Economics Bulletin

Volume 30, Issue 2

Oil Prices and Economic Activity: A Brief Update

Jamie Emerson
Salisbury University

Abstract

Using recent data, this paper investigates whether changes in oil prices have the expected effects on the US economy. Cointegration analysis and vector error correction models are employed in order to evaluate the impact of changing oil prices on US output and inflation. Further, impulse response analysis is performed to assess how shocks to oil prices affect the aggregate price level and aggregate economic activity. Our findings indicate, as expected, that regardless of the sample period considered, an oil price shock leads to higher inflation and lower industrial production in the US economy.

I would like to thank H. Sonmez Atesoglu for comments on previous versions of this paper.
Citation: Jamie Emerson, (2010) "Oil Prices and Economic Activity: A Brief Update", *Economics Bulletin*, Vol. 30 no.2 pp. 1411-1424.
Submitted: Feb 24 2010. **Published:** May 18, 2010.

1 Introduction

The motivation for this paper is the increase in oil prices that began after hurricane Katrina, with oil ultimately selling for over $100 per barrel during much of 2008. Since the subprime financial crisis took an even more virulent turn in September 2008, when the $700 billion bailout package proposed by the Bush administration was voted down, we have seen the price of oil drop back down (around $75 per barrel at the end of 2009). Although a considerable amount of research has been done since the mid-1970s concerning oil price shocks and their effects on US output and inflation, these recent changes in oil prices seem to warrant new investigation. The purpose of this paper is to include data on recent oil prices and investigate whether previous results continue to hold when this updated data is included in the analysis. Vector Autoregression (VAR) models which have been very popular in time series analysis of oil price shocks. Some important examples of the recent work in this area include Ferderer (1996), Hamilton (1996, 2003), Bernanke *et al.* (1997), Brown and Yücel (1999), Balke, *et al.* (2002), Barsky and Kilian (2004), Hamilton and Herrera (2004), Jones *et al.* (2004), Guo and Kliesen (2005), and Kliesen (2008). In this paper, we expand upon previous works[1] by using cointegration analysis and Vector Error Correction (VEC) models. In addition, our analysis uses monthly data from 1959 through 2009, giving us a much larger sample period for this study.

Much of the evidence from recent studies looking at the effects of oil price shocks on the US economy suggest that oil price shocks lead to changes in output and inflation in the US. However, Bernanke *et al.* (1997) have argued that it is monetary policy's response to the oil price shocks that caused the fluctuations in the US economy. Their findings are obtained from a structural VAR model using monthly data for the period 1965 – 1995. Defining a neutral monetary policy as one in which the federal funds rate is held constant, they argue that US monetary policy has not been neutral in response to oil price shocks. They argue that it is the reaction of monetary policy to oil price shocks that causes the aggregate economy to fluctuate.

Balke *et al.* (2002), Brown and Yücel (1999) and Ferderer (1996) have also investigated the role of interest rates as channels for oil price shocks to influence output and inflation in the US, all using VAR models for their analysis. Further, Balke *et al.* (2002) investigate interest rates as sources of possible asymmetry in the way that oil price shocks affect output and inflation in the US. They interpret the possibility of monetary policy responding differently to oil price increases and decreases as a source of asymmetry. In fact, they argue that the asymmetry is such that it is quite possible that monetary policy responds to increases in oil prices but not to oil price decreases. Brown and Yücel (1999) also employ a VAR model but do not impose a structure on the VAR model. They consider monthly data for the period 1965 – 1997. Their analysis focuses around variance decompositions and impulse responses. They find that with the Bernanke *et al.* (1997) definition of neutral monetary policy (constant federal funds rate), oil price shocks did indeed prompt a tightening of monetary policy. However, they argue that with a different definition of neutrality (constant nominal GDP), monetary policy has been neutral in response to oil price shocks. This implies that oil price shocks have a direct effect on the aggregate US economy, independent of any facilitating effect of monetary policy.

A recent study by Kliesen (2008) uses an augmented version of the single equation model approach proposed by Hamilton (2003) to investigate the effects of higher oil prices on real GDP growth and inflation. Using quarterly data from 1970-2007, Kliesen's (2008) results are consistent with the previous literature. Namely, Kliesen (2008) finds that although the US economy has become less sensitive to large changes in oil prices, permanent changes in the price of oil do matter and could have significant effects on GDP growth and inflation.

In this paper, we expand upon these recent studies to investigate the effects of oil prices on the US economy. Previous studies using VAR or Hamilton type single equation analysis ignore any long-run cointegrating relationships. By employing cointegration and VEC modeling in addition to using monthly data from 1959 through 2009, we are able to provide additional convincing evidence concerning the effects of recent changes in oil prices on aggregate output and price levels in the US.

2 Data

Monthly data for the period January 1959 through September 2009 are obtained from the Federal Reserve Bank of St. Louis (FRED). The variables considered are: CPI is the Consumer Price Index For All Urban Consumers: All Items, seasonally adjusted (CPIAUCSL); GS10 is the 10-Year Treasury Constant Maturity Rate, as a percent (GS10); PRO is the Industrial Production Index, seasonally adjusted with 2002=100 (INDPRO); OIL is the Spot Oil Price: West Texas Intermediate, dollars per barrel (OILPRICE); TB3 is the 3-Month Treasury Bill: Secondary Market Rate, as a percent (TB3MS); M2 is M2 Money Stock, seasonally adjusted (M2SL).

