Oil prices and the global economy: A causal investigation

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Abstract: In the context of national economies oil shocks have been often considered as exogenous factors causing economic downturns. In this study the context is changed to the global economy. Running cross-correlations, distributed lag-regressions, Granger causality tests, and VAR models applied to annual data 1961-2014, are used to investigate the potential causal effects between oil prices and global economic activity, in both directions. Results provide strong evidence that (a) the relation between oil prices and the global economy has significantly changed since the 1960s to the present; (b) oil prices are endogenously influenced by global economic activity, that is, changes in the global economy produce changes in oil prices; (c) the evidence for a negative effect in the opposite direction, with oil prices affecting the global economy, is weak for the whole sample and very weak for recent decades. These findings are consistent with former results using the Kilian index, which is shown to be a leading indicator of global economic activity. As such the Kilian index is significantly correlated with other indicators of the global business cycle, such as the rate of growth of world economic output and the annual growth of CO_2 global emissions.

1. Introduction

Randomly occurring shocks to productivity by technological change or shocks due to constraints to supply have been often mentioned as the cause of economic disturbances since real-business-cycle models were proposed in the 1980s. The nature of these shocks remains usually unspecified, but oil price shocks are often mentioned as major contributors, if not determinant factors, to explain the recessions occurring after World War II. James Hamilton has been probably the most prominent proponent of the view that recessions of the U.S. economy were related to oil shocks (Hamilton 1988, 2009, 2011). For Hamilton a plausible source of cyclically important supply shocks

> is a disruption in world oil supplies precipitated by political instability. The Suez Crisis of 1956-57, the Arab-Israeli war and the oil production cutback by the Organization of Arab Petroleum Exporting Countries in 1973-74, the Iranian revolution of 1978-79, and the Iran-Iraq war begun in 1980 all led to sharp increases in the world price of oil, and each was followed by a global economic recession. Indeed, a dramatic increase in the price of crude petroleum has preceded (typically by about nine months) all but one of the recessions in the United States since World War II (Hamilton, 1997).

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Hamilton's view is that spikes in oil prices followed by recessions can be interpreted as a causal effect consistent with "the disruption of the pattern of spending by consumers and firms on items whose utilization is sensitive to energy prices and supplies" (Hamilton, 2008). Similar views in which oil shocks were directly or indirectly (by triggering changes in monetary policy) causing downturns of national economies were espoused by many macroeconomists, including for instance Bernanke, Blanchard, Baumol and Blinder (Baumol & Blinder, 2009, p. 216; Blanchard, 2001, pp. 155-158).

The view that oil shocks are also responsible for *recessions of the global economy* has been recently espoused by an IMF publication. Its authors, Kose and Terrones, assert that a sharp increase in oil prices drove the global recession of 1975, that oil price shocks played significant roles in the global recessions of 1982 and 1991, and in the run up to the global recession of 2009 oil prices "also increased sharply (spiking to $133 a barrel in July 2008 from $53 in January 2007)" (Kose & Terrones, 2015, pp. 44-47). In considering oil shocks as causes of global downturns Kose and Terrones follow what was proposed long ago by Blanchard (Blanchard, 2001).

Versus the view that oil-price shocks are exogenous to the economy, determined by maneuvers of the producer nations, or political events like wars and revolutions, it has been argued that actually movements in oil prices are to a large extent endogenously determined by the demand for oil in international markets; the world economy itself would be only moderately responsive to changes in oil price (Barsky & Kilian, 2004; Kilian, 2009).

This investigation examines whether oil prices can be considered exogenously determined in a framework in which the unit to be analyzed is the wider system of which all national economies are part, the world economy. The analysis focuses on annual data of (a) real oil prices and (b) world economic output, as measured by global GDP.

Figure 1 shows how strongly correlated are the rates of growth of the US and the world economy. In the recessions of the US economy in 1974-1975, in the early 1980s, in 1991 and in 2001, the annual rate of growth of the US economy reached negative territory. Though in these occasions the global economy continued expanding, in each of them the rate of growth of the world economy had major dips. I have argued elsewhere (J. A. Tapia Granados, 2014) that these four episodes in the mid-1970s and in the early years of the next three decades can be considered indeed recessions or crises of the world economy. My claim is that these four episodes together with the slump of 2009, when the output of the US and the world economy shrank respectively by 2.8% and 2.1% (Table 1, Figure 1), constitute five crisis of the world economy. In other terms, they are the most recent troughs of the world business cycle. To organize this framework these global recessions can be named according to monikers already in use—even if they are quite improper. Thus we have the First and Second Oil Crises, respectively in the mid-1970s and the early 1980s, the Crisis of the Soviet Bloc Breakdown in the early 1990s, the Asian-Latin American Crisis at the turn of the century, and the Great Recession of 2008-2009.

Table 1. Annual growth of the world economy (gW, %) and annual mean price of crude oil in US dollars of 2009

Year	gW	Oil price	Year	gW	Oil price
1961	4.3	10.16	1988	4.7	24.05
1962	5.6	10.04	1989	3.8	28.29
1963	5.2	9.93	1990	3.0	35.50
1964	6.6	9.78	1991	1.4	28.96
1965	5.5	9.60	1992	1.9	27.35
1966	5.9	9.34	1993	1.6	23.47
1967	4.5	9.08	1994	3.1	21.42
1968	6.1	8.71	1995	2.9	22.58
1969	5.8	8.30	1996	3.3	26.93
1970	4.3	7.88	1997	3.7	24.45
1971	4.1	9.33	1998	2.6	16.11
1972	5.6	9.91	1999	3.4	22.44
1973	6.4	12.46	2000	4.3	34.80
1974	1.7	40.26	2001	1.8	29.15
1975	0.8	36.68	2002	2.1	29.40
1976	5.1	38.60	2003	2.8	33.27
1977	4.0	39.54	2004	4.1	42.97
1978	4.3	37.21	2005	3.6	59.18
1979	4.1	77.49	2006	4.1	68.97
1980	1.8	82.80	2007	3.9	74.70
1981	2.1	73.84	2008	1.5	98.43
1982	0.4	63.87	2009	-2.1	61.86
1983	2.7	55.07	2010	4.1	78.67
1984	4.6	51.80	2011	2.8	107.39
1985	3.8	48.06	2012	2.2	106.45
1986	3.2	24.66	2013	2.4	101.97
1987	3.6	30.77	2014	2.5	91.34

Rates of growth of the world economy are from the World Development Indicators database of the World Bank. Oil prices 1960-2000 in current dollars were taken from *BP Statistical Review of World Energy* 2010, prices 2001-2014 correspond to Dated Brent, from www.indexmundi.com/commodities/?commodity=crude-oil-brent&months=180. They were converted into 2009 dollars using the US GDP deflator.

An eyeball examination of the relation between movements in oil prices and changes in the rate of growth of the world economy (Figure 2) does not provide much evidence of a strong link between changes in oil prices and the world economy. Certainly in the recessions of 2001 and 2009 both oil prices and the world economic output dropped after having been rising together during the previous years of expansion. But in 1973-1974 oil prices grew at the same time that the world economy quickly decelerated and in the period 1980-1995 both variables seem to follow quite independent trajectories. In spite that the global downturns of the mid-1970s and early 1980s have been repeatedly blamed on oil shocks, particularly those caused by the actions of the Organization of Petroleum Exporter Countries (OPEC), no less an authority on oil issues as Robert Mabro wrote that "despite appearances to the contrary the price rises of 1973, 1979-80 and 1990 were fundamentally market phenomena although OPEC claimed, in macho style, kudos for the achievement and suffered the associated odium" (Mabro, 1992).

Spikes of oil prices in the years leading to these recessions were preceded by large increases in the world demand for oil and furthermore "the impact of demand on the movement of oil prices is also evident during periods of oil price decline" (Balardini, 2010). Thus, the longest period of falling oil prices during six consecutive years since 1981 (see Figure 2) occurred coinciding with the only episode in which in the past 40 years world demand for oil decreased for four consecutive years, 1981-1984 (Balardini, 2010).

The analyses in the present investigation show that the relation of crude oil prices with the global economy has considerably changed since the 1960s and add to the view that oil prices are largely endogenous to the world economy. Available world GDP data for the period 1961-2014 show that an expanding world economy *causes* rising oil prices, as well as a stagnant or contractionary oil economy *causes* cheapening of oil. The statistical analysis also provides some weak evidence that considering the period 1961-2014 oil prices have had a lagged effect on the world economy, so that falling oil prices stoked the world economy and rising prices dampened it. However, focusing in the past three decades, the evidence that oil prices have a negative effect on the rate of growth of the world economy is very weak; contrarily, the evidence that the level of global economic activity has a positive effect on the growth of oil prices is particularly strong.

