OIL PRICES, TERMS OF TRADE SHOCKS, AND MACROECONOMIC FLUCTUATIONS IN SAUDI ARABIA

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The article investigates the sources of macroeconomic fluctuations in Saudi Arabia using structural vector autoregression methods and pays particular attention to oil prices and changes in terms of trade. Using a macroeconomic model tailored to the Saudi Arabian economy, the authors identify terms of trade, supply, balance of payments, aggregate demand, and monetary shocks. The results show that the Saudi Arabian price level, real exchange rate, and to a lesser extent output is vulnerable to terms of trade shocks. Moreover, Saudi Arabian terms of trade are driven by output, trade balance, and aggregate demand shocks. To stabilize output and the real exchange rate, Saudi Arabia ought to continue diversifying its production base and aim for a stable nominal oil price. (*JEL* E32, Q43, C22)

I. INTRODUCTION

Oil prices occupy a central role in explaining the business cycle, particularly since the 1973 oil price shock. Hamilton (1983), Gisser and Goodwin (1986), and Ferderer (1996), among others, document recessions, uncertainty, and inflationary pressures associated with oil price shocks.[1] In general, the sharp increase in oil prices have been blamed on collusive behavior of the Organization of Petroleum Exporting Countries (OPEC) cartel,[2] and sharp price declines are associated with weakening of OPEC. By far, the Kingdom of Saudi Arabia is the largest oil producer in the world and the most prominent OPEC member. As such, Saudi Arabia has the potential to influence the world economy, and because it relies heavily on oil revenues, is susceptible to developments in the global oil market. Despite its pivotal potential on the global economy, scant attention has been paid to Saudi Arabia in empirical macroeconomics.

The primary objective of this article is to investigate the source of macroeconomic fluctuations in Saudi Arabia. Using a simple macroeconomic model tailored to the Saudi Arabian economy and a structural vendor autoregression (VAR), the authors assess the role of terms of trade, supply, trade balance, aggregate demand, and monetary shocks in macroeconomic fluctuations in Saudi Arabia. Specifically, the authors try to answer the following questions: to what extent Saudi Arabia influences and is influenced by real oil prices? What are the principal determinants of fluctuations in Saudi Arabian gross

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1. For example Hamilton (1983) concludes that seven of the eight U.S. postwar recessions were preceded by an increase of oil price.

2. Griffin (1985) and Jones (1990) provide evidence regarding OPEC's collusive behavior, and Spilimbergo (2001) cannot validate the market-sharing hypothesis against competitive behavior except for Saudi Arabia.

ABBREVIATIONS

ADF: Augmented Dickey Fuller
BOP: Balance of Payments
GDP: Gross Domestic Product
IRF: Impulse Response Function
OPEC: Organization of Petroleum Exporting Countries
SAMA: Saudi Arabian Monetary Agency
VAR: Vector Autoregression
VECM: Vector Error Correction Model

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TABLE 1
Selected Macroeconomic Indicators

Year	GDP Growth Rate (%/year)	CPI Inflation Rate (%/year)	Current Account Balance (U.S. $mill.)	Composition of Real GDP[a]			% of Oil in Total Government Revenue	Share of Saudi Arabia in World Oil production (%)
				Oil	Private	Govt.		
1980–84	1.00	1.38	10,690.7	53.1	27.5	19.4	79.5	12.5
1985–89	0.86	–1.26	–10,275.6	27.4	44.5	28.1	62.0	8.1
1990–94	4.36	1.54	–15,438.6	38.0	36.0	26.0	60.4	13.0
1995–99	1.26	0.80	−3415.3	36.6	36.8	26.6	70.7	12.7
2000–01[b]	3.00	−0.01	14,419.1	40.5	39.9	19.6	NA	12.0

[a]The percentage of real GDP attributable to the oil sector, the private sector, and the nonoil government sector.
[b]The 2001 figures are estimates. NA: not available.
Source: SAMA, *Annual Report*, various issues; Current account balance: International Financial Statistics (IFS). Oil production figures, British Petroleum (www.bp.com).

domestic product (GDP)? What are the sources of fluctuations in Saudi Arabian real exchange rate and price level?

Using quarterly data from 1980 to 2000, the macroeconomic model imposes long-run restrictions consistent with the model to identify the shocks. The authors then report innovation accounting to analyze the effects of various shocks on the Saudi Arabian economy.

II. THE SAUDI ARABIAN ECONOMY

Despite attempts at diversifying economic activity in Saudi Arabia, oil revenues still account for nearly 37% of Saudi Arabian GDP and over 70% of government revenue (Table 1). The table also shows that except for the late 1980s, Saudi Arabia's share of world crude oil production has been stable in the past two decades, providing about one-eighth of the world's crude oil. Growth has been moderate in the past two decades,[3] except for the early 1990s, when the economy recorded a respectable growth due to the increase in oil production relative to previous years. Table 1 indicates that during the past two decades, inflation has been modest. Though the merchandise trade balance has been recording surpluses, the current account balance has been mostly in deficit due to transfers, which largely reflect remittances by foreign workers working in the kingdom.

3. High growth in the early 1990s can be attributed to increased oil production undertaken to offset the impact of the Gulf crisis.

Saudi Arabia does not impose foreign exchange controls on capital receipts or payments by domestic or foreign residents. Foreign bank participation in riyal-denominated transactions inside or outside Saudi Arabia is subject to approval of the Saudi Arabian Monetary Agency (SAMA). Monetary policy in Saudi Arabia is subordinate to exchange rate policy in that the SAMA maintains a fixed exchange rate system. The riyal initially was pegged to the Special Drawing Rights of the International Monetary Fund, but the peg was shifted to the U.S. dollar in May 1981. Due to the relative openness of the economy, riyal interest rates closely track U.S. dollar rates since the mid-1980s and often with a small premium (Al-Jasser and Banafe, 1999). Thus instead of using interest rates to maintain the exchange rate, SAMA directly intervenes in spot and swaps market to defend the riyal.