In addition to the data obtained from the Federal Reserve Bank of St. Louis, we also obtained a commodity price index from the website economagic.com: CRB is the CRB Spot Index. The commodity price index is included as a control for information the Fed might have about future inflation that is not captured by the other variables considered. Sims (1992) suggested the inclusion of the commodity price index to eliminate this "price puzzle" in monetary policy VAR models[2].

Following the modeling strategies of Brown and Yücel (1999) and Bernanke *et al.* (1997), we consider natural logarithms of the consumer price index, industrial production index, spot oil price[3], and CRB spot index. The 3-month T-Bill rate and 10-year Treasury constant maturity rate are kept in levels. We also include the natural logarithm of M1 money stock to investigate the question of whether the US monetizes oil price shocks.

3 Estimation Results

Following a strategy similar to those of Bernanke *et al.* (1997) and Brown and Yücel (1999), we begin our analysis by considering a VEC model that includes standard macroeconomic variables, short-term and long-term interest rates, M2 money stock, and the CRB spot index (commodity price index). It is important to point out that a VEC model is a restricted VAR (or cointegrated VAR) that has the cointegrating relationship(s) built into the specification so that the endogenous variables are restricted to converge to the long-run equilibrium while allowing for short-run adjustment dynamics. In other words, the unrestricted VAR is written as:

$$y_t = \mu + A_1 y_{t-1} + \cdots + A_p y_{t-p} + \varepsilon_t \qquad (1)$$

where y_t is a k-vector of variables considered in the model (k = 7 in our model).
This unrestricted VAR can be rewritten as:

$$\Delta y_t = \mu + \pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \varepsilon_t \qquad (2)$$

where

$\pi = \sum_{i=1}^{p} A_i - I$ and $\Gamma_i = -\sum_{j=i+1}^{p} A_j$.

Finally, if the coefficient matrix π has reduced rank r < k, then there exist k x r matrices α and β each with rank r such that $\pi = \alpha\beta'$ and $\beta' y_t$ is stationary. Note that r is the number of cointegrating relationships, each column of β is the cointegrating vector, and the elements of α are the adjustment parameters in the vector error correction (VEC) model. We refer to this VEC model as model 1.

We begin the analysis by investigating the time series properties of the data. The first step of the analysis is to test for non-stationarity and determine the most likely order of integration. Table 1 reports the results of the Augmented Dickey-Fuller tests for each variable in levels and in first differences. The results of the unit root tests, carried out using EViews 6, suggest that all variables considered are likely to be integrated of order one[4]. Further, none of the data series appear to be trend stationary. Therefore, the trends in the data are assumed to be stochastic trends.

Table 1: Augmented Dickey-Fuller Unit Root Tests

Level Variable	Include Intercept	Include Trend and Intercept	None
lnCPI	0.7110	0.9252	0.9950
lnCRB	0.7084	0.6890	0.9691
lnPRO	0.3943	0.7150	0.9997
lnOIL	0.7427	0.4230	0.8950
lnM2	0.3339	0.9784	1.0
GS10	0.5749	0.8362	0.4661
TB3	0.1966	0.3847	0.2044

First Difference	Include Intercept	Include Trend and Intercept	None
lnCPI	0.0240	0.0750	0.0877
lnCRB	0.0000	0.0000	0.0000
lnPRO	0.0000	0.0000	0.0000
lnOIL	0.0000	0.0000	0.0000
lnM2	0.0000	0.0000	0.0899
GS10	0.0000	0.0000	0.0000
TB3	0.0000	0.0000	0.0000

Notes: The values reported in Table 1 are p-values.

The next step in the analysis is to investigate the cointegrating relationships. Trace statistics and maximum-eigenvalue statistics are used to determine the number of cointegration relationships. Based on the Akaike information criterion, eight lags in the level variables are included in the model. The results of the cointegration tests for model 1 are reported in Table 2. Trace statistics are reported in the upper block of the table, while maximum eigenvalue statistics are reported in the bottom block of the table. Cointegration tests are performed with the assumption that all trends are stochastic, as suggested by the unit root tests reported in Table 1. The trace test indicates that there are two cointegrating equations in this model, while the maximum eigenvalue test indicates that there is only one cointegrating equation at the 5% level of significance. However, the maximum eigenvalue statistic is close (p-value = 0.1239) to suggesting a second cointegrating equation. Therefore, we will proceed by including two cointegrating relationships in the VEC model.