The paper's structure is as follows. The next four sections present descriptive statistics as well as results of distributed lag regressions, Granger causality tests, and VAR models; section 6 discusses identification and causality issues, and section 7 concludes. Issues of stationarity of the series used in the analysis are examined in the Appendix, where I present results of additional analyses using series detrended with the Hodrick-Prescott filter.

2. Descriptive statistics and correlation analysis

In the period 1961-2013[4] real prices of crude oil—in 2009 US$ per barrel, Table 1— oscillated over a mean of $39.73, with a standard deviation of $28.88. Significant price increases occurred in 1972-1974, when prices multiplied fourfold (Table 1, Figure 2), in 1978-1979, when they doubled, and in the decade leading to the Great Recession when prices multiplied sixfold from $16.11 in 1998 to $98.43 in 2008. Only after the Great Recession prices went briefly over $100 per barrel, to drop steadily during 2015. Volatility of oil prices has gone down, as the coefficient of variation of real oil prices was 91.5% in 1960-1979, 52.3% in 1980-1999, and 42.9% in 2000-2014.

Correlations between the annual rates of growth of world GDP and crude oil price reveal a changing pattern. In 30-year samples (Figure 3) or 20-year samples (Figure 4) starting before the mid-1970s, correlations show a null or even negative correlation between the two variables (Figures 3 and 4, top left panels). Then with the passage of time a positive correlation appears, so that in samples including the years 1975-2014 world economic growth and change in oil prices correlate significantly. The lag-zero positive correlation between the oscillations of the world economy as measured by growth of world GDP and the changes in oil prices is thus a phenomenon of the most recent decades.

Lag correlations suggest mutual and changing influences between the world economy and oil prices. In 30-year samples starting before the mid-1970s the growth of oil prices was negatively correlated with the growth of the world economy next year (Figure 3, left mid panel). This is strongly suggestive that at that time increases in oil prices had a dampening effect on the world economy while declining oil prices worked as a stimulus for world economic activity. After the mid-1970s this effect seems to occur with a longer lag, as the correlation between oil prices and world economic growth 2 or 3 years later, which had been statistically zero before the mid-1970s, becomes negative and, at least at marginal levels, significant (Figure 2, middle center and right panels).

Examining correlations that would be suggestive of causality in the other direction, it seems that world economic growth was in the past a clear stimulus for the increase of oil prices, as in 30-year samples starting before the mid-1970s world economic growth had a positive and statistically significant correlation with change in oil prices next year (Figure 3, left bottom panel). This correlation, however, disappears in more recent decades. At longer lags of 2 or 3 years (Figures 3 and 4, bottom row) the growth of the world economy does not correlate significantly with change in oil prices—which is evidence against any causal effect. With a 4-year lag the world economy and oil prices are totally uncorrelated (Figures 3 and 4, center and right top panels), which is evidence against any of them having an effect on the other at this lag.

3. Lag regressions

To further explore the potential effects of changes in world economic activity on oil prices regressions of the annual growth of oil prices on the present value and lag values of the rate of growth of the world economy were computed. Then the explanatory and the dependent variables were switched to explore potential influences in the opposite direction. Eleven specifications were computed, including one without any lagged value of the explanatory variable, another one with one lagged value, and so on until ten lagged values. To be able to compare the goodness of fit of specifications—to choose the specification with the number of lags of the covariate that provides the best fit—specifications must have the same set of data for the dependent variable, so dependent variable data from 1971 to 2014 were used to have up to 10 available lags (1961-1970) for the explanatory variable.

Both for models of world economic growth regressed on growth of oil prices and for models of growth of oil prices regressed on world economic growth, the specification which minimized all criteria of goodness of fit (AIC, AICC, HQC and SBC) included just covariates at lags 0 and 1. That is:

$$gW_t = \underset{(0.233)}{3.103} + \underset{(0.005)}{0.005}\ gOIL_t - \underset{(0.005)}{0.010}\ gOIL_{t-1} \qquad R^2 = 0.11 \qquad \text{Durbin-Watson } d = 1.45 \qquad [1]$$

$$gOIL_t = -\underset{(16.83)}{25.45} + \underset{(4.22)}{1.38}\ gW_t + \underset{(4.20)}{10.50}\ gW_{t-1} \qquad R^2 = 0.15 \qquad \text{Durbin-Watson } d = 2.18 \qquad [2]$$

where gW_t is growth of the world economy at year t, $gOIL_t$ is growth of oil prices at year t, figures in parenthesis below parameter estimates are standard errors, and equation errors are omitted.

With a sample reduced to the period 1990-2014, also the specifications with only one lagged value of the explanatory covariate minimize the information criteria, indicating best fit. The corresponding equations are the following:

$$gW_t = \underset{(0.235)}{2.483} + \underset{(0.009)}{0.035}\ gOIL_t - \underset{(0.009)}{0.008}\ gOIL_{t-1} \qquad R^2 = 0.42 \qquad \text{Durbin-Watson } d = 1.61 \qquad [3]$$

$$gOIL_t = -\underset{(11.40)}{25.97} + \underset{(2.98)}{11.27}\ gW_t + \underset{(2.94)}{1.18}\ gW_{t-1} \qquad R^2 = 0.40 \qquad \text{Durbin-Watson } d = 1.77 \qquad [4]$$

Considering the results for the general sample, the estimated equations [1] and [2] indicate that the ability of world economic growth for predicting growth of oil prices is slightly higher than the ability of oil prices to predict world economic growth, 15% vs 11%. But in the general sample oil price has a significant negative effect (-0.010 ± 0.005) on world economic growth next year, while in the restricted sample 1990-2014—equations [3] and [4]—the significant effect of oil prices on world economic growth (0.035 ± 0.009) is at lag 0 and positive, and the lag 1 effect is negative and not statistically different from zero (-0.008 ± 0.009). It must be also noticed that the models computed for the restricted sample (equations [3] and [4]) have a much higher ability to explain the depended variable, over 40%, than the models computed with the general sample, which predict 15% or less of the variation of the dependent variable.

Assuming zero growth of the world economy in two consecutive years *t*-1 and *t*, the oil price model (either with the general or the restricted sample, i.e., equation [2] or [4]) predicts a decrease of about 25% in oil prices. In the restricted sample model (equation [4]) two consecutive years of world expansion at a rate of say, 4% (more or less the rate of expansion of the world economy in the years immediately before the Great Recession), would be associated with a rise of $-25.97 + 11.27 \cdot 4 + 1.18 \cdot 4 =$ 23.8% in oil prices. In the expanded sample model (equation [2]) the corresponding rise in oil prices would be very similar, 22%.

While the model estimated with the general sample (equation [1]) predicts world economic growth of 3.1% after two consecutive years of zero growth in oil prices, two consecutive years of 100% growth in oil prices would reduce world growth to a rate of 2.6% ($= 3.103 + 0.005 \cdot 100 - 0.010 \cdot 100$). That is, major changes in oil changes predict a relatively small change in global economic growth.

Equation [3] estimated with data from the past quarter century predicts a positive effect of rising oil prices on the world economy. Thus a 100% oil price increase during two consecutive years would be associated with an expansion of 5.2% of the world economy ($= 2.483 + 0.035 \cdot 100 - 0.008 \cdot 100 = 5.183$). Of course, to take this at face value would be naïve. The lag-0 positive statistical effect of oil prices on the world economy (0.035 ± 0.008) in equation [3] rather than indicating a stimulating effect of rising oil prices on the world economy must be picking the high lag-zero correlation of recent decades between changes in oil prices and changes in the world economy, which corresponds to the statistically significant lag-0 effect of the world economy on oil prices (11.27 ± 2.98) in equation [4]. It will be discussed later that these lag-0 correlation and effects in regression models are more appropriately interpreted as evidence of causality from the world economy to oil prices.

On the assumption that the lag-0 positive and statistically significant effect of oil prices on world economic growth is likely a spurious result of causality in the opposite direction, for identification purposes that effect can be set to zero to compute models in which world economic growth is a function of just *lag* values of growth in oil prices. For such kind of regression, computed for the sample 1971-2014, all information criteria are minimized by the model with just lag 1,

$$gW_t = \underset{(0.23)}{3.16} - \underset{(0.005)}{0.010}\, gOIL_{t-1} \qquad R^2 = 0.09 \qquad \text{Durbin-Watson } d = 1.35 \qquad [5]$$

in which the effect of oil prices on the world economy is very small and barely significant (P = 0.050). For the sample 1990-2014 the information criteria are minimized by the specification in which gW_t is regressed on just $gOIL_{t-1}$. In this specification the effect of $gOIL_{t-1}$ on gW_t is statistically zero (−0.007 ± 0.012). All this is quite inconsistent with oil prices having an effect on the rate of growth of the world economy particularly in the most recent decades.