The commitment of SAMA to a fixed exchange rate has not prevented speculators from massive short-selling of the riyal in the past two decades. Even though the last devaluation of the riyal took place in June 1986 when SAMA adjusted the exchange rate from 3.65 riyal per U.S. dollar to 3.75, there have been several occasions when the market expected an imminent devaluation. For example, when oil prices collapsed in the aftermath of the Gulf War and the kingdom suffered record current account deficits, the riyal came under severe pressure in August–November 1993. More recently, when oil prices slid again, and in the wake of large budget deficits, the riyal came under another wave of speculation in late 1998. SAMA again defended the riyal by intervening in the foreign exchange market.

III. THE MODEL AND METHODOLOGY

It is evident that if a macroeconomic model is to serve as a guide in isolating macroeconomic shocks, it ought to account for the peculiar characteristics of the Saudi Arabian economy. First, the model should incorporate terms of trade shocks because a major component of GDP is concentrated in one sector. Second, the model should incorporate exogenous shifts in the balance of payments, currency premiums, and currency substitution in wake of speculations. Other aspects of the Saudi economy, such as economic growth and price stability, can be modeled using a conventional aggregate supply/aggregate demand model.

To motivate the restrictions embedded in the structural VAR model, consider a dynamic, open economy aggregate supply/aggregate demand model:

(1) $h_t = h_{t-1} + \varepsilon_t^h$ Evolution of terms of trade

(2) $y_t^s = \breve{y}_t + \theta h_t$ Aggregate supply

(3) $\breve{y}_t = \breve{y}_{t-1} + \varepsilon_t^s$ Evolution of capacity output

(4) $k[i_t - i_t^* + (E_t s_{t+1} - s_t) - \rho_t] + \eta_1(s_t - p_t) - \eta_2 y_t + b_t = 0$ Balance of payments (BOP)

(4′) $i_t = (E_t s_{t+1} - s_t) - (\eta_1/k)(s_t - p_t) + (\eta_2/k)y_t + [i_t^* + \rho_t - (1/k)b_t]$

(5) $z_t = [i_t^* + \rho_t - (1/k)b_t]$ BOP shock

(5′) $z_t = z_{t-1} + \varepsilon_t^z$ Evolution of BOP shock

(6) $y_t^d = d_t - \gamma[i_t - E_t(p_{t+1} - p_t)] + \eta_1(s_t - p_t) - \eta_2 y_t$ Aggregate demand/IS

(7) $d_t = d_{t-1} + \varepsilon_t^d$ Aggregate demand shock

(8) $m_t^d = p_t + y_t - \lambda i_t - \mu z_t$ Money demand

(9) $m_t^s = m_{t-1}^s + \varepsilon_t^m$ Money supply

(10) $y_t^s = y_t^d = y_t$ Goods market equilibrium

(11) $m_t^s = m_t^d = m_t$ Money market equilibrium

where h is the terms of trade, y is domestic output, $\breve{y}$ is capacity output, i is the domestic nominal interest rate, i^* is the foreign interest rate, s is the exchange rate expressed as the domestic currency price of foreign currency, p is the domestic price level, m is the money stock, d is autonomous aggregate demand, ρ is a risk premium on domestic currency investments, b represents an exogenous shift in net exports due to (for example) a change in competitiveness, z represents exogenous elements in the balance of payments equation, ε^j is stochastic disturbance, E_t is the expectations operator conditional on information available at time t; all variables except interest rates are in logarithms, and the remaining Greek letters designate parameters that are assumed positive.

Equation (1) is the evolution of the terms of trade, which is assumed to follow a random walk. Equation (2) is an aggregate supply equation, where aggregate supply depends on capacity output and terms of trade. Capacity output in equation (3) is a function of the productive capacity of the economy (e.g., capital stock and employment), and for simplicity it is assumed to be a random walk process.

A distinguishing feature of the model is that it can accommodate noninstantaneous adjustment in the balance of payments. Capital inflows are a function of the net domestic rate of return adjusted for a risk premium. Note that the parameter k represents the degree of capital mobility, and large values of k indicate higher levels of capital mobility. The trade balance is a function of the real exchange rate $(s_t - p_t)$ and domestic income.[4] Moreover,

4. For simplicity, foreign prices are normalized to unity. In the empirical analysis the authors will use real effective exchange rates, which does not assume unit foreign prices.

due to exogenous changes in terms of trade, b_t represents exogenous increases in net exports. Although equation (4) may seem to impose a zero balance of payments, the existence of the shift term b_t provides a more general specification. For example, one can view b_t as an exogenous or target level for the balance of payments. Equation (4′) rewrites equation (4) in terms of the domestic nominal interest rate, whereas equation (5) pools all the exogenous elements in the balance of payments equation to define z_t. Equation (5′) specifies the evolution of z_t as a nonstationary stochastic process.[5]

Equation (6) is an aggregate demand (IS) equation where aggregate spending depends on the expected real interest rate and net exports. The autonomous portion of aggregate demand, d_t, is assumed to follow a random walk in equation (7). Equation (8) is a conventional money demand equation. To obtain a simple solution, money demand is assumed to have unitary income elasticity. Money demand is also a function of the exogenous elements in the balance of payments. This specification allows for reductions in money demand when there are exogenous shifts in the BOP, which may necessitate a depreciation of domestic currency. Moreover, when there is a risk premium associated with domestic currency or self-fulfilling fads in exchange rate expectations, z_t will be positive. In such cases, money demand is reduced by μz_t.

Equation (9) is the evolution of money supply, which for simplicity, is assumed to follow a random walk.[6] Finally, the authors close the model by postulating goods and money market equilibrium relationships (equations [10] and [11]) and proceed to solve the model for the rational expectations equilibrium.

