in 1990/1991.

This last finding is interesting in itself, but it gains a whole new importance in the context of how oil price hikes affect economic decisions that are based on information provided by oil prices. The third dimension of oil price hikes discussed in this paper is the oil field development decision under uncertain oil prices, as studied by Miller and Zhang (1996). Phases with temporarily high oil prices, such as those identified in this paper, lead to an increase in the value of undeveloped oil fields that affects the optimal development moment. This papers empirical findings, however, suggest that Miller and Zhang's (1996) model needs to be recalibrated, the expected result of which is that the development decision is more responsive to transitory hikes. Moreover, speculative demand shocks need to be added to the list of potential causes of temporary oil price hikes. As oil is a fossil resource, there is the additional effect on current carbon emissions and also, therefore, current atmospheric carbon concentration.

The remainder of the paper is organized as follows. Section 2 outlines the empirical method employed in the paper; Section 3 presents the empirical results. Section 4 discusses fundamental factors and speculative demand. Section 5 delves into the consequences of the empirical behavior of oil prices. Section 6 concludes.

2 Testing for Explosiveness

The statistical properties of monthly as well as daily oil prices are investigated here using a forward recursive application of an augmented Dickey-Fuller unit root test. The null of a unit root is tested against the alternative of an explosive root. Thus, the following equation is estimated:

$$x_t = \mu_x + \delta x_{t-1} + \sum_{j=1}^{J} \phi_j \Delta x_{t-j} + \epsilon_{x,t}, \quad \epsilon_{x,t} \sim \text{NID}(0, \sigma_x^2). \tag{1}$$

The hypothesis H_0: $\delta = 1$ is tested against the alternative H_1: $\delta > 1$. Initially, a subset of the sample with $\tau_0 = nr_0$ observations is used. In each subsequent regression, this subset is supplemented by successive observations, giving a sample of size $\tau = nr$ for $r_0 \leq r \leq 1$. This procedure yields a sequence of t-statistics with corresponding p-values. These sequences are used to identify origination $\hat{r}_e$ and collapse dates $\hat{r}_f$ of explosive behavior in the data:

$$\hat{r}_e = \inf_{s \geq r_0} \{s : \text{ADF}_s > \text{cv}_{\beta_n}^{\text{adf}}(s)\}$$

$$\hat{r}_f = \inf_{s \geq \hat{r}_e} \{s : \text{ADF}_s < \text{cv}_{\beta_n}^{\text{adf}}(s)\}$$

This procedure is derived from a test for periodically collapsing bubbles recently proposed by Phillips et al. (2011) as a further-development of cointegration-based tests for the existence of bubbles.[2]

This paper uses nominal monthly oil prices from 1982 to 2010 as well as nominal daily oil prices from 1986 to 2010 (WTI) to test for explosiveness in oil prices. The following section presents the empirical results.

[2] Attempting to discover whether or not there are oil price bubbles requires a clear definition of the fundamental value of the oil price. To the best of the authors knowledge, no such series exists. Therefore, this paper focuses on the sheer statistical behavior of oil prices, namely, whether or not oil prices are (temporarily) explosive. Note that the finding of explosiveness in oil prices has no implication whatsoever as to whether this behavior is justified from a fundamental point of view.

3 Results

This section presents the results obtained from applying the test procedure outlined above to monthly as well as daily oil prices. Initially, the results for monthly data are considered. The upper panel of Figure 2 displays oil prices as well as the sequence of p-values. p-values below 5 % indicate rejection of the null hypothesis. As explained above, for periods in which the null of a unit root is rejected, oil prices are said to exhibit explosive behavior. This is the case in particular for 2005/2006 as well as for 2007/2008, but the price hike associated with Gulf War at the end of 1990 is classified as explosive as well. While the earlier phase is of relative short duration, the two later ones are about a year long. Analysis of daily oil prices generally confirms these results (see Figure 2, lower panel).

The finding of temporary phases of explosiveness adds to the vast literature on short-run as well as long-run oil price behavior. In the long run, oil prices are assumed to follow either deterministic (Slade, 1982a; Lee et al., 2006) or stochastic trends (Slade, 1988). On the short-run behavior front, a number of recent studies provide evidence of jumps in oil prices (Lee et al., 2010; Gronwald, 2012).[3] Despite the concentrated effort that has been made to understand oil price behavior, oil price hikes like those observed in 2007/2008 are not well described by any of the extant theories.

In other words, this paper highlights a new empirical feature of oil prices. Therefore, it is worthwhile to discover the underlying causes of this behavior.

4 On Fundamental Factors and Speculative Demand

In the aftermath of the 2008 oil price surge, a vast literature emerged discussing its underlying causes. One main focus of this work is empirically testing the so-called Masters hypothesis, according to which there is excessive trading activity in oil futures markets. This idea is also very popular with the public and there have already been calls for regulation of oil derivatives markets. However, no empirical support has been found for the Masters

[3] Among the most prominent explanations for this behavior are low short-run demand and supply elasticity, as well as political influences (see, e.g., Smith, 2009).

