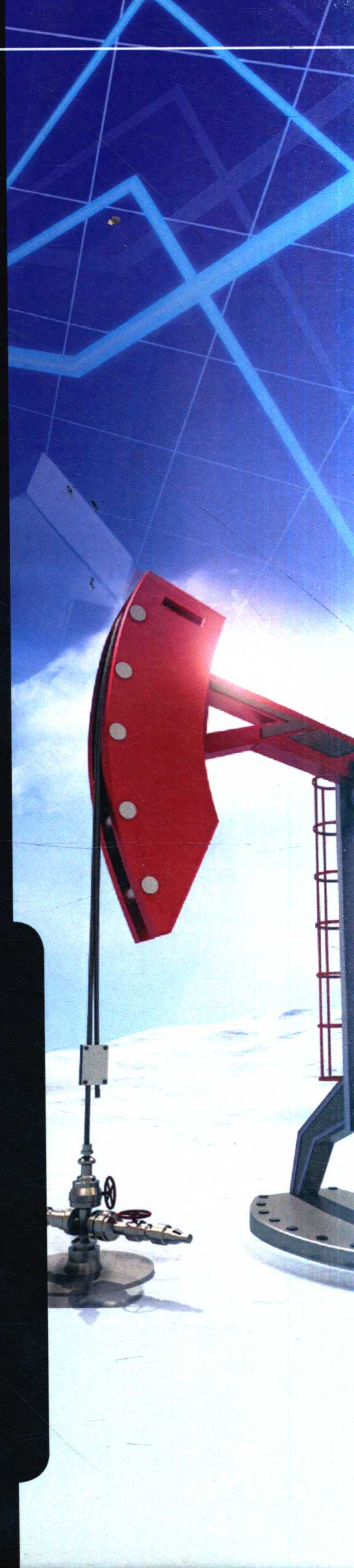
World Scientific

OIL PRICE UNCERTAINTY

Apostolos Serletis



OIL PRICE UNCERTAINTY

Apostolos Serletis
University of Calgary, Canada

World Scientific

NEW JERSEY • LONDON • SINGAPORE • BEIJING • SHANGHAI • HONG KONG • TAIPEI • CHENNAI

Published by

World Scientific Publishing Co. Pte. Ltd.

5 Toh Tuck Link, Singapore 596224

USA office: 27 Warren Street, Suite 401-402, Hackensack, NJ 07601

UK office: 57 Shelton Street, Covent Garden, London WC2H 9HE

Library of Congress Cataloging-in-Publication Data

Serletis, Apostolos.

Oil price uncertainty / by Apostolos Serletis.

p. cm.

Includes bibliographical references and index.

ISBN 978-9814390675

1. Petroleum products--Prices. 2. Petroleum industry and trade--Econometric models.
3. Petroleum reserves. 4. Macroeconomics. I. Title.

HD9560.4.C37 2012

338.2'3282--dc23

2012016532

British Library Cataloguing-in-Publication Data

A catalogue record for this book is available from the British Library.

In-house Editor: Juliet Lee Ley Chin

Printed in Singapore.

To the sweetest little girl, Adia.

Preface

The relationship between the price of oil and the level of economic activity is a fundamental empirical issue in macroeconomics. As James Hamilton noted in a paper published in the *Journal of Political Economy* in 1983, at that time 7 out of 8 postwar recessions in the United States had been preceded by a sharp increase in the price of oil. More recently, in a paper published in a special issue of *Macroeconomic Dynamics* in 2011 on *Oil Price Shocks*, Hamilton continues this line of argument, by saying that "Iraq's invasion of Kuwait in August 1990 led to a doubling in the price of oil in the fall of 1990 and was followed by the ninth postwar recession in 1990-91. The price of oil more than doubled again in 1990-2000, with the tenth postwar recession coming in 2001. Yet another doubling in the price of oil in 2007-2008 accompanied the beginning of recession number 11, the most recent and frightening of the postwar economic downturns. So the count stands at 10 out of 11, the sole exception being the mild recession of 1960-61 for which there was no preceding rise in oil prices" (p. 364).