To solve the model, the authors eliminate the interest rate from equations (6) and (8) using equation (4′) to obtain the following system:[7]

$$(12)\quad \begin{vmatrix} \lambda(1+[\eta_1/k]) & 1-(\lambda\eta_1/k) \\ \gamma(1+[\eta_1/k])+\eta_1 & -\gamma(1+[\eta_1/k])-\eta_1 \end{vmatrix} \times \begin{vmatrix} s_t \\ p_t \end{vmatrix} = \begin{vmatrix} \lambda & 0 \\ \gamma & -\gamma \end{vmatrix} \begin{vmatrix} E_t s_{t+1} \\ E_t p_{t+1} \end{vmatrix} + \begin{vmatrix} m_t-([\lambda\eta_2/k]-1)y_t+(\mu-\lambda)z_t \\ (1+\eta_2[\eta_2\gamma/k])y_t-d_t-\gamma z_t \end{vmatrix}.$$

The system can be written compactly as $AY_t = BE_tY_{t+1} + W_t$, or $Y_t = \Pi E_t Y_{t+1} + CW_t$ where $C = A^{-1}$ and $\Pi = A^{-1}B$. The eigenvalues of the matrix Π are $\{1/(1+\lambda);\ \gamma k/(\gamma k + \gamma\eta_1 + k\eta_1)\}$. The eigenvalues are both within the unit circle for finite values of the parameters, hence the forward looking solution is convergent. The forward-looking solution to the system in (12) is

$$(13)\qquad E_tY_{t+1} = C\sum_{i=1}^{\infty} \Pi^i E_t W_{t+i+1}.$$

Given the stochastic processes for the exogenous variables, it is evident that $E_tW_{t+i} = W_t$ for $i = 1, 2, \ldots$. Then the solutions for the real exchange rate, real money balances, and the price level in terms of the exogenous variables are:

$$(14)\quad s_t - p_t = [(k/\eta_1(\gamma+k)) + (\eta_2/\eta_1)]y_t - (\gamma k/\eta_1(\gamma+k))z_t - (k/\eta_1(\gamma+k))d_t$$

$$(15)\quad m_t - p_t = c_1y_t + c_2z_t + c_3d_t,\quad c_1 \equiv [2\lambda\eta_2 + \lambda k/k(\gamma+k)] - 1;\quad c_2 \equiv (\lambda k/[\gamma+k]) - \mu;\quad c_3 \equiv -(\lambda/[\gamma+k]);$$

$$(16)\qquad p_t = m_t - c_1y_t - c_2z_t - c_3d_t.$$

The observed movements in the vector of variables $X_t = [h_t\ y_t\ (m_t - p_t)\ (s_t - p_t)\ p_t]$ are due to

5. Although ε_t^z is labeled a BOP shock, it is evident that it captures foreign interest rate shocks, risk premium shocks, and competitiveness shocks. Without further structure, it is impossible to disentangle ε_t^z into its constituent parts. To keep the dimensions of the VAR tractable, ε_t^z will be a composite shock of the above.

6. In the empirical model, the authors do not restrict exogenous variables to follow any particular process; the assumption of random walk is to illustrate the identification restrictions.

7. Saudi Arabia maintains a fixed exchange rate system; as such, the money supply is more likely to be endogenous. Hence, it is more appropriate to define monetary shocks as money supply shocks rather than interest rate shocks.

five observed movements in the vector of variables $X_t = [h_t\, y_t\, (m_t - p_t)\, (s_t - p_t)\, p_t]$ are due to five mutually uncorrelated "structural" shocks with finite variances, $\varepsilon_t = [\varepsilon_t^h \varepsilon_t^s \varepsilon_t^z \varepsilon_t^d \varepsilon_t^m]$. These are terms of trade shocks, ε_t^h; aggregate supply shocks, ε_t^s; BOP shocks, ε_t^z; aggregate demand shocks, ε_t^d; and money supply shocks, ε_t^m.[8]

It can be shown that the long-run impact of the structural shocks on the endogenous variables has a peculiar structure. To show the long-run effect of structural shocks, ε_t, on X_t, the authors express the solution to the model in first differences:

$$(17) \qquad \Delta h_t = \varepsilon_t^h$$

$$(18) \qquad \Delta y_t = \theta \varepsilon_t^h + \varepsilon_t^s$$

$$(19) \qquad \Delta(m_t - p_t) = c_1(\varepsilon_t^s + \theta\, \varepsilon_t^h) + c_2 \varepsilon_t^z + c_3 \varepsilon_t^d$$

$$(20) \qquad \Delta(s_t - p_t) = [(k/\eta_1(\gamma + k)) + (\eta_2/\eta_1)] \times (\varepsilon_t^s + \theta \varepsilon_t^h) - (\gamma k/\eta_1(\gamma + k))\varepsilon_t^z - (k/\eta_1(\gamma + k))\varepsilon_t^d$$

$$(21) \qquad \Delta p_t = -c_1 \theta \varepsilon_t^h - c_1 \varepsilon_t^s - c_2 \varepsilon_t^z - c_3 \varepsilon_t^d + \varepsilon_t^m.$$

Note from equations (15) and (21) that the long-run effect of a BOP shock on the price level depends on the degree of capital mobility and on the magnitude of the semi-interest elasticity of money, λ, relative to the elasticity of money demand with respect to a BOP deterioration, μ. Assuming k is sufficiently large, the coefficient c_2 in equation (21) reduces to $\lambda - \mu$. When $\mu < \lambda$ ($\mu > \lambda$), the predicted effect of a BOP shock on the price level is positive (negative). Consequently, the long-run effect of a BOP shock on the price level is an empirical question. Similarly, the long-run effect of a supply shock on the price level can be of either sign. Notice that although all endogenous variables are unit root stochastic processes, the vector X_t is difference stationary. Finally, the long-run impact of the structural shocks on the endogenous variables is 'near-triangular', which is shown in the next section.