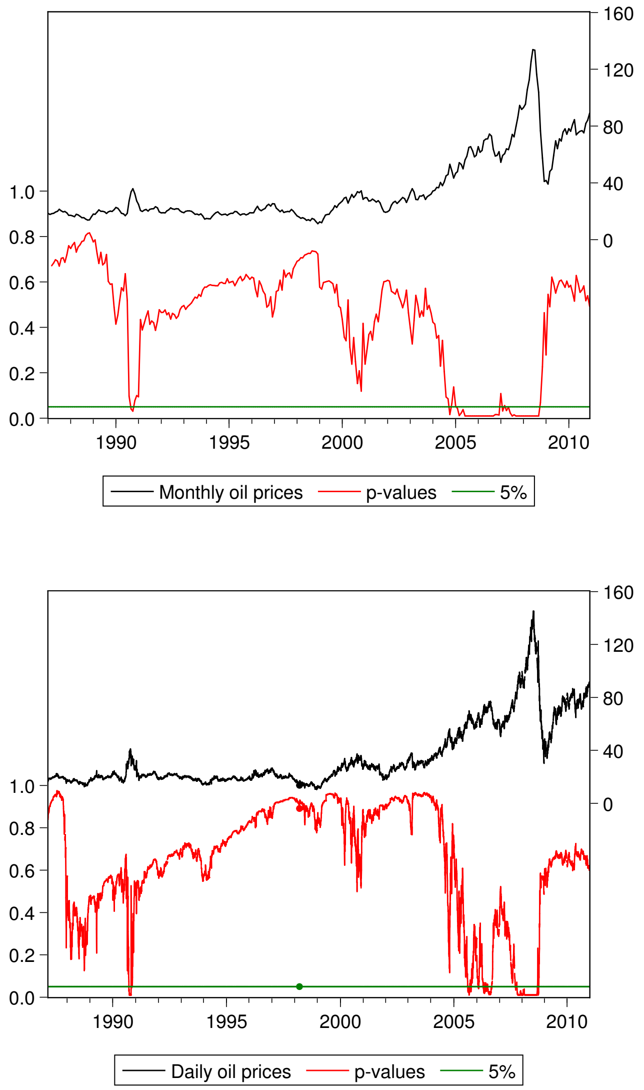

Figure 2: Explosiveness of monthly and daily oil prices

hypothesis. For example, Irwin and Sanders (2013) use an extensive dataset on index fund investment in various commodity futures markets, and employ different statistical techniques. While their focus is on how financialization influences futures markets, Kilian and Murphy (2013) specifically analyze the oil inventory channel. Within their four-variable structural VAR model (global crude oil production, a measure of global real activity, the real price of crude oil, and change in oil inventories above the ground), they identify four different types of shocks: an oil flow supply shock, an oil flow demand shock, a residual oil demand shock, and, most importantly, a speculative demand shock. This last shock is defined as a shock to the demand for "above-ground oil inventories arising from forward-looking behavior not otherwise captured by the model." The core finding that emerges from their paper is, as already mentioned, that the 20032008 oil price surge "was caused by unexpected increases in world oil consumption driven by the global business cycle." However, the authors (Kilian and Murphy, 2013), also show that during oil price episodes in 1979 and 1986, as well as in 1990, "speculative demand shocks played an important role." Indeed, the authors calculate that about "one third of the price increase from July to August of 1990 was caused by speculative demand shocks." Hamilton (2009) argues that "a low price elasticity of demand and the failure of physical production to increase, rather than speculation per se, should be construed as the primary cause of the oil shock of 2007-08." Fattouh et al. (2013) provide an excellent survey of this literature, concluding that "the co-movements between spot and futures prices reflect common economic fundamentals rather than the financialization of oil futures markets."[4]

[4]There are some studies expressing the opinion that "speculation" is of higher importance. Kaufmann and Ullman (2009) argue that there is a fundamentally driven long-term increase in oil prices, which, however, is "exacerbated by speculators." In the same vein, Miller and Ratti (2009) show that there is a "change in the relationship between real oil prices and real stock prices which may suggest the presence of several stock market and/or oil price bubbles." These papers, however, employ a very broad definition of "speculation." In consequence, their results are not particularly reliable.

5 Explosive Oil Prices and Oil Field Development

In extant work on the economic consequences of oil price shocks, it is predominantly consequences for macroeconomic activity that are considered. This paper, however, shines a spotlight on an entirely different issue: decisions that are based on oil price information, particularly the decision to develop an oil field under uncertain oil prices.

The foundation for studying this issue is Miller and Zhang's (1996) analysis of the relationship between transitory oil price hikes and oil field development. The point of departure from their analysis is a situation in which a firm discovers an offshore oil field of a certain size.[5] Developing this oil field involves investing a lump-sum irreversible charge. Once the field is developed, it is assumed that the extraction rate is geologically determined. The firm decides when to develop the field. A real option model is used to analyze the influence of uncertain oil prices on this irreversible investment decision.