To explore potential nonlinearities in the effect of oil prices of the world economy equation [5] was expanded by adding as covariate the square of the change in oil prices either in year t or in year t – 1. In both cases the added covariate had a non-significant effect.

Table 2. Results of G-causality tests. The null hypothesis in test 1 is that oil prices are not influenced by the world economy; in test 2 the null hypothesis is that the world economy is not influence by oil prices. AR is the autoregressive order of the test model

AR	Test 1	Test 2
1	†	**
2		*
3		*
4		*
5		*
6		†
7		†
8		
9		
10		
11		
12	*	
13	*	
14		
15		
16		
17		

The sample includes 1961-2014. For AR orders above 17 the number of data points was insufficient for the model to be computed. *P<0.05, **P < 0.01, ***P<0.001, †P<0.1.

4. Granger causality

Using the whole set of annual rates of growth of oil prices and the world economy, tests provide evidence of G-causality from oil prices to the world economy in specifications including five or less lags (Table 2). In the other direction, G-causality from the world economy to oil prices is supported by a marginally significant P-value in the specification including just one lag. Specifications including 12 and 13 lags are consistent with evidence that the world economy predicts oil prices, but the fact that they appear isolated among specifications with more or less lags in which G-causality is rejected suggests that they are likely to be false positives (Eichler, 2006).

Testing G-causality in different samples (Table 3) reveals that for autoregressive (AR) orders of 5 or less, G-causality from world economic growth to oil prices is found in samples not including recent years (Table 3, left panel). This is consistent with the fact that correlations of lagged world economic growth and present change in oil prices are basically zero in both 30-year and 20-year samples starting after 1975 (Figures 3 and 4, bottom row).

G-causality from oil prices to world economic growth is found in basically all samples when the AR order is 1 and the sample does not include recent decades. For any AR order, samples including the three or four past decades do not support G-causality from oil price change to growth of the world economy.

Table 3. Results of G-causality tests in 30-year samples for specifications of autoregressive order between 1 and 5

First year of the window	H_0: the growth of oil prices does not depend on the growth of the world economy					H_0: the growth of the world economy does not depend on oil prices				
	Autoregressive order					Autoregressive order				
	1	2	3	4	5	1	2	3	4	5
1961	†					*	†	†	*	*
1962	†					*	†		†	†
1963	†					*	†		†	
1964	†	†				*	†		†	
1965	*	†				*	†		†	
1966	*	*		†	†	*	†		†	
1967	*	*	*	†	†	*			†	
1968	*	*	*	*	†	*				
1969	**	**	*	*	*	*				
1970	**	**	**	*		†		†		
1971	**	**	**			*				
1972	**	*				*				
1973	**					*				**
1974						*		*	**	*
1975							*	**	*	**
1976							*	**	*	**
1977								*		**
1978										*
1979						†		†		
1980										
1981										
1982						†				
1983						†				
1984										

*P<0.05, **P < 0.01, ***P<0.001, †P<0.1.

Thus the evidence of G-causality between changes in the price of oil and growth of the world economy is mostly restricted to samples that exclude the years after the mid-1970s. Since G-causality tests only consider the effect of past but not present values of the supposedly causal variable, this would be consistent with a causal relation between world economic growth and oil prices which in an annual timeframe occurs in recent decades exclusively at lag zero.

5. VAR models

In VAR models including the whole sample 1961-2014, information criteria (AIC, AICC, HBP, and FPEC) are minimized by including just one lag and no moving average term (p=1, q = 0). The estimated VAR equations (error terms omitted) are as follows:

$$gW_t = \underset{(0.06)}{0.92}\, gW_{t-1} - \underset{(0.006)}{0.013}\, gOIL_{t-1} \qquad [6]$$

$$gOIL_t = \underset{(1.40)}{3.08}\, gW_{t\text{-}1} - \underset{(0.14)}{0.01}\, gOIL_{t\text{-}1} \qquad [7]$$

With samples restricted to more recent years the VAR model cannot be computed unless the sample includes at least years from 1985 to 2014. In this sample the estimated equations are:

$$gW_t = \underset{(0.10)}{0.93}\, gW_{t\text{-}1} - \underset{(0.01)}{0.03}\, gOIL_{t\text{-}1} \qquad [8]$$

$$gOIL_t = \underset{(1.63)}{2.06}\, gW_{t\text{-}1} - \underset{(0.20)}{0.10}\, gOIL_{t\text{-}1} \qquad [9]$$

In both the general and the restricted sample there is a small and barely significant negative effect of the change of oil prices at time *t*-1 on global economic growth at time *t*. But the correlation of VAR residuals at lag 0 in the 1961-2014 model (equations [6] and [7]) is -0.14 while in the model 1985-2014 (equations [8] and [9]) is 0.39. This high correlation of residuals at lag 0 in the 1985-2014 VAR indicates that unexplained innovations in both variables are consistently moving in the same direction.

Impulse response functions computed for VAR models of AR order 1 or 2 reveal sustained and significant positive responses (Figure 5) of oil prices to the world economy for several years after the innovation in global economic activity, while the negative response of the world economy to oil prices is small and mostly non-significant in the years following the innovation in oil prices.

6. Identification and causality

In the past three decades the annual rates of growth of oil prices and world economic activity have been highly correlated. For the sample 1985-2014 the correlation is 0.44 (P = 0.014), while correlations of each of these variables with the other one lagged one year are far from being significant. G-causality tests suggest that lagged values of each variable have presently little ability to help predicting the other value, though they had more ability in samples including the 1970s and 1960s. VAR models suggest positive responses (Figure 5) of oil prices to the world economy and a small and mostly non-significant response of the world economy in the years following innovations in oil prices. Is it possible to interpret this array of statistical evidence in terms of causality and identify the actual relation between the two variables?

Cross-correlations, distributed lag regressions, G-causality tests and VAR models suggest that both oil prices and the level of activity of the global economy had a lagged effect on each other in the expected direction. That is, while growth of oil prices was followed by dampened world economic activity, the growth of the world economy was followed by rising oil prices. Both associations seem to reflect lagged causal effects, but statistically these lagged effects appear strongly diminished in recent decades in which basically only a lag-zero correlation persists. Is this lag-zero positive correlation indicative of causality?

Since John Stuart Mill it is accepted that the explanation of two variables being associated in their movements is one causing the other if a third variable is not the cause of both (Mill, 1846; Pearl, 2000). In the modern language of direct acyclical graphs (DAGs) the three sources of statistical association are causation, confounding, and endogenous selection (Elwert, 2013). Thus a lag-0 association between world economic activity gW and change in oil price gO could be explained by

(a) a causal relation, either gW causing gO (gW → gO), or gO causing gW (gO → gW);

(b) a situation of confounding in which the association is spurious because a third variable X is causing both gW and gO (that is gW ← X → gO); or

(c) a situation of endogenous selection, in which both gW and gO cause X, which is a collider (that is gW → X ←gO).

For endogenous selection bias to occur the prerequisite is conditioning on an endogenous variable (Elwert, 2013). But the association between gW and gO first occurs in models in which no other variable is included, and second, the way gW is computed from estimates of the world economic output and gO is calculated from observed oil prices excludes any possibility of a common source of bias. It seems therefore endogenous selection must be excluded.

Confounding would imply a third variable causing a change of both oil prices and the world economy in the same direction. The existence of such a variable looks very unlikely. Political changes affecting at the same time and in the same direction oil prices and the level of activity in the global economy do not seem credible. The precautionary demand for crude oil has been extensively discussed as a reason for sharp increases in the price of oil when the supply of oil is inelastic and political events like wars or the threat of war in the Middle East led to oil consumers to demand more oil for being suspicious about future supply. But for this mechanism to generate a lag-0 positive correlation between oil price and global economic growth the same uncertainty generating demand for oil should led to happy consumers expending more, or enthusiastic animal spirits leading to increased investment. All of which is highly hypothetical. Thus confounding seem a very unlikely possibility and the only plausible explanation of the lag-0 correlation between gW and gO seems a causal link gW → gO, with global economic activity being the cause of changes in oil prices. Interpreting the lag-0 correlation as a manifestation of causation in the opposite direction, gO → gW, would mean that rising oil prices stimulates the growth of the global economy, something that is inconsistent with economic theory of any kind.

(Hamilton, 2008) has proposed nonlinearities to keep up the view that oil price shocks are responsible of economic downturns. As Hamilton puts it, whether oil shocks

> are operating through an effect on demand for items such as less fuel-efficient cars, the influence would depend not just on the size of the oil price increase but also the context in which it occurred (...) When oil prices go up, consumers may postpone their car purchases, but when oil prices go down, they do not go out and buy a second car. In fact, it is a theoretical possibility that, as a result of the output that is lost from trying to reallocate capital and labor, the short-run effect of an oil price decrease would actually be a decline rather than an increase in output.