Identification of the Shocks

Because the vector ΔX_t is covariance stationary, it can be written as an infinite moving average process in the structural shocks:

$$(22) \qquad \Delta X_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i} = A(L)\varepsilon_t,$$

where $A(L)$ is a matrix whose elements are polynomials in the lag operator L. Denote the elements of $A(L)$ by $a_{ij}(L)$. The time path of the effects of a shock in ε_j on variable i after k periods can be denoted $\omega_{ij}(k)$. The authors also adopt the notation such that $A(1)$ is the matrix of long-run effects whose elements are denoted $a_{ij}(1)$; each element gives the cumulative effect of a shock in ε_j on variable i over time. Similarly, A_0 is the matrix of the contemporaneous impact effects and consists of $\omega_{ij}(0)$. The objective of identification is to discern the 25 elements of A_0. Given the model structure, the long-run effects of the shocks on the endogenous variables are given by

$$(22) \qquad \begin{vmatrix} \Delta h_t \\ \Delta y_t \\ \Delta(m_t - p_t) \\ \Delta(s_t - p_t) \\ \Delta p_t \end{vmatrix} = \begin{vmatrix} a_{11}(1) & 0 & 0 & 0 & 0 \\ a_{21}(1) & a_{22}(1) & 0 & 0 & 0 \\ a_{31}(1) & a_{32}(1) & a_{33}(1) & a_{34}(1) & 0 \\ a_{41}(1) & a_{42}(1) & a_{43}(1) & a_{44}(1) & 0 \\ a_{51}(1) & a_{52}(1) & a_{53}(1) & a_{54}(1) & a_{55}(1) \end{vmatrix} \times \begin{vmatrix} \varepsilon_t^h \\ \varepsilon_t^s \\ \varepsilon_t^z \\ \varepsilon_t^d \\ \varepsilon_t^m \end{vmatrix}$$

Note that the matrix of long-run effects is lower triangular except that $a_{34}(1)$ is not zero. However in the limit, the model yields convenient

8. If one assumes a stable money demand function, ε_t^m can be interpreted as a money supply shock. However, if money demand is not stable, ε_t^m will capture money supply shocks *net of* money demand shocks.

restrictions for identification depending on the degree of capital mobility. For example if one assumes perfect capital mobility so that $k \rightarrow \infty$, aggregate demand shocks have no long-run effect on real money balances. An aggregate demand shock in this case has no effect on real interest rates; any autonomous changes in aggregate demand have to be offset by a nominal and real appreciation of domestic currency. As a result, net exports decline and aggregate demand shocks have no *long-run* effect on real money balances under perfect capital mobility. Perfect capital mobility implies that the coefficient $c_3 = -\lambda/(\gamma + k)$ in equations (15) and (19) and the long-run response, $a_{34}(1)$ in equation (23), is zero.

If capital is completely immobile so that $k \rightarrow 0$, the model has recursive long-run impact multipliers. This can be seen by using the definition of z_t from equation (5) and taking the limit of equation (14) as $k \rightarrow 0$:

$$(14') \qquad s_t - p_t = (\eta_2/\eta_1)y_t - (1/\eta_1)b_t.$$

In this case, the long-run effects of the shocks on the endogenous variables are

$$(23') \quad \begin{vmatrix} \Delta h_t \\ \Delta y_t \\ \Delta(s_t - p_t) \\ \Delta(m_t - p_t) \\ \Delta p_t \end{vmatrix} = \begin{vmatrix} a_{11}(1) & 0 & 0 & 0 & 0 \\ a_{21}(1) & a_{22}(1) & 0 & 0 & 0 \\ a_{31}(1) & a_{32}(1) & a_{33}(1) & 0 & 0 \\ a_{41}(1) & a_{42}(1) & a_{43}(1) & a_{44}(1) & 0 \\ a_{51}(1) & a_{52}(1) & a_{53}(1) & a_{54}(1) & a_{55}(1) \end{vmatrix} \times \begin{vmatrix} \varepsilon_t^h \\ \varepsilon_t^s \\ \varepsilon_t^b \\ \varepsilon_t^d \\ \varepsilon_t^m \end{vmatrix}.$$

The new trade balance shock in equation (23′), ε_t^b, is a pure exogenous shift in the balance of payments, as opposed to ε_t^z in equation (5′), which is a composite shock that includes exogenous changes in the foreign interest rate, changes in the currency risk premium, as well as exogenous changes in the balance of payments.

The model implies that domestic supply shocks have no long-run effect on the terms of trade. Admittedly, this identifying assumption is controversial for Saudi Arabia. Even though Saudi Arabia can affect the crude oil price, it may be reasonable to assume that it has no effect on the *real* oil price in the long-run. First, crude oil price changes are known to be inflationary in the long run (Rosser and Sheehan, 1995), and it is likely that changes in crude oil prices will be fully reflected in export prices of industrial countries and the real oil price will be left unaffected in the long run. Second, even a country like Saudi Arabia, which produces one-eighth of world supply of crude oil, may not enjoy enough market power to give control over the real price of a commodity such as oil, because of alternative energy sources and, more important, alternative sources of oil (North Sea, Central Asian, and Russian sources). Nevertheless, it is important to assess the sensitivity of the results to the exogeneity of the real oil price in the long run. To that end, the authors present results from an alternative specification.

IV. EMPIRICAL RESULTS

Quarterly data from Saudi Arabia on the real exchange rate, Consumer Price Index, GDP, terms of trade, and money supply (M1) run from 1980:1 to 2000:1. Due to the lack of quarterly data for GDP, the oil production index is used as an indicator and the Chow-Lin procedure (Chow and Lin, 1971) to extract quarterly GDP from annual data.[9] The proxy for the terms of trade is the real oil price. The latter is obtained by deflating the crude oil price by the export price index of industrial countries. The measure for the real exchange rate is the real effective exchange rate. All data are taken from the International Monetary Fund's International Financial Statistics CD-ROM database.