There is an ongoing debate in the macroeconomics literature about whether positive oil price shocks cause recessions in the United States (and other oil-importing countries); see, for example, Kilian (2008), Hamilton (2009), Blanchard and Riggi (2009), Edelstein and Kilian (2009), and Blanchard and Galí (2010). Those of the view that positive oil price shocks do not cause recessions appeal to theoretical models of the transmission of exogenous oil price shocks that imply symmetric responses of real output to oil price increases and decreases. These models cannot explain large declines in the level of economic activity in response to unexpected increases in the price of oil. On the other hand, those of the view that positive oil price shocks have been the major cause of recessions in the United States (and other oil-importing countries) appeal to models that imply asymmetric responses of real output to oil price increases and decreases. These models are able to explain larger recessions in response to positive oil price shocks as well as smaller expansions in response to negative ones.

Clearly, the question of how asymmetric the responses of real output are to exogenous oil price shocks is central in the debate of whether positive oil price shocks have been the major cause of recessions. Most of the empirical evidence is in support of the presence of asymmetries in the transmission of oil price shocks. Recently, however, Lutz Kilian and Robert Vigfusson (2011a) argue that this evidence is invalid. As they put it, in their paper in the special issue of *Macroeconomic Dynamics* in 2011, much of the empirical work cited in being in support of asymmetries "has not directly tested the hypothesis of an asymmetric transmission of oil price innovations. In fact, many of the papers quantifying these asymmetric responses are based on the censored oil price VAR methodology that Kilian and Vigfusson (2011b) proved to be invalid."

In this book I use recent state-of-the-art advances in macroeconometrics and financial econometrics to investigate the effects of oil price shocks and uncertainty about the price of oil on the macroeconomy. In focusing on the effects of uncertainty about the future price of oil on the level of economic activity, I abstract from other possible transmission mechanisms of exogenous oil price shocks. I present strong evidence of asymmetric responses of real output to positive and negative oil price shocks.

Of the five essays which follow, Chapters 1, 2, and 3 are new, while Chapters 4, 5, and 6 are reprints, with relatively minor revisions, of recently published work. The revisions which I have made were meant to eliminate repetitive passages and a certain amount of overlap between the individual essays.

A number of institutions and individuals have made the completion of these essays possible. I would like to thank my coauthors, John Elder and Sajjadur Rahman, of the original papers that have been reprinted in this book as Chapters 4, 5 and 6. Thanks are also due to the colleagues that commented on one or more of these essays — James Hamilton, Lutz Kilian, the Editor of the *Journal of Money, Credit and Banking*, Pok-sang Lam, the Editor of *Macroeconomic Dynamics*, William Barnett, the Editors of *Energy Economics*, Beng Ang, Richard Tol, and John Weyant, and the anonymous referees of these journals. Of course, none of them is responsible for the finished product.

Finally, I would like to thank Joanne Canape for a thoroughly professional job of preparing the camera-ready copy of this book. Without her help, this venture would not have been possible.

Contents

Chapter 1

Introduction

As noted in the *Preface*, the relationship between the price of oil and the level of economic activity is a fundamental empirical issue in macroeconomics. The theoretical literature suggests the existence of a number of *transmission mechanisms* (or *channels*) through which oil price innovations affect real output, and most of these transmission mechanisms (but not all) imply asymmetric responses of real output to oil price increases and decreases.

In what follows I discuss some of these channels through which oil price innovations affect real output.

1.1 Transmission Mechanisms

1.1.1 *The income transfer channel*

This channel emphasizes the price of imported crude oil and the change in the purchasing power of domestic households associated with increases in the real price of oil. As Rubin and Buchanan put it, in a CIBC World Markets *Report* published in 2008,

> "the transfer of income from US consumers to Saudi producers involves moving money from basically a zero-savings-rate economy to one in which the savings rate is around 50%. While many of those petro-dollars get recycled back into the financial assets of OECD countries, many of them never get spent" (p. 4).

Rubin and Buchanan continue by saying that it hasn't been only consumers in the United States that have been socked with

> "mounting fuel bills. It's been true for households from all OECD countries. Over the last five years their annual fuel bill has grown a staggering $700 billion. Of this, $400 billion annually has gone to OPEC producers" (p. 5).