Table 2: Cointegration Tests: Model 1

	H_0:		
	r ≤ 2	**r ≤ 1**	**r = 0**
Trace Statistics	60.52	96.88*	147.20*
Maximum Eigenvalue Statistics	22.84	36.35	50.32*

*Notes: A * indicates the test value is significant at the 5% level or less.*

We continue the analysis by estimating the VEC model. The VEC model improves upon previous VAR models by incorporating the cointegration relationships into the specification so that the long-run behavior of the endogenous variables is restricted to converge to the long-run equilibrium while allowing for short-run adjustment dynamics. In other words, the first step of estimating a VEC model is to estimate the cointegration relationships. The second step is to estimate a VAR in first differences including the error-correction terms (cointegration relationships) estimated in the first step. The estimated cointegration relationships from the first step are reported in Table 3.

Table 3: Cointegration Relationships for Model 1

Variable	**Cointegrating Equation 1**	**Cointegrating Equation 2**
lnCPI(-1)	1	0
lnCRB(-1)	0	1
lnPRO(-1)	-0.56 (0.34)	1.95 (0.81)
lnOIL(-1)	-0.19 (0.06)	-0.17 (0.15)
lnM2(-1)	-0.28 (0.19)	-1.24 (0.45)
GS10(-1)	0.06 (0.02)	0.29 (0.06)
TB3(-1)	-0.06 (0.02)	-0.18 (0.05)
Constant	0.45	-4.62

Notes: Standard errors are reported in parentheses.

Table 4 reports only the error-correction terms from the second step VAR in first differences along with the R^2 values for each equation. The complete estimation results of the second step VAR in first differences including the error-correction terms are available upon request.

Table 4: Vector Error Correction Model Estimation Results

	ΔlnCPI	**ΔlnCRB**	**ΔlnPRO**	**ΔlnOIL**	**ΔlnM2**	**ΔGS10**	**ΔTB3**
CointEq1	-0.003 (0.001)	-0.001 (0.011)	0.014 (0.003)	-0.001 (0.033)	-0.004 (0.001)	0.148 (0.116)	0.198 (0.175)
CointEq2	0.002 (0.0004)	-0.005 (0.004)	0.0005 (0.001)	-0.011 (0.013)	0.001 (0.0004)	-0.161 (0.045)	-0.025 (0.068)
R-squared	0.602	0.181	0.273	0.181	0.548	0.325	0.387
Adj. R-squared	0.565	0.105	0.206	0.105	0.506	0.263	0.330

Notes: Standard errors are reported in parentheses. Each column in the table corresponds to an equation in the VEC model. The VEC model includes 7 lags in first differences. Lags are determined using the Akaike Information Criterion.

The expectation is that an oil price shock will lead to a decrease in output, an increase in interest rates, and an increase in the price level. Additionally, if the US monetizes oil price shocks, we should find that an oil price shock leads to an increase in the money supply. In order to investigate whether this model supports our expectations, we use impulse responses to evaluate the relationship between an oil price shock and aggregate economic activity.

Figure 1 shows the impulse responses to an oil price shock. We use the generalized impulses of Pesaran and Shin (1998), which do not depend on the ordering of the variables in the VEC model. We consider a generalized one standard deviation innovation to lnOil and follow the responses of the variables in the model over a 48 month time horizon. A positive shock to the oil price leads to an increase in the price level, a decline in industrial production, and an increase in both short-term and long-term interest rates. These results are consistent with our expectations and are also consistent with results in the literature. A positive oil price shock also leads to an initial decrease in the money supply but the response of the money supply turns positive in the 34th month and remains positive throughout the remainder of the time horizon. This suggests that the US does ultimately monetize the oil price shock.

4 Alternative Sample Periods

As pointed out in footnote 2, an oil price has been included in the commodity price index since 1987. In addition, in February 1987 the federal funds rate became the operating target of the Fed. For these reasons we consider an alternative sample period of February 1987 through September 2009. We also consider the most recent decade as an alternative sample period. The analysis for each alternative sample period mirrors the analysis for the entire sample period from the previous section[5].

We begin by considering the sample period of February 1987 through September 2009. Figure 2 shows the impulse responses to an oil price shock. A positive shock to the oil price leads to an increase in the price level, a decline in industrial production until the 33rd month of the time horizon, and an increase in both short-term and long-term interest rates. These results are similar to the impulse responses for the full sample with the exception that industrial production begins to increase after the 33rd month of the time horizon. The results for the response of money supply to an oil price shock are quite different than for the full sample. The impulse responses for this sample period show that the money supply declines in response to an oil price shock.

Next, consider the most recent decade. Figure 3 shows the impulse responses to an oil price shock. A positive shock to the oil price leads to an increase in the price level, a decline in industrial production, an increase in short-term interest rates and a decrease in long-term interest rates. These results are similar to the impulse responses for the full sample and are all as expected, except for the decline in long-term interest rates. A positive oil price shock also leads to an increase in the money supply beginning in the eighth month of the time horizon. This suggests that the US has monetized oil price shocks over the past decade.

5 Robustness Checks

In this section, we repeat the analysis for the full sample using quarterly frequencies and annual frequencies[6]. Since monthly data can be quite noisy, the comparison of the monthly results with results using both quarterly and annual frequencies provides a robustness check on the conclusions drawn from the analysis using monthly data.