To specify the empirical model properly, an important step is to test for unit roots and stationarity. Panel A of Table 2 presents the results of augmented Dicky Fuller (ADF) and KPSS statistics. The ADF test statistics

9. The authors wish to thank John Frain from the Central Bank of Ireland for providing the RATS code to implement the Chow-Lin procedure.

TABLE 2
Unit Root, Stationarity and Cointegration Tests

A. Unit Root and Stationarity Tests

Tests	p	y	h	$m-p$	q
ADF statistic	– 0.99	– 0.52	– 1.90	– 1.28	– 1.69
KPSS statistic	0.90	1.36	1.18	1.60	1.40

B. Cointegration Test

Null Hypothesis	Likelihood Ratio	5% Critical Value	1% Critical Value
$r=0$	86.87	87.31	96.58
$r\leq 1$	51.76	62.99	70.05
$r\leq 2$	25.55	42.44	48.45
$r\leq 3$	13.11	25.32	30.45
$r\leq 4$	5.33	12.25	16.26

Notes: Unit root tests: lag truncation is set at 4. The test assumes a constant in both ADF and KPSS procedures. The ADF critical values are −2.89 (5%) and −3.51 (1%). The KPSS critical values are 0.463 (5%), and 0.739 (1%). Cointegration: number of lags = 5. Variables included in the VAR: h, y, $m-p$, q, p. Change in OPEC production quota is included as an exogenous variable. The test assumes linear deterministic trends in the data.

indicate that the presence of a unit root in output, the real exchange rate, the real oil price, real money balances, and the price level cannot be rejected. Similarly the KPSS test rejects stationarity for all variables at conventional significance levels.

Saudi Arabia is a major OPEC oil producer, and large oil price changes have been results of OPEC decisions; as such, one needs to account for changes in OPEC oil policy. Since the early 1980s, OPEC relies on so-called production ceilings, whereby each member is assigned a production quota. The effectiveness of the quota system can be questioned due to deviations from assigned quotas by individual members; nevertheless the changes in the aggregate OPEC production quota can be taken as a proxy for OPEC oil policy. For example, when OPEC reduces the quota, it signals a tight oil policy. In what follows, the authors include changes in OPEC aggregate production quota as an exogenous variable accounting for OPEC oil policy in all VARs.[10]

Panel B of Table 2 presents the likelihood ratio statistic for cointegration among the variables using the Johansen method. The exogenous variable (the change in OPEC production quota) is rendered a zero-mean variable so that it only affects the mean and not the trend of the endogenous variables (Johansen, 1995, p. 84). The tests show weak evidence of one cointegrating vector among terms of trade, output, real money balances, the real exchange rate, and prices. As a benchmark model, the article will provide results from VAR in first differences. As an alternative specification, the article presents results from a vector error correction model (VECM) in which one cointegrating vector is imposed on the model.

Given the openness of the Saudi Arabian economy, the benchmark model assumes perfect capital mobility. Results from a model with no capital mobility will be provided. First, let $\mathbf{X_t}=[\Delta h_t \Delta y_t \Delta(m_t-p_t)\Delta(s_t-p_t)\Delta p_t]$. After estimating the benchmark VAR with five lags, the diagnostic tests indicate that five lags are appropriate for the residuals to approximate white noise. To identify the shocks, the authors impose the triangular structure on the matrix of long-run effects $A(1)$ in equation (23) with $a_{34}(1)=0$, which is consistent with perfect capital mobility. The dynamic effects of the innovations can best be understood by variance decompositions and impulse response functions typical of VAR methods.

Table 3 reports variance decompositions for the terms of trade, output, real exchange rate, and prices. At a one-quarter forecasting horizon, Saudi Arabian terms of trade are influenced by domestic supply and to a lesser

10. OPEC behavior per se is beyond the scope of the current article. Thus the authors take changes in OPEC aggregate oil production quota to be exogenous to the model. The OPEC production quotas are taken from the OPEC *Statistical Bulletin*.