It is to be noted that according to this transmission mechanism, it is the price of imported oil that is relevant; changes in the price of domestically produced oil lead to a redistribution of income, with no reduction in aggregate income. Also, the direct effect of an increase in the price of imported oil is symmetric in positive and negative oil price shocks. That is, a positive oil price shock will reduce aggregate income by as much as a negative oil price shock of the same magnitude will increase aggregate income.

Clearly, the rationale for asymmetric responses of real output to oil price increases and decreases hinges on the existence of other indirect transmission mechanisms of unexpected oil price changes, to which I now turn.

1.1.2 *The reallocation channel*

In another *Journal of Political Economy* paper in 1988, Hamilton argues that oil price shocks are relative price shocks and can cause intersectoral and intrasectoral reallocations of factors of production throughout the economy. For example, an unexpected increase in the real price of oil may reduce expenditures on energy intensive durables and cause a reallocation of capital and labor away from energy intensive industries. If capital and labor cannot be employed easily in other sectors, such reallocations will cause these factors of production to be unemployed, resulting in reduced real output beyond that from the decline in the purchasing power of households triggered by unexpectedly high oil prices.

As Kilian and Vigfusson (2011a, p. 339) put it, regarding this indirect transmission mechanism of unexpected oil price changes,

> "in the case of an unexpected real oil price increase, the reallocation effect reinforces the recessionary effects of the loss of purchasing power, allowing the model to generate a much larger recession than in standard linear models. In the case of an unexpected real oil price decline, the reallocation effect partially offsets the increased expenditures driven by the gains in purchasing power, causing a smaller economic expansion than implied by a linear model. This means that in the presence of a reallocation effect, the responses of real output are necessarily asymmetric in unanticipated oil price increases and unanticipated oil price decreases."

1.1.3 *The monetary policy response channel*

Another explanation for asymmetric responses of real output to oil price innovations focuses on how monetary policy responds to oil price shocks — see, for example, Bernanke *et al.* (1997). According to this channel, an unexpected increase in the price of oil leads to an increase in the price level, thereby reducing real money balances held by households and firms. The decline in real money balances leads to a decline in aggregate demand through traditional monetary policy effects, such as the *interest rate effect* and the *exchange rate effect*.

For example, the decline in real money balances leads to an increase in real interest rates, which in turn increases the cost of capital, causing a fall in investment spending, thereby leading to a decline in aggregate demand and a decline in output. In addition to interest rate effects, this channel also involves exchange rate effects. In particular, the increase in real interest rates leads to an appreciation of the domestic currency, making domestic goods more expensive than foreign goods, thereby causing a fall in net exports and hence in aggregate demand.

The premise is that the central bank responds to such inflationary pressures associated with unexpected increases in the price of oil by raising the interest rate. This in turn amplifies the economic contraction. Also, the asymmetry arises because the central bank responds vigorously to positive oil price shocks, but does not respond as vigorously to negative oil price shocks.

Regarding this explanation for asymmetric responses of real output to oil price innovations, in the past, when oil prices rose prior to recessions so did interest rates, and as has been argued by Bernanke *et al.* (1997) it was the increase in the interest rate that led to the downturn. However, this view has been challenged by Hamilton and Herrera (2004), who argue that contractionary monetary policy plays only a secondary role in generating the contractions in real output and that it is the increase in the oil price that directly leads to contractions. See also Herrera and Pesavento (2009) and Kilian and Lewis (2011) regarding the 'fragile' empirical evidence in support of the monetary policy response channel.

1.1.4 *The uncertainty channel*

Finally, another indirect transmission mechanism of unexpected oil price changes, focuses on the effects of uncertainty about the price of oil in the future on investment spending. In particular, according to the *real options theory*, also known as investment under uncertainty, uncertainty about the future price of oil will cause firms to delay production and investments. The theoretical foundations of real options are provided by Bernanke (1983), Brennan and Schwartz (1985), Majd and Pindyck (1987), and Brennan (1990), among others.

For example, an increase in the uncertainty about the future price of oil will reduce investment spending that has uncertain future return, is costly to reverse, and for which there is flexibility in timing, thereby leading to a decline in output. In fact, many firm expenditures fall in this category, including fixed investment in large manufacturing facilities (i.e., an automobile plant), investment associated with the hiring and training of labor, investment in equipment that does not have a well functioning secondary market, and investment in energy intensive (i.e., manufacturing) and energy extensive (i.e., mining) industries.