Figure 4 shows the impulse responses to an oil price shock using quarterly frequencies. The results using quarterly data are nearly identical to the results using monthly data. A positive shock to the oil price leads to an increase in the price level, a decline in industrial production, and an increase in both short-term and long-term interest rates. A positive oil price shock also leads to an initial decrease in the money supply but the response of the money supply turns positive in the 10th quarter and remains positive throughout the remainder of the time horizon.

Figure 5 shows the impulse responses to an oil price shock using annual frequencies. The results using annual data are very similar to the results using monthly data. A positive shock to the oil price leads to an increase in the price level, a decline in industrial production, and an increase in both short-term and long-term interest rates. However, a positive oil price shock also leads to a decrease in the money supply. Unlike the results using both monthly and quarterly frequencies, the response of the money supply remains negative.

6 Conclusion

In this paper, we used impulse responses from VEC models to assess how oil price shocks affect aggregate economic activity and the price level in the United States. Our findings indicate that regardless of the sample period considered, an oil price shock leads to higher inflation and lower industrial production. However, the impulse response analysis leads to mixed results concerning the question of whether the US monetizes oil price shocks: the analysis using both monthly and quarterly data suggest that the US does monetize oil price shocks, however, the analysis using annual data suggests the oil price shocks are not monetized by the US. This result is somewhat puzzling and could be a topic of further research.

The results in this paper complement other studies of oil price shocks on the US economy. However, the analysis used in this paper incorporates recent changes in oil prices by including monthly data through September 2009, investigates cointegration among the variables considered, and estimates VEC models. Although our VEC results are very similar to those of previous VAR studies, by using cointegration and VEC models we are able to provide additional convincing evidence concerning the effects of recent changes in oil prices on aggregate output and price levels in the United States.

Footnotes

[1] See Jones, Leiby, and Paik (2004) for a recent survey.

[2] As pointed out by Bernanke, Gertler, and Watson (1997), the commodity price index appears to have excluded oil and other energy prices for most of its history. An oil price has been included since 1987.

[3] Brown and Yucel (1999) use log first differences of the oil price to make it comparable to the Hamilton oil price variable. However, as Bernanke, Gertler, and Watson (1997) point out, the log difference of the oil price is nearly equivalent to the log level of the oil price given the presence of freely estimated lag parameters.

[4] Only the ADF unit root test results are reported here. However, the results of other unit root tests (Phillips-Perron, Dickey-Fuller with GLS detrending, Kwiatkowski-Phillips-Schmidt-Shin, Elliot-Rothenberg-Stock point optimal, and Ng-Perron) provide similar results and are available upon request.

[5] We only report the impulse responses for the alternative sample periods. Complete estimation results are available upon request.

[6] We only report the impulse responses for the quarterly and annual data frequencies. Complete estimation results are available upon request.

References

Balke N.S., Brown S.P.A., and Yücel M.K. (2002) Oil price shocks and the US economy: Where does the asymmetry originate?, *The Energy Journal*, **23**, 27-52.

Barsky, R.B. and Kilian, L. (2004) Oil and the macroeconomy since the 1970s, *Journal of Economic Perspectives*, **18**, 115-134.

Bernanke B.S., Gertler M., and Watson M. (1997) Systematic monetary policy and the effects of oil price shocks, *Brookings Papers on Economic Activity*, **no. 1**, 91-142.

Brown S.P.A. and Yücel M.K. (1999) Oil prices and US aggregate economic activity: A question of neutrality, *Economic & Financial Review*, **second quarter**, 16-23.

Dotsey M. and Reid M. (1992) Oil shocks, monetary policy, and economic activity, *Federal Reserve Bank of Richmond Economic Review*, **78**, 14-27.

Ferderer J.P. (1996) Oil price volatility and the macroeconomy, *Journal of Macroeconomics*, **18**, 1-26.

Guo, H. and Kliesen, K.L. (2005) Oil price volatility and US macroeconomic activity, *Federal Reserve Bank of St. Louis Review*, **87**, 669-683.

Hamilton J.D. (1996) This is what happened to the oil price-macroeconomy relationship, *Journal of Monetary Economics*, **38**, 215-220.

Hamilton J.D. (2003) What is an oil shock?, *Journal of Econometrics*, **113**, 363-398.

Hamilton, J.D. and Herrera, A.M. (2004) Oil shocks and aggregate macroeconomic behavior: The role of monetary policy, *Journal of Money, Credit, and Banking*, **36**, 256-286.