TABLE 3
Variance Decompositions: Perfect Capital Mobility

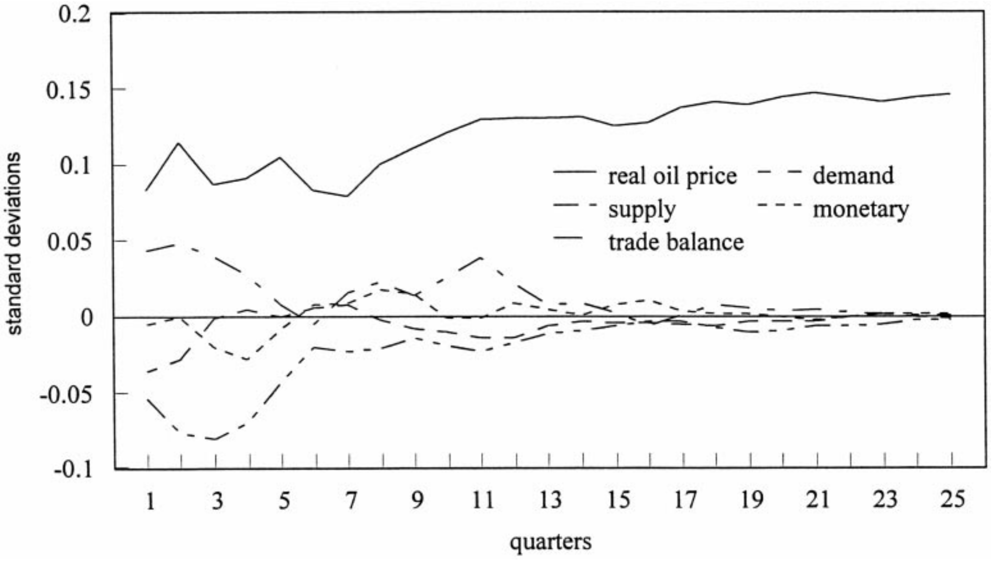
	Percent of Forecast Error Variance Attributable To				
Horizon	ε_t^h	ε_t^s	ε_t^z	ε_t^d	ε_t^m
Terms of trade (real oil price)					
1	52.8	22.8	14.3	10.0	0.2
4	54.1	30.9	9.8	3.2	1.9
8	66.6	22.6	7.0	2.1	1.7
16	82.8	10.7	4.3	1.2	1.0
24	89.7	6.4	2.6	0.8	0.6
Long run	100.0	0.0	0.0	0.0	0.0
Output					
1	1.4	85.0	10.8	2.4	0.4
4	4.4	78.1	15.0	0.6	1.9
8	10.7	76.0	10.2	1.7	1.4
16	20.1	73.7	4.5	1.0	0.8
24	24.8	71.4	2.7	0.6	0.5
Long run	35.2	65.8	0.0	0.0	0.0
Real exchange rate					
1	14.2	10.8	12.2	61.9	0.9
4	20.6	17.8	10.3	50.3	1.1
8	40.0	10.4	4.3	44.4	0.9
16	62.8	4.8	1.9	29.8	0.6
24	70.6	3.7	1.9	23.5	0.3
Long run	79.4	3.6	2.0	15.0	0
The price level					
1	0.0	2.3	1.6	7.9	88.2
4	12.2	1.8	2.8	8.4	74.7
8	29.2	4.9	8.2	2.7	55.0
16	42.8	13.2	2.8	1.3	40.0
24	51.2	14.6	1.8	0.7	31.6
Long run	64.4	17.5	0.7	0.0	17.3

extent by trade balance and aggregate demand shocks. The influence of domestic supply shocks peaks at a one-year forecasting horizon explaining about 31% of the forecast error variance of the terms of trade. As a major oil producer with a large oil-producing capacity, Saudi Arabia has a sizable impact on its terms of trade in the short run. However, by construction, domestic supply shocks have no long-run effect on the terms of trade. As this assumption may be questionable for Saudi Arabia, results from an alternative decomposition are given shortly.

The variance decomposition of output indicates that trade balance shocks account for about 11% of the forecast error variance within one quarter. Terms of trade shocks have a minimum effect in the short run, but they account for over 35% of the forecast error variance of output in the long run. Even though Saudi Arabia has a growing nonoil sector and a large government sector as documented by Choudhury and Al-Sahlawi (2000), Saudi Arabian GDP is still vulnerable to real oil price developments, particularly in the long run. To reduce the vulnerability of Saudi Arabia to terms of trade shocks, the authorities should continue to diversify the production base in Saudi GDP. Moreover, because terms of trade shocks mostly emanate from nominal oil price changes, oil-producing countries should aim for a stable oil policy that minimizes fluctuations in the world price of oil.

Although there is a moderate effect of supply and trade balance shocks on the real exchange rate in the short run, demand shocks

FIGURE 1
Responses of Terms of Trade



seem to explain the bulk of real exchange rate movements in the short run. In the long run, real exchange rates seem to be driven by real oil price shocks. Monetary shocks explain a sizable proportion of price level movements in the short run, and domestic supply and real oil price shocks seem to drive the price level in the long run. Notice the preponderance of real oil price shocks in explaining the price level movements in the long run. This may be due to the fact that domestic prices are subsidized in Saudi Arabia, so that they are not influenced from real oil price developments in the short run. However oil prices affect government revenues and may ultimately affect government programs, including subsidies, in the long run. The influence of monetary shocks on the price level in the short run confirm evidence presented by Bashir et al. (1995).

Figures 1–4 display the impulse response functions (IRFs). Each figure shows the dynamic response of the endogenous variables to real oil price, supply, trade balance, aggregate demand, and monetary shocks. Figure 1 shows that real price shocks respond positively to own shocks with permanent effects. However, as expected, the real oil price declines in response to a Saudi Arabian supply shock. Notice that by construction, the effects of all shocks die down in the long run. Figure 2 shows that output expands in response to supply, demand, trade balance, and oil price shocks; however, except for terms of trade and supply shocks, the responses are moderate to negligible. Notice the significant expansionary effect of a positive terms of trade shock on output. This is in line with Spatafora and Warner (1995), who found that positive terms of trade shocks have expansionary effects on investment and output in the long run in oil exporting countries.

In Figure 3, the real exchange rate responds positively to demand and oil price shocks, whereas the effects of trade balance, supply, and monetary shocks is initially negative and relatively moderate in size. Figure 4 confirms that monetary and terms of trade shocks figure prominently in explaining price level movements and prices respond positively to both shocks. Note that the effects on the price level seem permanent except for the trade balance and demand shocks. Although the price level responds negatively to supply, the response turns positive within two quarters. The response of the price level to a real oil price may reflect the effect of rising oil prices on world prices and hence on domestic prices. Overall, the IRFs indicate that the responses mostly confirm to theoretical predictions dictated by the coefficients of the shocks in equations (17) through (21) and the overidentification restrictions of the model are generally satisfied.