The idea is that the uncertainty effect amplifies the negative effects of positive oil price shocks and also offsets the positive effects of negative oil price shocks, resulting in asymmetric responses of real output to oil price innovations, much like the reallocation effect.

1.2 Testing for Nonlinearity

Most of the empirical work cited as being in support of asymmetric responses of real output to oil price shocks is based on 'slope-based' tests of the null hypothesis of linearity.

Let y_t denote the growth rate of real output ($y_t = \Delta \ln Output_t$) and x_t that of the real or nominal price of oil ($x_t = \Delta \ln Oil_t$). In the context of a forecasting regression, testing the null hypothesis that the optimal one-period ahead forecast of y_t is linear in past values of x_t involves estimating (by ordinary least squares) the following regression

$$y_t = \alpha_0 + \sum_{j=1}^{p} \alpha_j y_{t-j} + \sum_{j=1}^{p} \beta_j x_{t-j} + \sum_{j=1}^{p} \gamma_j \tilde{x}_{t-j} + \varepsilon_t \qquad (1.1)$$

where α_0, α_j, β_j, and γ_j are all parameters, ε_t is white noise, and $\tilde{x}_t$ is a known nonlinear function of oil prices. In equation (1.1), testing for nonlinearity is equivalent to testing the null hypothesis that the coefficients on the nonlinear measure, $\tilde{x}_t$, are all equal to zero — that is, $\gamma_1 = \gamma_2 = \cdots = \gamma_p = 0$. If the joint null of linearity and symmetry in the coefficients can be rejected, then the conclusion is that the relationship is nonlinear.

Mork (1989) was the first to censor the oil price change to exclude all oil price decreases and test the joint null hypothesis of linearity and symmetry, after the dramatic decline in oil prices in the mid 1980s failed to lead to a boom in output growth. In particular, in the context of (1.1), he proposed the following nonlinear transformation of the (real) price of oil

$$\tilde{x}_t = \max\{0, o_t - o_{t-1}\} \qquad (1.2)$$

where o_t is the logarithm of the real price of oil. Mork showed that oil price increases preceded an economic contraction, but he could not reject the null hypothesis that declines in the price of oil did not lead to economic expansions.

Hamilton (1996) refined this approach and captured nonlinearities in the nominal price of oil by the 'net oil price increase' over the previous 12 months (so as to filter out increases in the price of oil that represent corrections for recent declines)

$$\tilde{x}_t = \max\left\{0, \, o_t - \max\left\{o_{t-1}, \cdots, o_{t-12}\right\}\right\} \tag{1.3}$$

with o_t in this case denoting the logarithm of the nominal price of oil ($o_t = \ln Oil_t$). He found that sustained increases in oil prices have more predictive content for real output than transitory fluctuations. Hamilton (2003) reaffirmed this finding, by focusing on net oil price changes over the previous 36 months

$$\tilde{x}_t = \max\left\{0, \, o_t - \max\left\{o_{t-1}, \cdots, o_{t-36}\right\}\right\}. \tag{1.4}$$

A large number of papers have tested the joint null of linearity and symmetry in the slope coefficients of the predictive regression (1.1) and rejected it. For example, Hamilton (2011) builds on Hamilton's (1996, 2003) analysis of the postwar period, and after extending the sample period to include the recent Great Recession, he concludes that the evidence is convincing that the predictive relation between GDP growth and nominal oil prices is nonlinear.

Also, Herrera *et al.* (2011) investigate whether the oil price-output relation is nonlinear by testing the null hypothesis of linearity (and symmetry) in the context of the reduced form (1.1), using monthly United States data on oil prices and 37 industrial production indices (of which 5 represent aggregates). In doing so, they use Mork's oil price increase, as defined by equation (1.2), Hamilton's (1996) net oil price increase over the previous 12 months, as defined by equation (1.3), as well as Hamilton's (2003) net oil price increase over the previous 36 months, as defined by equation (1.4). They reject the null hypothesis of linearity (and symmetry) for a large number of industrial production indices with the evidence against the null appearing stronger when the net oil price increase over the previous 36 months is used.