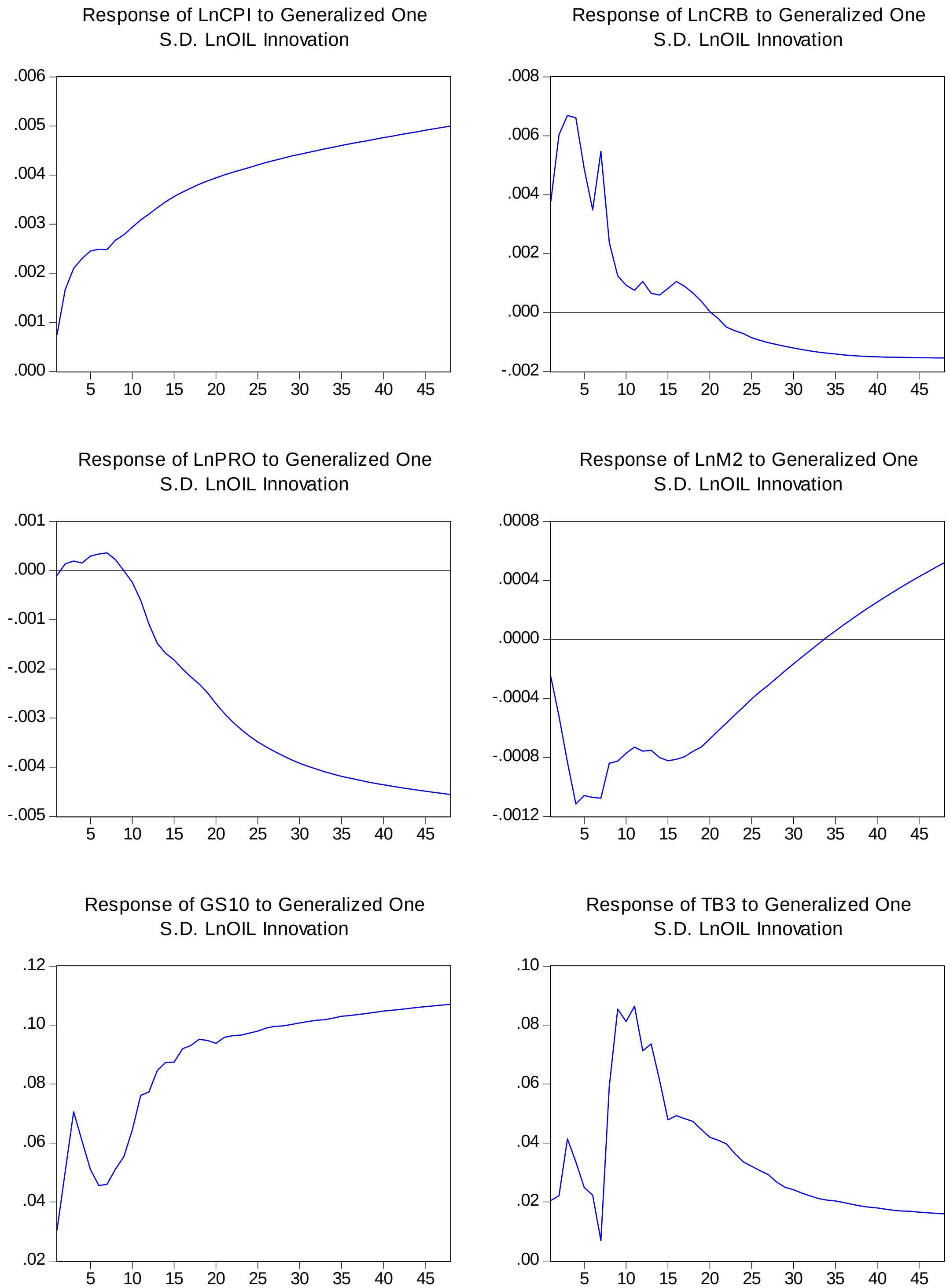
Jones, D.W., Leiby, P.N., and Paik, I.K. (2004) Oil price shocks and the macroeconomy: What has been learned since 1996?, *Energy Journal*, **25**, 1-32.

Kliesen K.L. (2008) Oil and the US macroeconomy: An update and a simple forecasting exercise, *Federal Reserve Bank of St. Louis Review*, **90**, 505-518.

Pesaran M.H. and Shin Y. (1998) Generalised impulse response analysis in linear multivariate models, *Economics Letters*, ***58***, 17-29.