Hamilton has also criticized the idea that economic expansions may produce a surge in oil prices,

> so that both the oil price increase and the subsequent recession result from the same business cycle dynamics. This is difficult to reconcile with the fact that, at least for the early post-war period, oil price changes could not be predicted from earlier movements in other macro variables (...), and that most of the oil spikes can be attributed to exogenous events such as military conflicts (Hamilton, 2008).

Now, Hamilton's assertion that for the early post-war period oil price changes cannot be predicted from other macroeconomic variables is not consistent with the fact that in 30-year samples starting until the early 1970s, world GDP growth lagged one or two years is predictive of oil prices, as shown by both G-causality tests (Table 3) and simple correlations (Figure 3, left bottom panel). On the other hand, Hamilton proposes nonlinearities which would be responsible for triggering effects of increasing (or decreasing!) oil prices on the economy. But these nonlinearities leave unexplained the strong positive lag-0 correlation between changes in oil prices and world economic growth of recent years. Versus an appeal to complex nonlinearities, a quite parsimonious explanation is that oil prices rise or decline respectively in expansions and downturns of the global economy because respectively rising or declining demand for energy and oil.

Evidence obtained in the analysis of annual data 1961-2014 in this investigation leads to conclude that oil prices are endogenous, which is confirmative of the analysis by Lutz Kilian, who analyzed the relation between global economic activity and oil prices in a monthly timeframe for the years 1973-2007 (Kilian, 2009). Kilian created an ingenious index of global economic activity based on rates of cargo shipment. Since cargo shipment rates are low when demand for transportation of commodities is low in global downturns and they rise when there is more demand for transportation of commodities, and more demand for transport means more economic activity worldwide, a composite index of cargo rates can provide an index of activity in the global economy. Kilian showed that his index had a high explanatory ability to predict changes in oil prices.

The Kilian index in both annual and monthly timeframes is indeed highly correlated with oil prices (Figure 6). For the years 1973-2007 in which the Kilian index is publicly available, the correlation between the annual mean of the Kilian index and the annual real price of oil is 0.40 at lag 0 (n=35, P=0.017) and 0.56 (n=35, P= 0.0005) when the index is lagged one year. The correlation decays at longer lags and with the index lagged 3 years is already statistically insignificant. Lagging one year oil prices with respect to the Kilian index, the correlation is just 0.06 (n = 35, P = 0.75). The correlation of the index with the annual rate of growth of oil prices is 0.59 (n = 35, P = 0.0002) which declines to 0.38 when the index is lagged one year and is not significant at longer lags. Also, when the rate of growth of oil price is lagged just one year, it correlates only 0.18 (n=35, P= 0.31) with the Kilian index.

Using data for the months 1973:2-2007:12, the Kilian index correlates with monthly averages of real prices of crude oil 0.37 at lag zero (n = 419, P <0.0001), but the crosscorrelation increases when the index is lagged, reaching its highest value, 0.47, at lag 11 (n = 408, P < 0.0001). The correlation is still significant at lags of more than 30 months, suggesting an extended effect of the level of global economic activity on the price of oil. Lagging instead the price of oil, the crosscorrelation with the Kilian index decreases rapidly, and it is no longer significant at the usual levels of confidence when the price of oil is lagged 10 months. The asymmetries in these crosscorrelations, with lagged oil price (or oil price change) correlating zero with the Kilian index while the lag Kilian index correlates significantly positive with oil price (or oil price growth) argue in favor of causality from economic activity—proxied by the Kilian index—to oil prices, and against causality in the opposite direction.

The Kilian index and the rate of growth of the global economy as estimated by the World Bank are validated as measures of global economy activity by being strongly correlated between them and with other indicators of global economic activity. Though the correlation between the Kilian index and the rate of growth of the global economy at lag zero is just 0.23 ($n = 35$, $P = 0.180$), the index correlates 0.45 with the growth of world GDP lagged one year (n=35, $P = 0.006$). This shows that the Kilian index is indeed a leading indicator of the business cycle of the global economy. An additional validation of the Kilian index and the World Bank estimate of global economic growth is given by their correlations with the growth of global emissions of CO_2. Both national and global emissions of CO_2, estimated by the Carbon Dioxide Information Analysis Center (CDIAC) from consumption of fossil fuels, production of cement, etc., depend tightly on the level of activity in the respective economy (Tapia Granados & Carpintero, 2013; Tapia Granados, Ionides, & Carpintero, 2012). Therefore any index of annual economic activity at the global level should correlate with the annual growth of global emissions of CO_2. Indeed in the period 1973-2007 for which the Kilian index is available, the annual growth of global CO_2 emissions correlates 0.72 ($P < 0.0001$, $n = 35$) with the rate of growth of global output at lag zero, while the annual Kilian index correlates 0.23 ($P = 0.18$) with the growth of CO_2 emissions at lag zero and 0.45 ($P = 0.007$) with the rate of global emissions lagged 1 year. This provides a further confirmation that the Kilian index is a leading indicator of global economic activity.

The results of this paper raise the issue of why in an annual timeframe the lagged effects between world economic activity and oil prices have mostly disappeared to be substituted by be a contemporaneous association that has to be interpreted as a causal effect of the world economy—and therefore, world demand for energy—on oil prices. A possible explanation would be a decreasing capacity of oil supply to respond to increases in oil demand. Total consumption of oil almost doubled from the 1950s to 2013 (from 50 million barrels per day in the early 1950s to 91 mb/d in 2013) and the increase was only momentarily reversed in the early 1980s and in 2008-2010, during two major crisis of the world economy. With demand steadily climbing in the long run, production in the past two decades declining in a number of major producers, and OPEC's spare production capacity declining since the mid-1980s (Fattouh, 2006), it seems plausible that slack production capacity is becoming increasingly tighter (Robert S. Strauss Center for International Security and Law, The University of Texas at Austin, 2015). But this issue is beyond the scope of this investigation.

7. Conclusion

Annual data 1960-2014 of world GDP and oil prices show that the relation between both variables has substantially changed during the past five decades. The evidence presented here suggests that analyses assuming stability of parameters for a long period are problematic. At any rate, results are consistently suggestive that global economic growth is a major determinant of crude oil prices. For the whole period since the 1960s to the present, spikes and drops of oil prices are largely explained by upturns and downturns of the global economy, but this effect is even more intense in the past three decades. On the other hand, evidence of a stimulating effect of cheap oil on the global economy—or a dampening effect of expensive oil—is weak considering the whole sample, and very weak for recent decades. These results are consistent with the fact that the demand for oil is tightly connected with economic activity and oil prices are responsive to the global demand of oil. Because demand for oil is tightly connected with the world demand for energy, it is also correlated with the level of industrial activity, trade and transportation of goods, services, and people, as proxied for example by the global emissions of CO_2 or the rates of cargo shipment summarized in the Kilian index.

Acknowledgement

I am grateful to Lutz Kilian for clarifications on his index, as well as for his comments on several issues. Duncan Foley also offered useful comments on a former draft. The usual disclaimers apply.

Figure 1. Annual rates of growth (%) of the world economy (gray line) and the US economy (black dots)

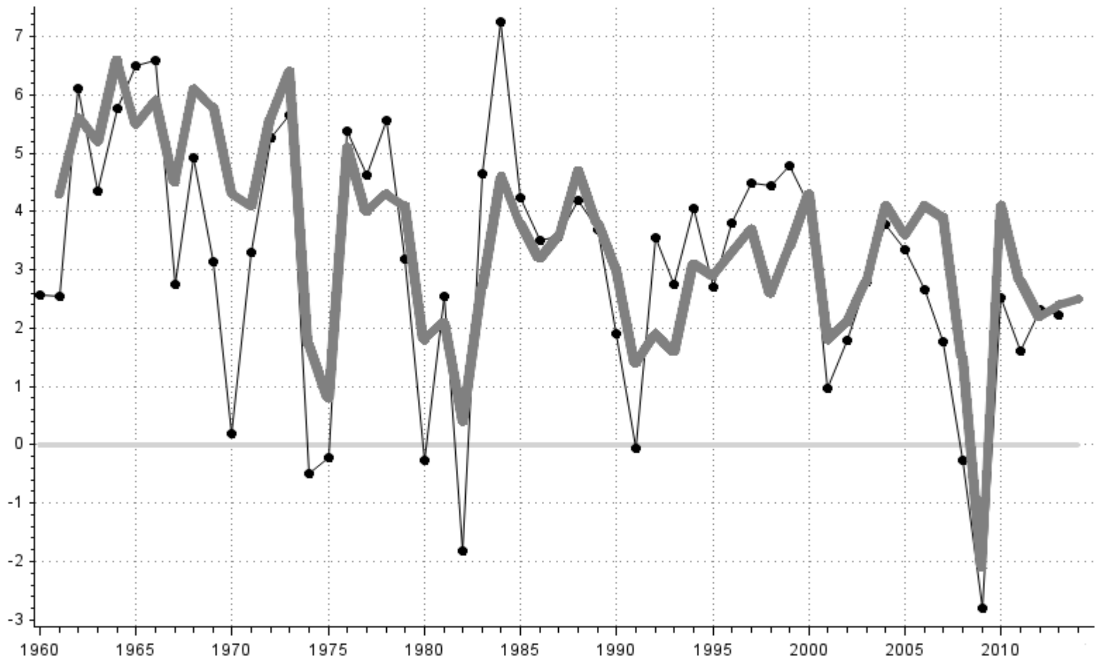


Figure 2. Annual rates of growth (%) of the world economy (left scale) & oil prices (right scale)