In the basic version of the model, it is assumed that oil prices follow a continuous Brownian motion with drift:

$$dP_t = \alpha P_t dt + \sigma P_t dB_t$$

Based on this assumption, Miller and Zhang (1996) show that the oil field is developed once oil prices exceed a certain trigger price. This trigger price is higher than the one in the absence of uncertainty.

Motivated by the oil price hike associated with the Gulf War of 1990/1991, the authors investigate whether transitory oil price hikes might also lead to oil field development. Therefore, they augment the price process with a jump component so that oil prices are now assumed to follow a Brownian motion mixed with a jump component. In peacetime, prices are expected to jump up by a certain amount when a war occurs:

[5] For a detailed exposition of the model, the reader is referred to the original publication. For a general introduction to investment decisions under uncertainty, see Dixit and Pindyck (1994).

$$\frac{dP_t}{P_t} = \alpha dt + \sigma dB_t + \phi dq_t^N.$$

Once the war started, it is expected that oil prices will go down again once the war is over:

$$\frac{dP_t}{P_t} = \alpha dt + \sigma dB_t - \frac{\phi}{1+\phi} dq_t^N$$

Miller and Zhang's (1996) main finding is that not only permanent, but also transitory, oil price hikes lead to development of oil fields. These transitory hikes, however, need to be four times as large as a permanent one to have the same effect.

Miller and Zhang (1996) assume that transitory oil price hikes are associated with wars, occur relatively rarely (every 20 years), and are relatively short (36 months). In the following, it is assumed that the periods of explosive oil price behavior and transitory oil price hikes are different ways of capturing the same phenomenon. Under that assumption, this papers empirical results clearly indicate that, first, transitory oil price hikes can have causes other than just wars. Second, due to this finding, it is implausible to assume that oil price hikes will occur only once in 20 years. Finally, the price hikes can last considerably longer than just 6 months. Carrying forward the comparative statics in Miller and Zhang (1996), it can be shown that these different features make oil field development more responsive to jumps.

The effect described here emerges regardless of what is driving an oil price increase: the key mechanism is an increase in the value of the oil field. This value certainly also increases if speculative demand shocks simply lead to an increase in oil prices, but not necessarily an explosive phase. In explosive phases, however, the effect is stronger.

Admittedly, this paper reconsiders a very stylized model. However, the model follows a long tradition of adding additional considerations to resource extraction decisions made under various forms of uncertainty (see, e.g., Pindyck's (1980) analysis of demand and reserve uncertainty). In more recent papers, issues such as uncertainty and the timing of environmental policies (Pindyck, 2000) are discussed. In addition, oil prices are assumed to be exogenous.[6] Support for this assumption is found in Slade (1982b), who argues that the influence of single oil production sites on long-run oil prices is small as such sites are a very small fraction of the market. Clearly, there is a great deal of scope for further research on this and related issues. For example, some of these ideas could be extended to literature on optimal taxation of exhaustible resources, one of the main fields in the area of traditional resource economics. Indeed, modeling resource extraction decisions has recently become very popular again. However, insights from the real options and the oil price behavior literature have not to date been adequately considered in this literature.

6 Conclusions

Academic studies on crude oil are anything but scarce, but they do appear to be episodic. The oil crises of the 1970s sparked enormous efforts in investigating the macroeconomic consequences of oil price shocks. The emergence of various resource economic studies focusing on the scarcity of resources can also be linked to these incidents. A recent offshoot of this literature is motivated by increasing awareness of climate change and its consequences. And there seems to be an almost permanent interest in studying the statistical behavior of oil prices.

Motivated by the oil price hikes witnessed at the end of the past decade, this paper contributes to the literature in three ways. First, the behavior of oil prices is investigated by testing whether or not oil prices experience temporary explosive phases. Finding that they do, the second contribution is to provide explanations for this observed behavior based in the literature on macroeconomic fundamentals and speculative demand shocks. Third, the consequences of the observed behavior for resource extraction decision are highlighted.

The key finding that emerges from this study is that oil prices have indeed

[6]See Pindyck (1981) for another paper that makes this particular assumption.

experienced transitory explosive phases, notably in 1990/1991, 2005/2006, and 2007/2008. This finding illustrates that transitory oil price hikes cannot be considered rare events. Looking at this finding in light of existing studies on the relationship between this type of oil price hike and oil field development indicates that the oil field development response is stronger than previously found in the literature. This result holds irrespective of what causes the oil price hike, be it fundamentally driven or attributable to speculative influences. However, Kilian and Murphy (2013) provide at least some indication that speculative demand shocks can play a role during oil price hikes. However, Fattouh et al. (2013) assert that "one of the problems in this literature and, more importantly, in the public debate about speculation is that it is rarely clear how speculation is defined and why it is considered harmful to the economy." It is hard to disagree with this statement, but this paper's empirical findings, in combination with the identified influence of transitory oil price hikes on the oil field development, provide some support for concluding that there can be (undesirable) effects of speculative demand shocks that seem to have been overlooked thus far.

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