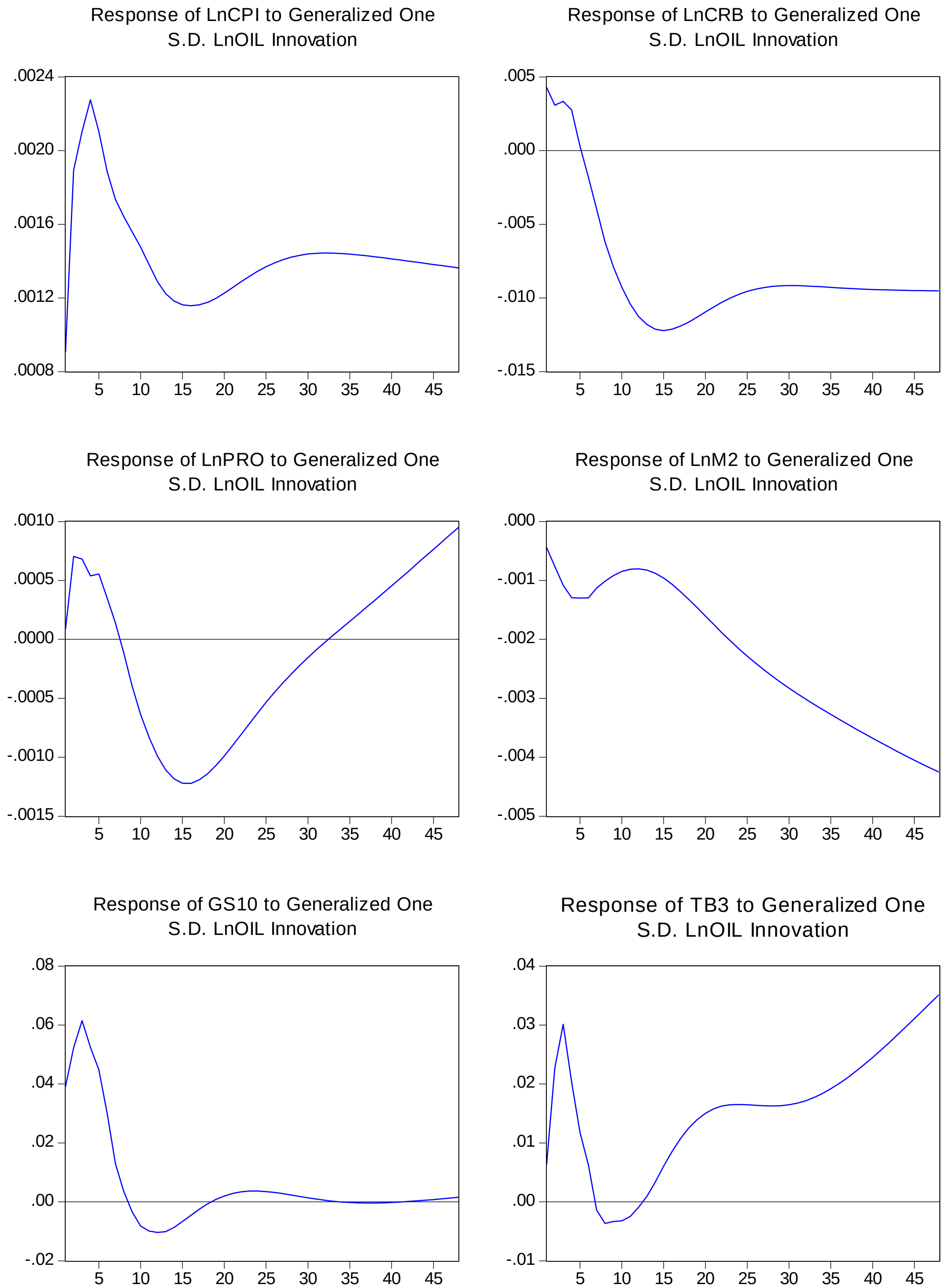
Sims C.A. (1992) Interpreting the macroeconomic time series facts: the effects of monetary policy, *European Economic Review*, **36**, 975-1011.

<u>Figure 1: Impulse Responses for Vector Error Correction Model 1</u>



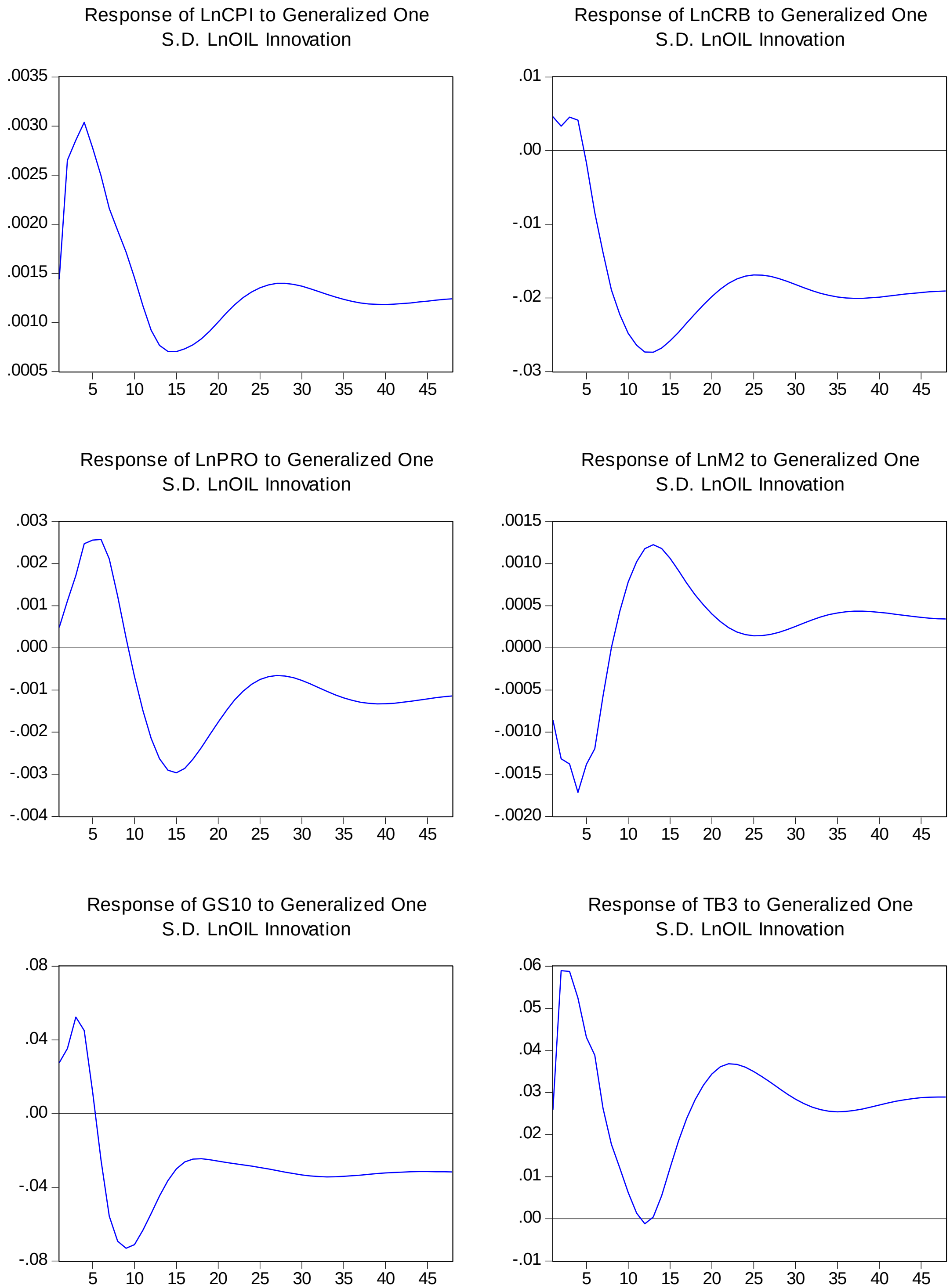
Notes: Graphs show 48 months of responses of the variables to an oil price shock. Impulse response standard errors are not available for VEC models.