Finally, recent work by Kilian and Vigfusson (2011a) shows that substantively identical test results are obtained for the real price of oil in the sample period since 1973. That finding holds even using a 'modified' slope-based test developed in Kilian and Vigfusson (2011b) that includes additional contemporaneous regressors in model (1.1). In particular, this modified test is based on the following structural equation

$$y_t = \alpha_0 + \sum_{j=1}^{p} \alpha_j y_{t-j} + \sum_{j=0}^{p} \beta_j x_{t-j} + \sum_{j=0}^{p} \gamma_j \tilde{x}_{t-j} + \varepsilon_t \qquad (1.5)$$

and testing the joint null hypothesis of linearity and symmetry involves testing the null that the coefficients on the nonlinear measure, $\tilde{x}_t$, are all equal to zero — in this case, $\gamma_0 = \gamma_1 = \cdots = \gamma_p = 0$. Kilian and Vigfusson reject the null hypothesis although with slightly larger p-values than Hamilton does. Herrera *et al.* (2011) also report results based on the structural equation (1.5) that are very similar to their results based on the reduced form (1.1).

Thus, there is a consensus that slope-based tests generally support the view that the predictive relationship between the price of oil and U.S. real output is nonlinear.

1.3 Nonlinearity versus Asymmetry

The evidence of nonlinearity based on slope-based tests (either the traditional or the modified ones) has so far been taken as being in support of an asymmetric relation between the price of oil and real output. Recently, however, Kilian and Vigfusson (2011b) argue that slope-based tests focus on the wrong null hypothesis and propose a direct test of the null hypothesis of symmetric impulse responses to positive and negative oil price shocks based on impulse response functions (rather than slopes), arguing that this is the hypothesis of interest to economists. The idea is that asymmetric slopes are neither necessary nor sufficient for asymmetric responses of real output to positive and negative oil price shocks. As Kilian and Vigfusson (2011b, p. 436-437) put it,

> "what is at issue in conducting this impulse-response-based test is not the existence of asymmetries in the reduced form parameters, but the question of whether possible asymmetries in the reduced form imply significant asymmetries in the impulse response function."

In particular, slope-based tests are not informative with respect to whether the asymmetry in the impulse responses is economically or statistically significant. This is because impulse response functions are nonlinear functions of the slope parameters and innovation variances and it is possible for small and statistically insignificant departures from symmetry in the slopes to cause large and statistically significant departures from symmetry in the implied impulse response functions. Similarly, it is possible for large and statistically significant departures from symmetry in the slopes to cause small and statistically insignificant departures from symmetry in the implied impulse response functions. In addition, Kilian and Vigfusson argue that slope-based tests of symmetry cannot allow for the fact that the degree of asymmetry of the response function by construction depends on the magnitude of the shock. In other words, the degree of asymmetry may differ greatly for an oil price innovation of typical magnitude (say, one standard deviation) compared with large oil price innovations (say, two-standard deviation shocks).

Kilian and Vigfusson (2011b) investigate whether the impulse responses of U.S. real GDP over the post-1973 period are asymmetric to oil price increases and decreases and find no evidence against the null hypothesis of symmetric response functions. Also, Kilian and Vigfusson (2011) extend the sample period to include the Great Recession and find no evidence against the null hypothesis of symmetry in the case of shocks of typical magnitude. However, they find statistically significant evidence of nonlinearity when they examine the effects of large (two standard deviation) shocks and discuss the possibility that this evidence could be an artifact of the simultaneous occurrence of the financial crisis

Herrera *et al.* (2011) also use the Kilian and Vigfusson (2011b) impulse-response based test and reject the null hypothesis of symmetric impulse responses with both aggregate and disaggregate monthly industrial production series, for both typical and large shocks, in samples that include pre-1970s data. However, for the post-1973 period they find no evidence against the null of symmetry at the aggregate level, consistent with the results by Kilian and Vigfusson (2011b) for aggregate real GDP, but continue to find some evidence at the disaggregate level in response to large shocks.

Thus, based on the Kilian and Vigfusson (2011b) impulse-response function tests, it appears that for shocks of typical magnitude the nonlinearities in the impulse-response functions are immaterial.

1.4 Modeling Uncertainty

In this book, I focus on the effects of uncertainty about the future price of oil on the level of economic activity and abstract from other possible direct and indirect effects of oil price changes.