FIGURE 2
Responses of Output

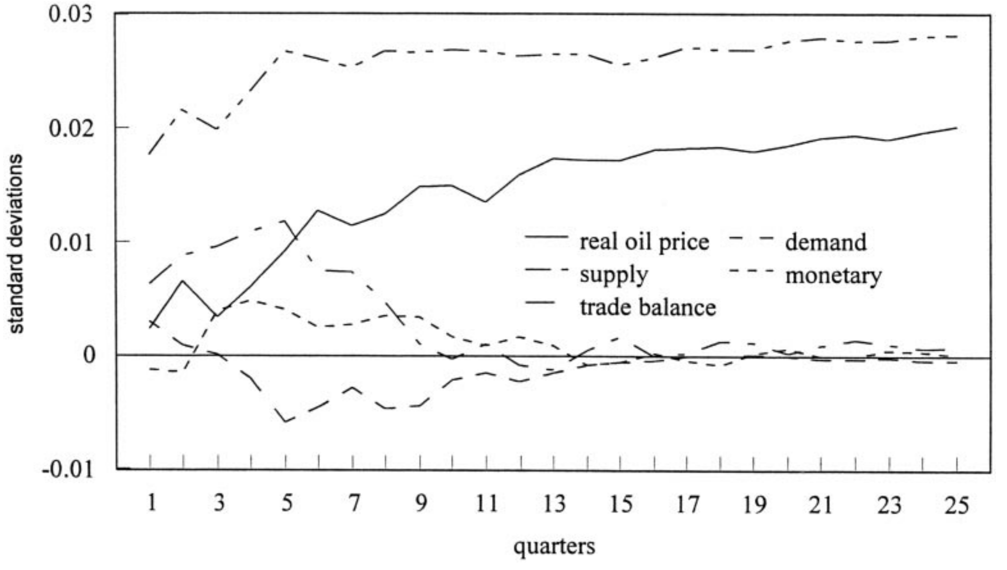
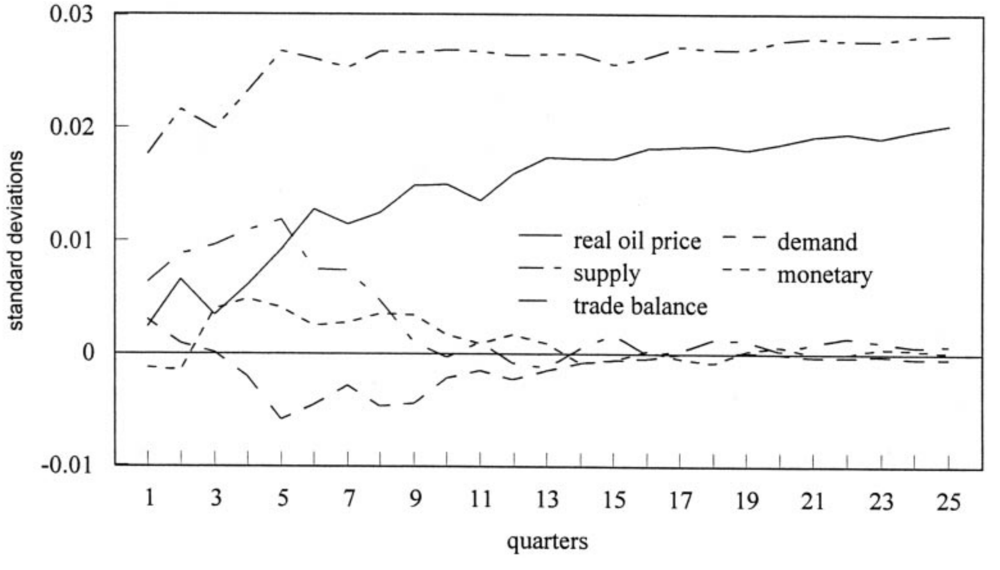


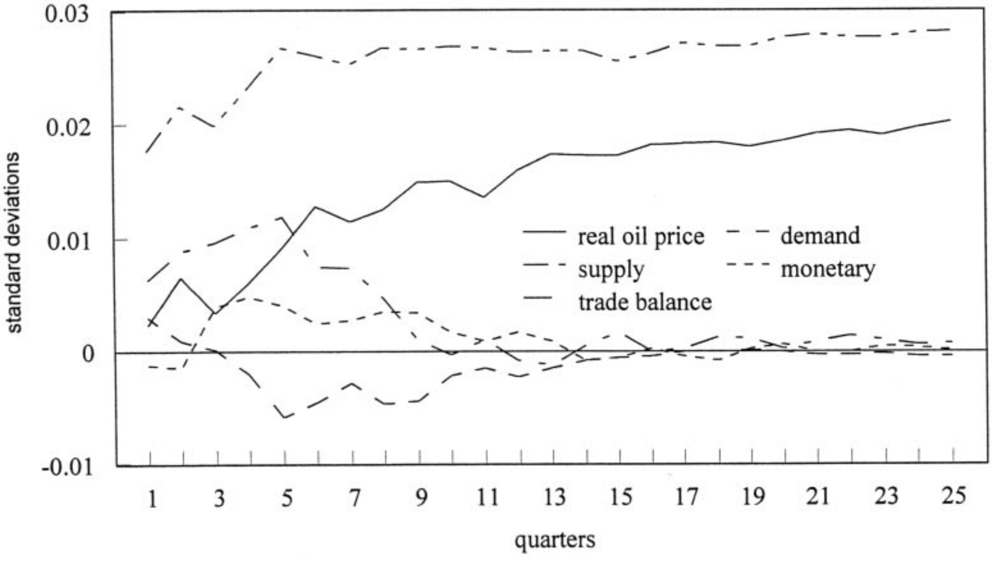
FIGURE 3
Responses of the Real Exchange Rate



Alternative Specifications

In the benchmark model, the article assumed that domestic supply shocks have no long-run effect on the terms of trade. However, Saudi Arabia is a large oil producer, and Saudi Arabian supply shocks may have long-run effects on the real oil price. To account for this possibility, the article presents an alternative decomposition: the restriction $a_{12}(1) = 0$ is replaced with $\omega_{21}(0) = 0$. Instead of restricting the long-run effect of supply shocks on the terms of trade, the article restricts the contemporaneous effect of terms of trade shocks on

FIGURE 4
Responses of the Price Level



Saudi Arabian output to be zero and estimate the model.[11] Results are given in Table 4. In this decomposition, supply shocks explain less that 2% of the forecast error variance of the terms of trade in the long run. It is possible that increases in oil prices lead to proportionate inflation, and therefore real price of oil may not be affected much from increases in nominal oil prices. If Saudi Arabian output supply shocks affect nominal oil prices, which lead to world inflation, the terms of trade will be left largely unaffected in the long run. This is consistent with results reported by Rosser and Sheehan (1995), who found that nominal oil price increases lead to worldwide inflation. In the alternative model, terms of trade shocks explain moderate proportion of output in the long run. The rest of the results are broadly similar to the benchmark model.