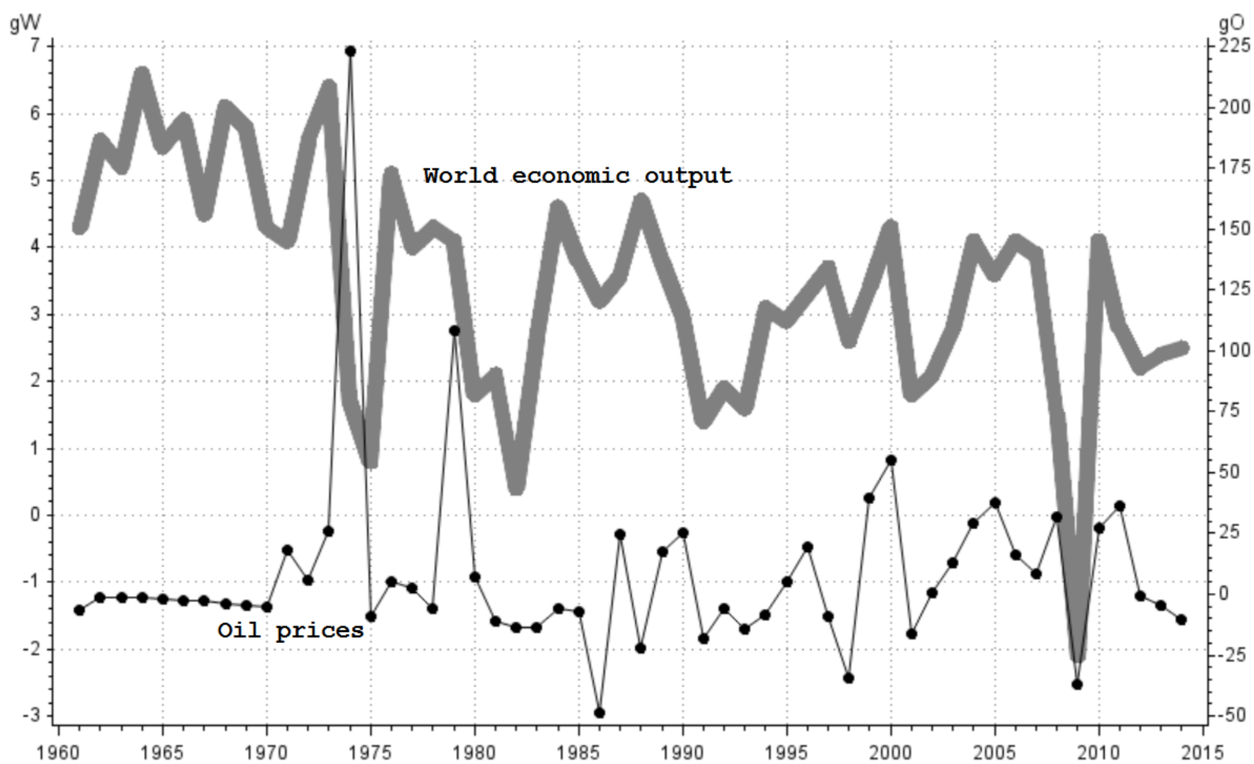


Figure 3. Correlations between the annual rates of growth of oil prices (gOIL) and the world economy (gW) at lags 0 to 4. The dotted line is the correlation computed in 30-year samples starting at the year indicated in the horizontal axis, the smooth lines are the upper and lower limits of a 95% confidence band

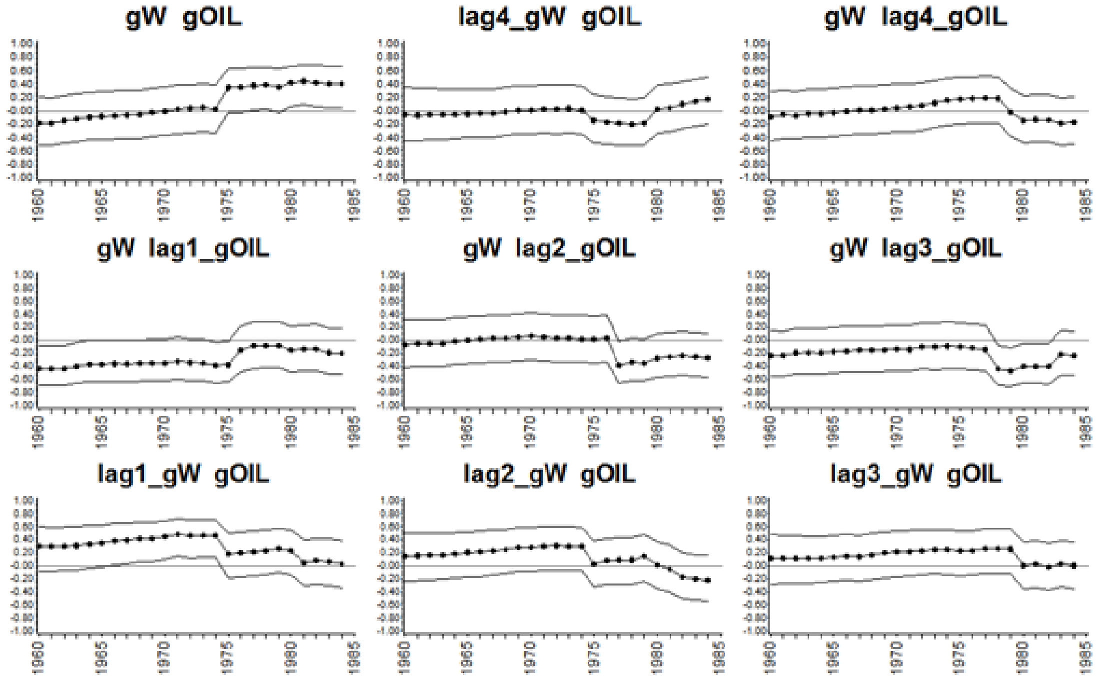


Figure 4. Correlations between oil prices and world economic growth at lags 0 to 4. All specifications as in Figure 3 but with 20-year rather tan 30-year samples