Figure 2: Impulse Responses Alternative Sample February 1987 – September 2009



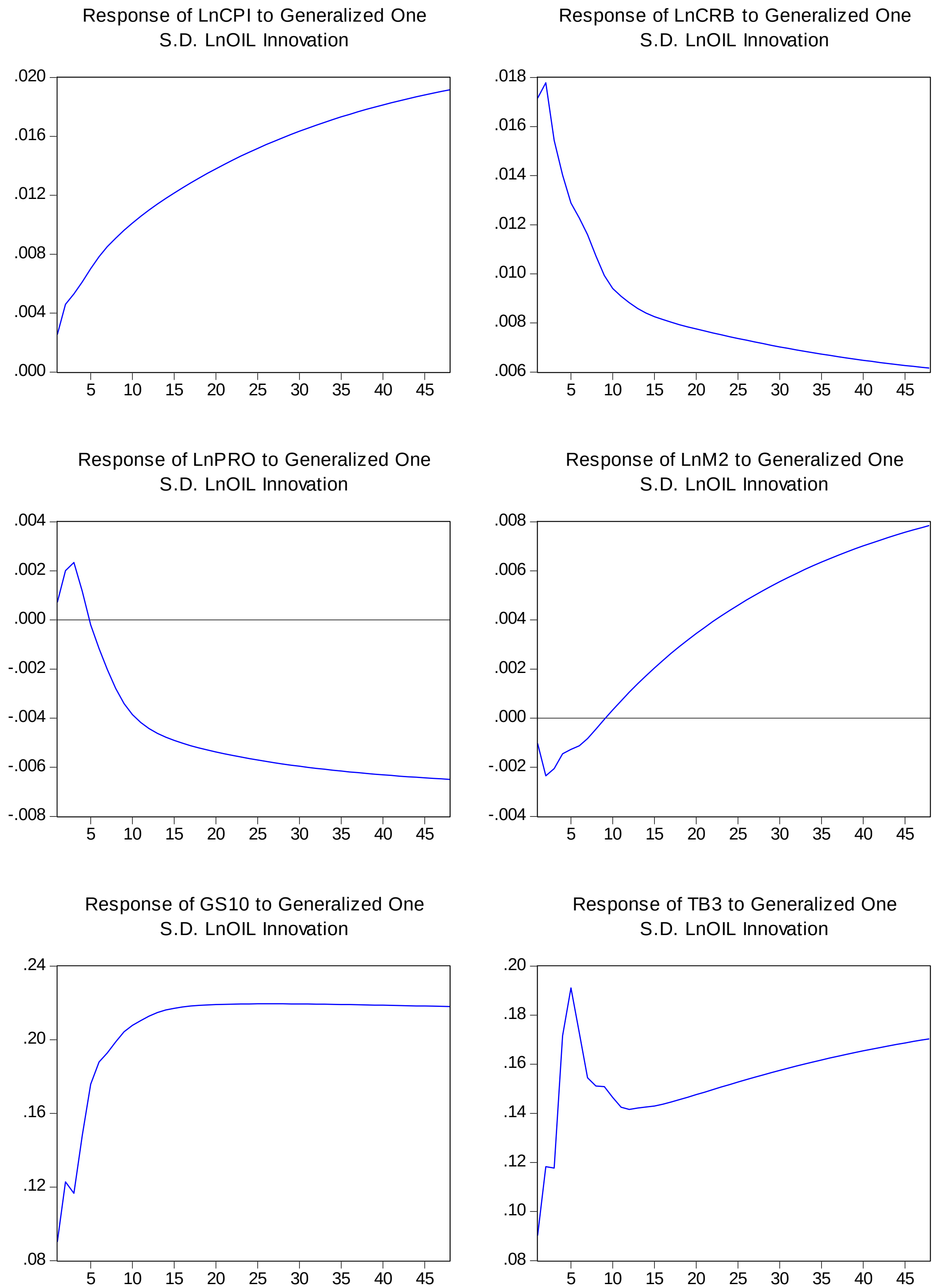
Notes: Graphs show 48 months of responses of the variables to an oil price shock. Impulse response standard errors are not available for VEC models.