Next, the article relaxes the assumption of perfect capital mobility and identify the shocks assuming zero capital mobility. To that end, the authors impose the triangular long-run impact matrix in equation (23). Variance decompositions of output under this assumption are given in panel A of Table 5. Results show that the contribution of terms of trade shocks to output under this assumption is the same as under perfect capital mobility. However, when capital is immobile, the effect of trade balance shocks are minimum. Instead, domestic aggregate demand shocks have a moderate effect on output in the short run. This is to be expected because in an open economy, shocks emanating from the rest of the world are more likely to affect the domestic economy.

Panel B of Table 5 presents results from a VECM where one cointegrating vector is imposed on the VAR. Recall from Table 2 that there is weak evidence for the existence of one cointegrating vector among the variables. To identify the shocks, the authors use a Choleski decomposition. The order of the variables is that implied in the table; terms of trade → output → real money balances → real exchange rate → prices. This orthogonalization is consistent with responses of the endogenous variables to the structural shocks given in equations (17)–(21). A notable difference in this model is that the effect of trade balance shocks is absent and monetary shocks play a somewhat important role in explaining output movements. However, terms of trade shocks still play some role in explaining output movements in the long run, albeit a smaller one as compared to the benchmark model.

11. In all models estimated, the contemporaneous effect of the terms of trade shocks on output is negligible.

TABLE 4
Variance Decompositions: An Alternative Decomposition

	Percent of Forecast Error Variance Attributable To				
Horizon	ε_t^h	ε_t^s	ε_t^z	ε_t^d	ε_t^m
Terms of trade (real oil price)					
1	61.1	14.4	14.3	10.0	0.2
4	64.1	20.9	9.8	3.2	1.9
8	74.8	14.3	7.0	2.1	1.7
16	87.0	6.5	4.3	1.2	1.0
24	91.9	4.1	2.6	0.8	0.6
Long run	98.3	1.7	0	0	0
Output					
1	0.0	86.4	10.8	2.4	0.4
4	1.1	81.4	15.0	0.6	1.9
8	4.9	81.8	10.2	1.7	1.4
16	11.6	82.2	4.5	1.0	0.8
24	15.6	80.8	2.6	0.6	0.4
Long run	23.5	76.5	0	0	0
Real exchange rate					
1	17.3	7.7	12.2	61.9	0.9
4	25.4	13.0	10.3	50.3	1.1
8	43.8	6.5	4.3	44.4	0.9
16	61.9	5.8	1.9	29.8	0.6
24	68.1	6.6	1.9	23.1	0.3
Long run	73.8	9.2	2.0	15.0	0.0
The price level					
1	0.1	2.2	1.6	7.9	88.2
4	12.6	1.4	2.8	8.4	74.8
8	26.3	7.8	8.2	2.7	55.0
16	36.5	19.5	2.8	1.3	40.0
24	44.4	22.3	1.7	0.7	31.0
Long run	55.1	26.9	0.7	0.0	17.3

V. CONCLUSIONS

Given the relative importance of oil price shocks to the world economy, it is important to investigate the impact of real oil price shocks to oil producing countries as well. In that regard, Saudi Arabia, as the largest oil producer in the world, warrants particular attention. This article investigates the sources of macroeconomic fluctuations in Saudi Arabia for the 1980–2000 period using structural VAR methods with an emphasis on oil prices and the resulting terms of trade changes. The results show that Saudi Arabia has a sizable impact on the real oil price, particularly in the short run. Moreover, the results show that Saudi Arabian output is somewhat vulnerable to terms-of-trade shocks. Except for modest trade balance shocks and aggregate demand shocks in the short run, supply shocks explain a sizable proportion of Saudi Arabian output fluctuations. The rest of output is explained by the real oil price. Similarly the real exchange rate seems to be driven by real oil prices and domestic aggregate demand shocks. Monetary shocks in the short run and real oil prices in the long run explain the bulk of price level movements. These results call for diversification of the production base in Saudi GDP. Moreover, oil-producing countries should aim for a stable nominal oil price because such a policy will reduce terms-of-trade variability in the short run.

TABLE 5
Variance Decompositions of OUTPUT: Zero Capital Mobility and the VECM Model

A. No Capital Mobility

Percent of Forecast Error Variance Attributable To					
Horizon	ε_t^h	ε_t^s	ε_t^z	ε_t^d	ε_t^m
1	1.4	85.0	0.1	13.1	0.4
4	4.4	78.1	2.1	13.4	1.9
8	10.7	76.0	4.2	7.7	1.4
16	20.1	73.7	2.0	3.4	0.8
24	24.8	71.4	1.2	2.1	0.5
Long run	35.2	64.8	0.0	0.0	0.0

B. Vector Error Correction Model (VECM)

Percent of Forecast Error Variance Attributable To Innovations In					
	h_t	y_t	$(m_t - p_t)$	q_t	p_t
1	8.9	91.1	0.0	0.0	0.0
4	3.8	83.3	0.6	2.5	9.8
8	3.5	76.8	1.2	3.7	14.8
16	11.0	69.4	1.0	3.7	14.9
24	12.4	69.0	0.7	3.7	14.1
Long run	15.1	68.1	0.0	3.8	13.0

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