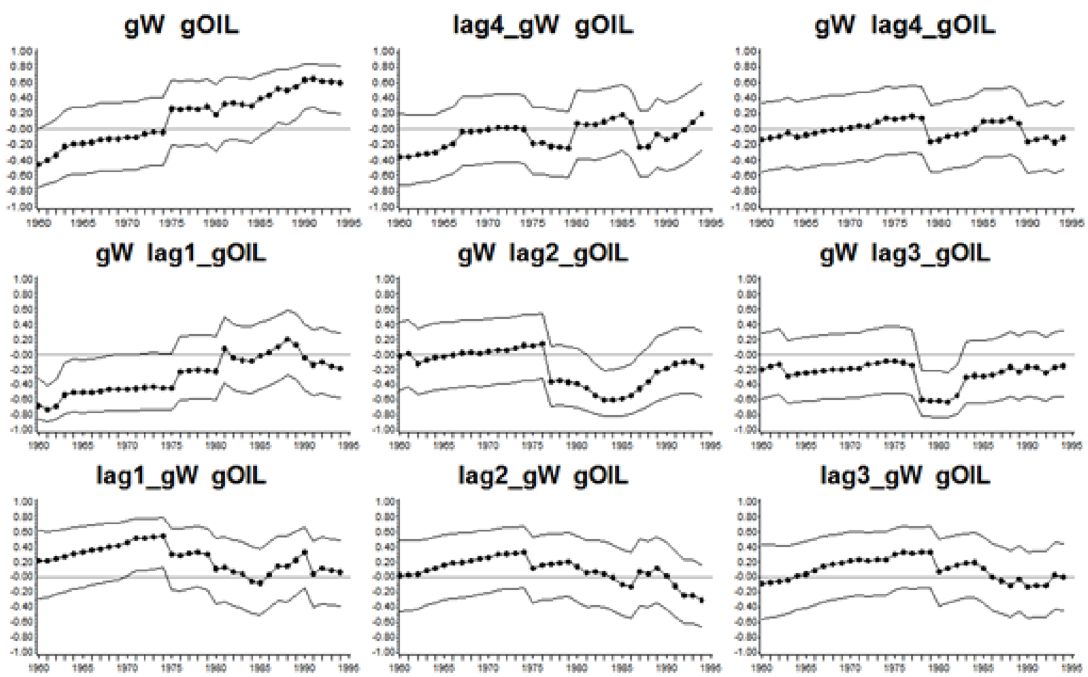
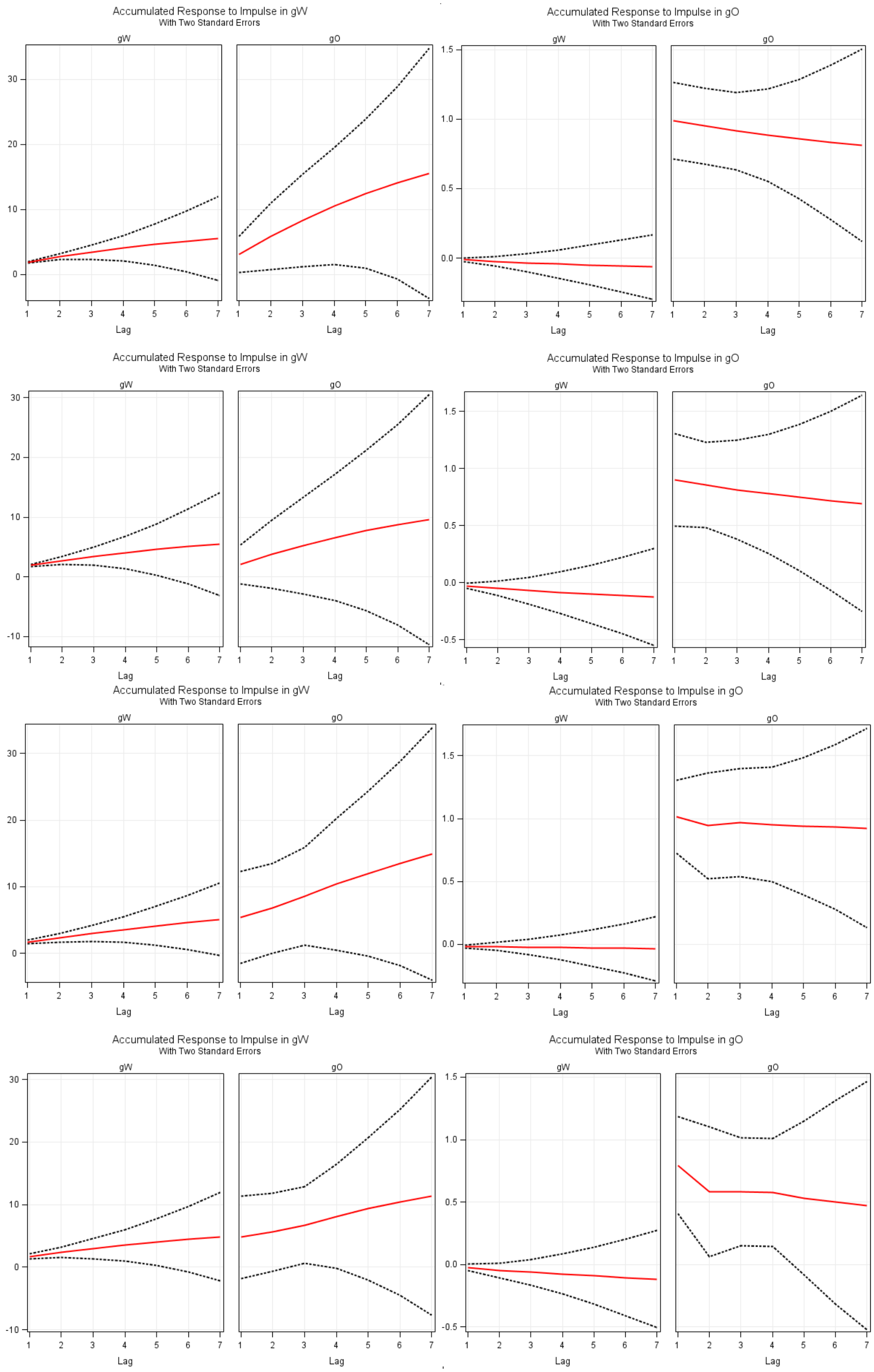


Figure 5. Impulse response graphs in VAR models for the general sample 1961-2014 and a restricted sample 1985-2014, and autoregressive order p=1 and p=2



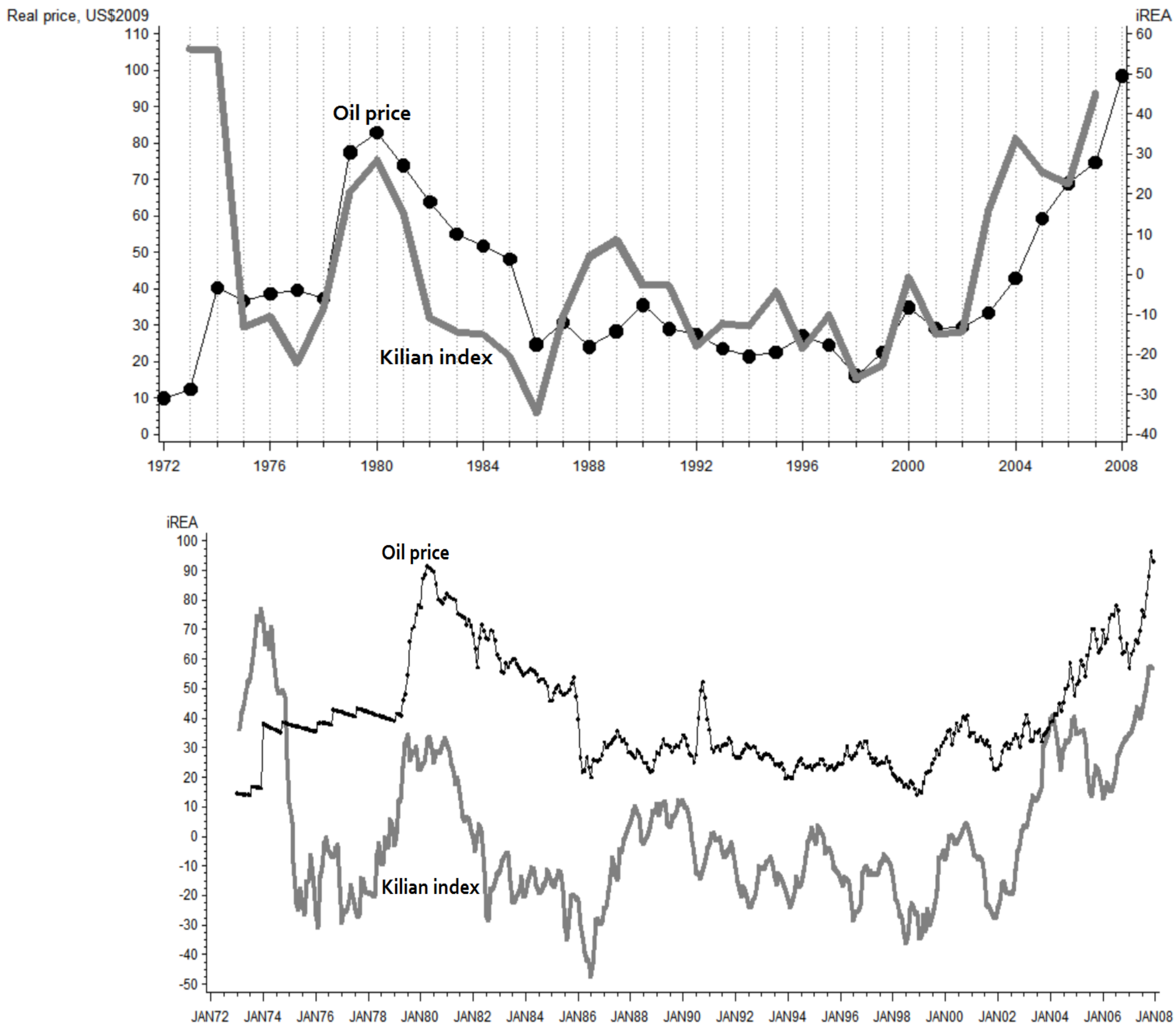
p=1
1961-2014

p=1
1961-2014

p=2
1961-2014

p=2
1985-2014

Figure 6. Kilian index of world economic activity and oil prices, annual (top panel) and monthly values (bottom panel). The correlation is 0.40 for the top panel of annual data (n=35, P = 0.017) and 0.37 for the bottom panel of monthly data (n=419, P<0.0001)



Appendix

Some of the statistical tests in this paper rely on the assumption that annual rates of growth of both real oil prices and the world economy are stationary series. Testing of stationarity of these two series provides strong evidence that the annual rate of growth of oil price is a stationary series, as for a reasonable number of lags included in the regression the ADF test systematically rejects the hypothesis of a unit root (results not shown). Only for very large lags (over 4 years) some P-values greater than 0.05 are found, compatible with a unit root. However, in the case of the annual rate of growth of the global economy, including less than 4 lags in the test some *P*-values are found that do not allow rejecting the hypothesis of a unit root at the usual levels of statistical confidence (Table A1). Thus for instance, for a zero mean ADF test with only one lag included in the regression, the hypothesis of a unit root cannot be rejected ($P = 0.105$). More clear evidence however to consider the rate of growth of the global economy as non-stationary series is just a linear regression of the series on time (year), which produces a estimated slope of -0.057 ± 0.012, $t = -4.61$, which is strong evidence that the rate of growth of the world economy series declines on the long run over the period 1961-2014.