<u>Figure 3: Impulse Responses Alternative Sample October 1999 – September 2009</u>



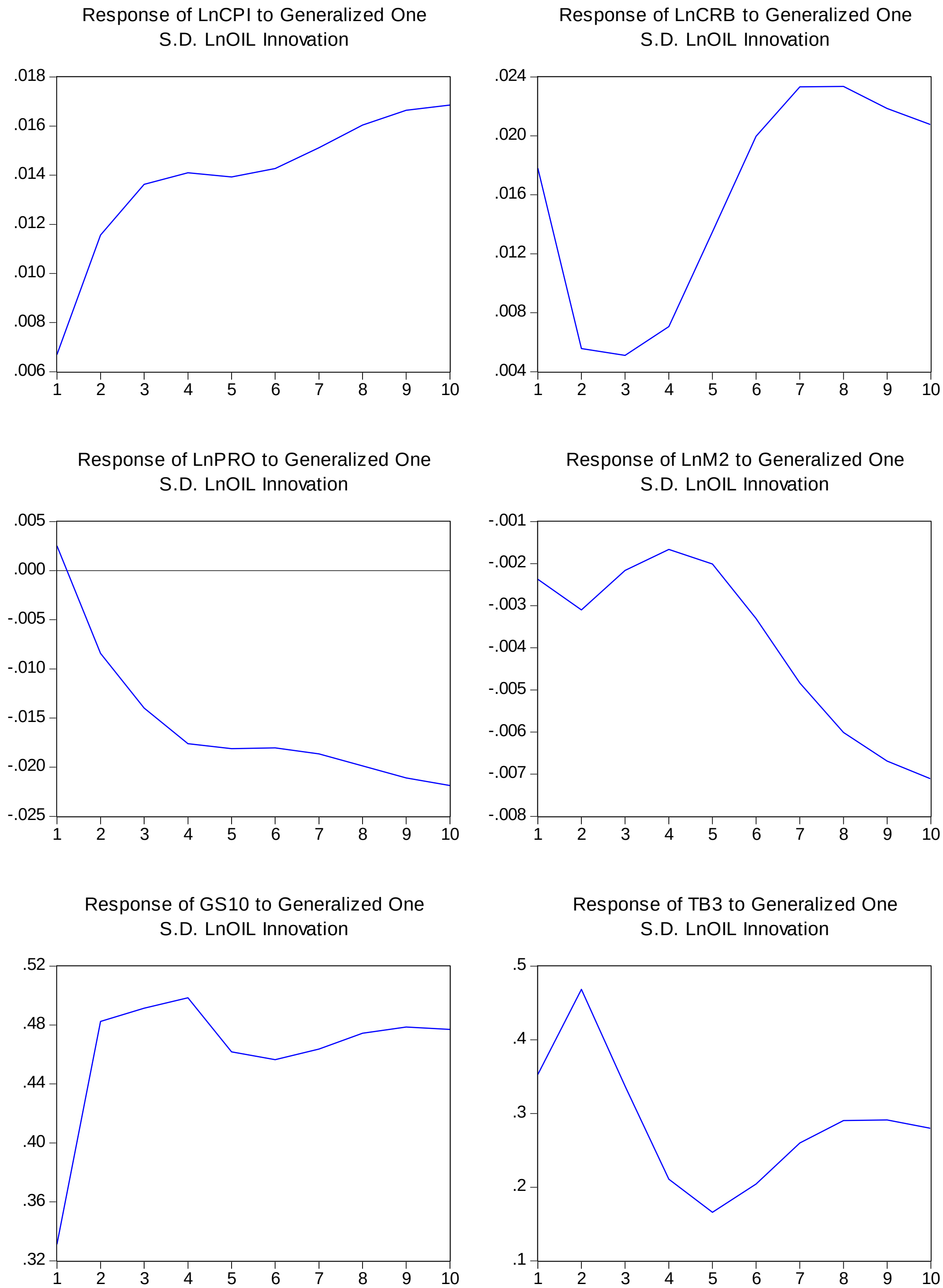
Notes: Graphs show 48 months of responses of the variables to an oil price shock. Impulse response standard errors are not available for VEC models.

Figure 4: Impulse Responses Using Quarterly Data



Notes: Graphs show 48 quarters of responses of the variables to an oil price shock. Impulse response standard errors are not available for VEC models.

Figure 5: Impulse Responses Using Annual Data



Notes: Graphs show 10 years of responses of the variables to an oil price shock. Impulse response standard errors are not available for VEC models.