It seems therefore reasonable to test how robust are the results to using different measures of the business cycle that fit more astringently the requirements of stationarity. For that purpose I computed the Hodrick-Prescott trend for the series of world GDP values in 2005 US dollars and as a measure of the business cycle I used the percent deviation of world GDP with respect to the GDP Hodrick-Prescott trend. Since for annual data there is no consensus on what is the more proper value to be chosen for the smoothing parameter γ in computing the Hodrick-Prescott trend (Maravall & del Río, 2007; Ravn & Uhlig, 2002), I used the two values that constitute the extremes of the range of the recommended values, that is γ = 6.25 and γ = 100. For the years

Table A1. Augmented Dickey-Fuller unit root tests for the series of annual rates of growth of the global economy, 1961-2014

Type	Lags	Pr < Rho	Pr < Tau	Pr > F
Zero Mean	0	0.098	0.072	
	1	0.156	0.105	
	2	0.292	0.185	
Single Mean	0	0.001	0.001	0.001
	1	0.001	0.005	0.001
	2	0.010	0.072	0.098
Trend	0	<0.001	<0.001	0.001
	1	<0.001	0.001	0.001
	2	<0.001	0.020	0.022

1961-2014 the percent deviation from the HP filter computed with γ = 6.25 has a correlation of 0.41 (P = 0.002) with the rate of growth of world GDP, while the corresponding correlation is 0.28 (P = 0.038) when γ = 100. Figures A1, A2, A3, and A4 are the corresponding correlates of figures 3 and 4 in the paper when the deviations from the Hodrick-Prescott trend are used instead the rate of growth of world GDP.

I also computed the contemporaneous and lagged correlations of world GDP and real oil prices, both detrended with the Hodrick-Prescott filter (Table A2).

The evidence of associations between the world business cycle and movements in oil prices derived from Table A2 and Figures A1 to A4 is basically consistent with that in Figures 3 and 4. At long lags of 3 or 4 years (right panels and middle panel of the top row) there is no evidence of effect except an association of change in global activity with change in oil prices in the opposite direction 4 years later which disappears in recent decades (Figure A1 top middle panels). Also, it seems as if in recent decades a negative correlation would be appearing between the global business cycle and movements in oil prices 2 years later (Figures A1 to A4, mid bottom panel), but the association is just marginally significant.

Table A2. Correlations between world GDP and real oil prices both detrended with the Hodrick-Prescott filter (computed with a smoothing parameter γ = 6.25 or γ = 100). In the first panel the correlations are contemporaneous, in the other two panels one variable is lagged one year with respect the other

A. Contemporaneous correlations

Sample	γ = 6.25	γ = 100
1960-2014	0.15	-0.03
1960-1979	-0.30	-0.25
1970-1989	-0.21	-0.25
1980-1999	0.34	-0.02
1990-2009	0.73***	0.65**
2000-2014	0.82***	0.76***

B. Correlation between detrended world GDP and detrended real oil prices lagged 1 year

Sample	γ = 6.25	γ = 100
1960-2014	-0.29*	-0.38**
1960-1979	-0.75***	-0.70***
1970-1989	-0.55*	-0.56**
1980-1999	0.14	-0.30
1990-2009	-0.02	0.05
2000-2014	0.00	0.16

C. Correlation between detrended world GDP lagged one year and detrended real oil prices

Sample	γ = 6.25	γ = 100
1960-2014	0.26	0.15
1960-1979	0.31	0.11
1970-1989	0.36	0.17
1980-1999	0.26	0.24
1990-2009	0.14	0.30
2000-2014	0.19	0.26

*P<0.05, **P < 0.01, ***P<0.001

Figures A1 to A4 (top left panels) show a positive correlation at lag 0 between oil prices and the business cycle as measured by deviations of world GDP from trend. This significant correlation, maintained in both 20-year and 30-year running samples in the period since the 1960s to the present, is consistent with oil prices being endogenous to the world economy, but, as discussed in the paper, it is not consistent with oil shocks being determinants of global recessions.

The correlations in Table A2 provide consistent evidence that a lagged negative association of oil prices and global economic growth, which was apparent at lag 1 in the 1960s, is presently missing (Table A2, panel B). On the other hand, the lag-0 correlations between detrended world GD and detrended oil prices (Table A2, panel A) indicate that both series, which were contemporaneously decoupled or even perhaps slightly negatively correlated in the 1970s and 1970s, are today strongly coupled oscillating contemporaneously with a very strong correlation.

Since the rate of growth of world GDP seems to be a trended series I tried distributed lag regressions like equations [1] to [9] in which I used the percent deviation from a Hodrick-Prescott filter rather that the rate of growth of world GDP. The results obviously change in term of magnitude, but they are basically identical in terms of sign and statistical significance of the effects for specific lags. However, as it can be guessed from the results of running correlations, the effect of lag-1 growth in oil price on the world economy—this one measured by GDP deviation from trend—is not significant.

VAR models using Hodrick-Prescott detrended series of world GDP and oil prices produced results generally similar to those obtained with rates of growth of oil prices and world output presented in the text.

Figure A1. Correlations between gOIL (the annual percent growth of oil prices) and Yd625 (the percent deviation of world GDP from a Hodrick-Prescott trend computed with γ = 6.25) at lags 0 to 4. The dotted line is the correlation computed in 30-year samples starting at the year indicated in the horizontal axis, the smooth lines are the upper and lower limits of a 95% confidence band

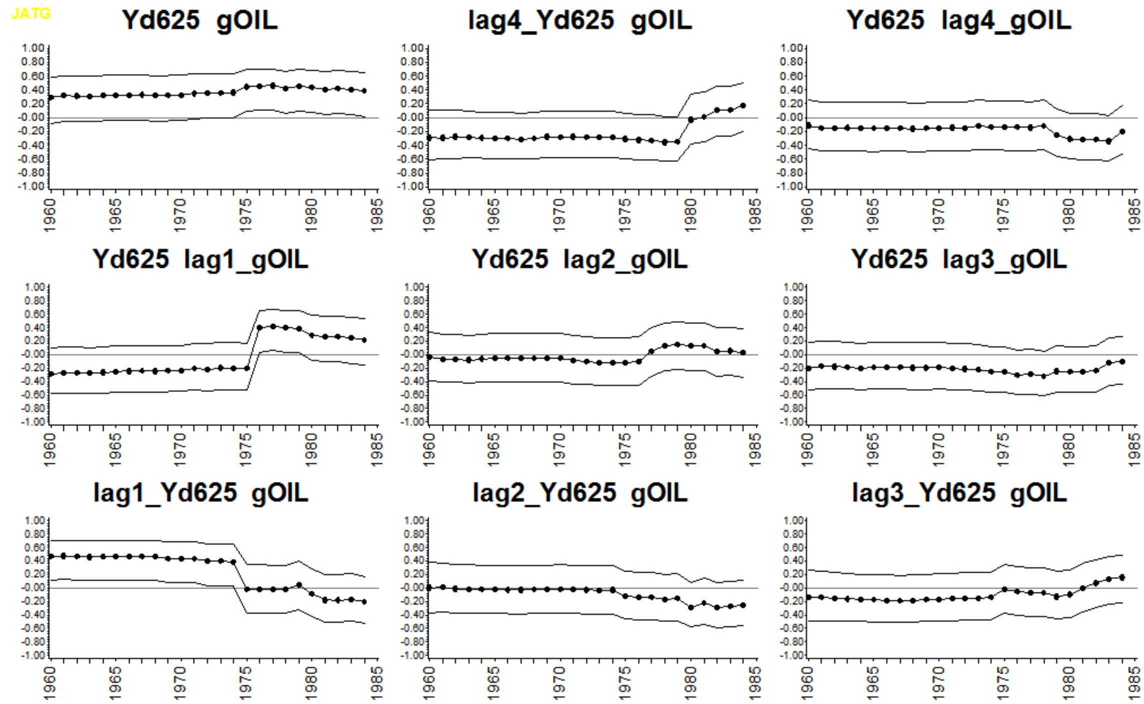


Figure A2. Correlations between gOIL and Yd625 at lags 0 to 4. All specifications as in Figure A1 but with 20-year rather tan 30-year samples.

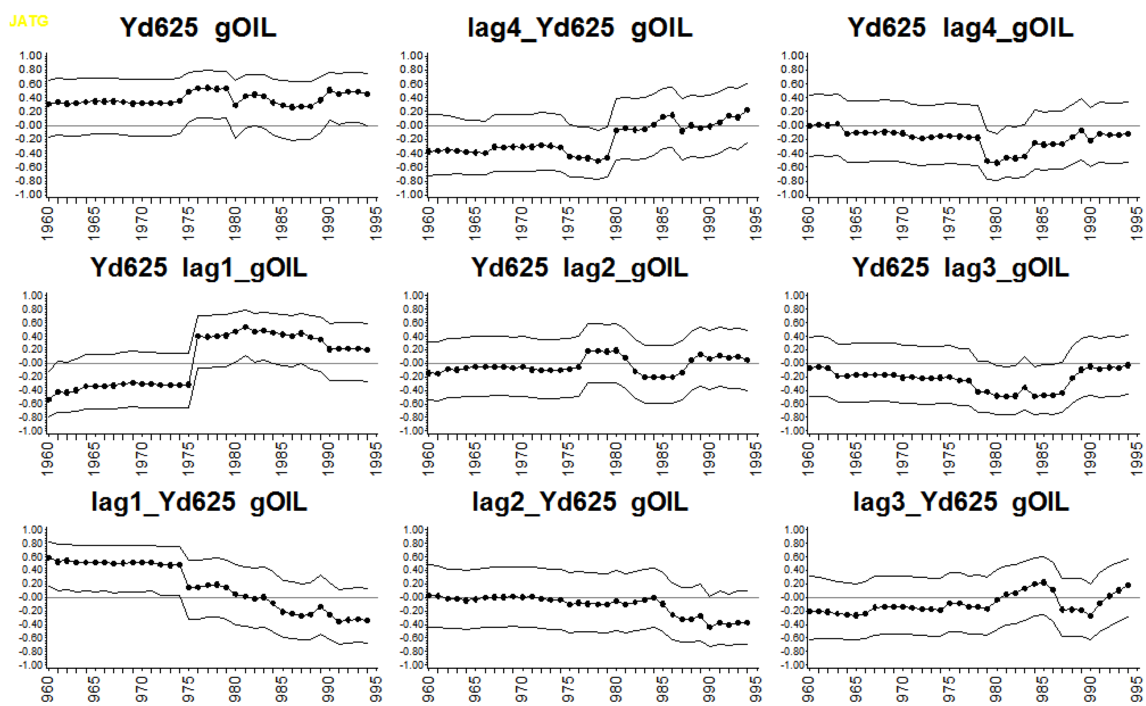


Figure A3. Correlations between gOIL (the annual percent growth of oil prices) and Yd100 (the percent deviation of world GDP from a Hodrick-Prescott trend computed with γ = 100) at lags 0 to 4. The dotted line is the correlation computed in 30-year samples starting at the year indicated in the horizontal axis, the smooth lines are the upper and lower limits of a 95% confidence band

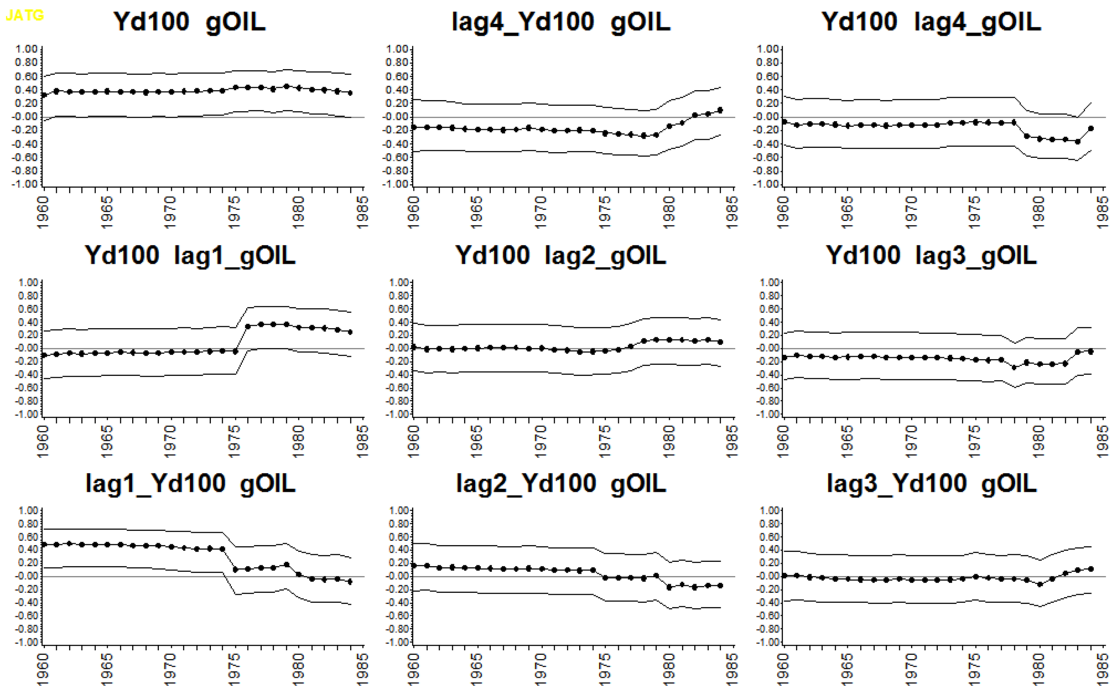
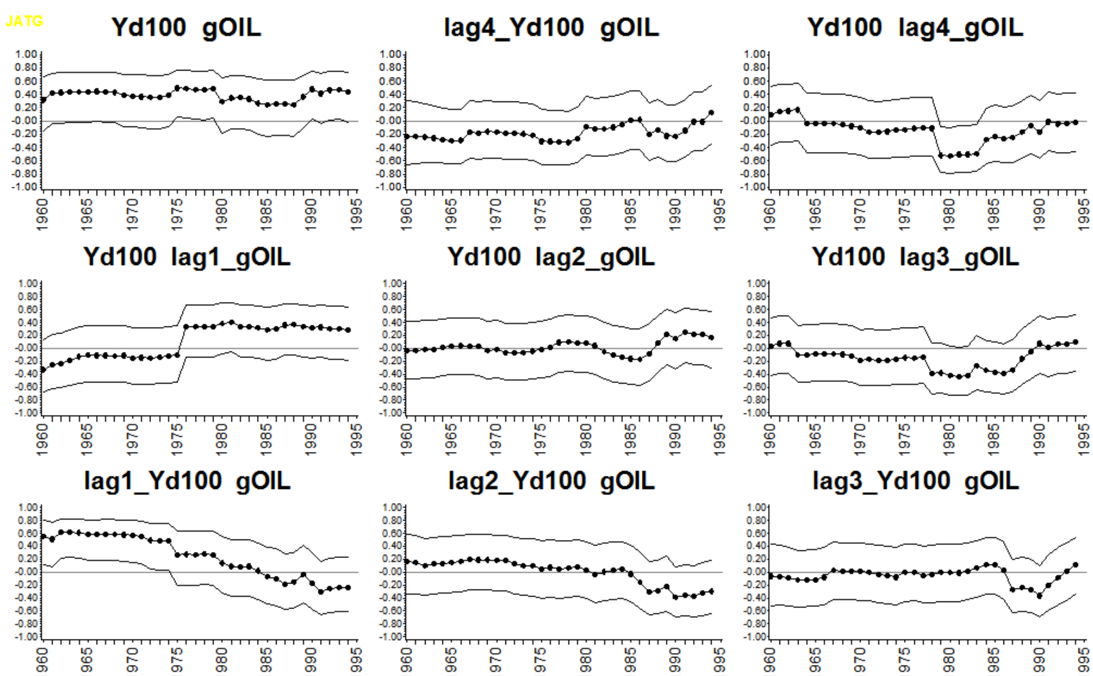


Figure A4. Correlations between gOIL and Yd100 at lags 0 to 4. All specifications as in Figure A3 but with 20-year rather tan 30-year samples.



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