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Effects of Changes in Oil and Gas Prices and State Offshore Petroleum Production on the Louisiana Economy, 1969-1999

U.S. Department of the Interior
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Cooperative Agreement
Coastal Marine Institute
Louisiana State University

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ABSTRACT

This study examines the interactions between changes in crude oil and natural gas prices, oil and gas production in the state offshore waters and measures of economic activi

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EXECUTIVE SUMMARY

Louisiana has been a major player in petroleum exploration, development and production among oil producing states in the U.S. for decades. The state is currently ranked third among natural gas producing states and fourth among crude oil producing states in the U.S. If production activities in the federal OCS are included, then the state is the second and third leading producers of gas and oil, respectively, in the U.S.

The focus on Louisiana in this study is motivated by the fact that economic and social life in the state, especially in the coastal communities, have depended to a large extent on the exploration and production (E&P) activities in the region, over the years. Apart from providing direct jobs, E&P operators generate severance tax revenues in addition to royalty and cash bonus payments for state leases. However, in more recent years, a larger proportion of oil and gas production in Louisiana comes from the federal OCS area, which is outside the tax jurisdiction of the state, thereby diminishing the proportion of revenue from E&P activity in the state waters.

For the purpose of this report, three macroeconomic variables are evaluated to gauge the economic strength of Louisiana. They include state annual revenue, quarterly employment levels and quarterly personal income:

> *Revenue:* In the past, Louisiana has derived a significant proportion of its general revenue from the oil and gas industry located within its borders and has a substantial number of industries that are highly energy-dependent. In 1980, revenue derived from oil and gas extraction in the state accounted for more than 50 percent of the general state revenue. This period also corresponds to when the price of oil and gas, as proxied by the crude petroleum price index (CPPI), was at its peak.
>
> E*mployment*: A lot of people in Louisiana are employed directly or indirectly in the oil and gas sector. As a result, any unusual developments in the sector will reflect on state's welfare; unemployment level is one such closely watched variable. In the absence of enough data on the gross state product (GSP), employment level provides an important indication of the level of economic activity in the state. The trends in employment levels seemed to follow similar patterns with the petroleum price index. Generally, there was high growth in employment, especially in the mining sector, until the early 1980s, followed by a rapid decline that lasted until the mid-1990s.
>
> *Personal Income:* Apart from the substantial number of jobs produced by the oil and gas

VAR Model: For most oil producing regions, changes in oil and gas prices affect revenue and personal income of communities in regions where the oil and gas industry looms large in the economy and revenue from petroleum taxation is a major source of fiscal revenue. A decline or increase in firm's profits can further influence this tax base significantly. Furthermore, increases in oil and gas prices can provoke cost-cutting measures by firms, and usually labor inputs are the most easily affected in such a situation. To get to equilibrium following an increase in oil and gas prices, firms cut output and employment, wages are also cut, and consequently, the household income is negatively affected.

As in most studies analyzing the macroeconomic impact of oil and gas price shocks, a vector auto-regression (VAR) model has been adopted in this study. In its standardized formulation each endogenous variable in the model is specified as a function of its own lag(s); other endogenous variables and their lags. Exogenous variables may also be included in the model specification. For the purpose of this study, we have assumed that shocks to an endogenous macroeconomic aggregate such as employment would be as a result of shocks first to oil and gas prices and subsequently to E&P activity in the state offshore waters in that order, *ceteris paribus*.

The estimated VAR system equations for unemployment, personal income, and total state revenue portray the effects of a price and/or offshore production shock on the Louisiana economic system using innovating accounting procedures called impulse response function and variance decomposition analyses. In general, variance decomposition analysis provides a useful process for investigating the proportion of the variation in macroeconomic variable attributable to each variable in the VAR system. Impulse response function, on the other hand, provides a complementary analytical framework to further characterize the dynamic paths of the effects of an exogenous shock on other macroeconomic variables and to portray the stability and duration of such effects.

Variance Decomposition Results: According to the empirical results, the dynamic VAR analysis of the interactions among changes in oil and gas prices, oil and gas production in Louisiana state offshore waters, and aggregate economic indicators in Louisiana shows:

- The effects of changes in oil and gas prices on Louisiana employment and personal income are statistically significant, but the impact of price on state revenue in the context of offshore production from state waters is not statistically significant.
    - Oil and gas prices account for as much as 44 percent and 33 percent, respectively, of the observed variation in Louisiana employment level, as high as 24 percent and 35 percent, respectively, of the variation in personal income, and 14 and 16 percent, respectively, of the variation in revenue, over time.
- There is no statistically significant effect of autonomous oil and gas production for state offshore waters on Louisiana aggregate economic performance measures--employment, personal income and state revenues.

Impulse Response Function Results: The empirical results derived from the impulse response function have been characterized in terms of short-run or long run responses as follows:

- Responsiveness to oil and gas price shocks
    - The responsiveness of employment to o

that region may face increases in input costs. The converse may also be true for an oil-importing state. However, price decreases may also produce depressed demand in some sectors of a state economy, and unemployed labor is not immediately shifted elsewhere. Potential structural rigidities and the degree of sector dependencies in a particular region's economy will largely influence this situation. A region with a high concentration of oil dependent sectors will be especially complex to analyze. Thus, the interrelationships between energy prices and regional economies can be quite complex. The strength and duration of the effect of oil price movements are often dependent on the degree of inter-sector linkages in the economy. Apart from the natural linkage between energy production sectors and energy-related industries, the level of economic activities in other sectors such as manufacturing, banking, and construction may also be significantly affected.

In the past, most boom and bust economic cycles in oil rich states such as Louisiana, Texas, and Oklahoma have been linked to developments in the oil and gas markets, which invariably center on changes in prices in these markets. In fact, as Brown and Yucel (1995) reported, such price movements in the oil and gas markets in the 1970s and 1980s led many to suggest that energy is "the tail that wags the dog". Increasing energy prices may spur higher activities in the oil and gas sectors as well as sectors such as banking as investors demand more funds, which in turn leads to higher levels of demand as employment rises, thus implying higher income for families. On the other hand, a price that is too high may hinder the refinery and petrochemical sectors, for example, as cost of inputs rises substantially implying potential loss of jobs and income in these sectors.

This study was motivated by the MMS' desire to undertake more socio-economic analyses of communities that are impacted by the activities of the oil and gas industry under its jurisdictional mandate. The focus on Louisiana is motivated by the role of the state in meeting U.S. oil and gas consumption needs. Louisiana is the third leading producer of natural gas and fourth in crude oil production in the U.S. If offshore production activities are included, then the state is the second and third leading producer, respectively (http://www. lmoga.com/industryoverview.html). In this study, a time series econometric model has been de

2. SOURCES, DESCRIPTION AND ANALYSIS OF DATA

2.1 Sources of Data

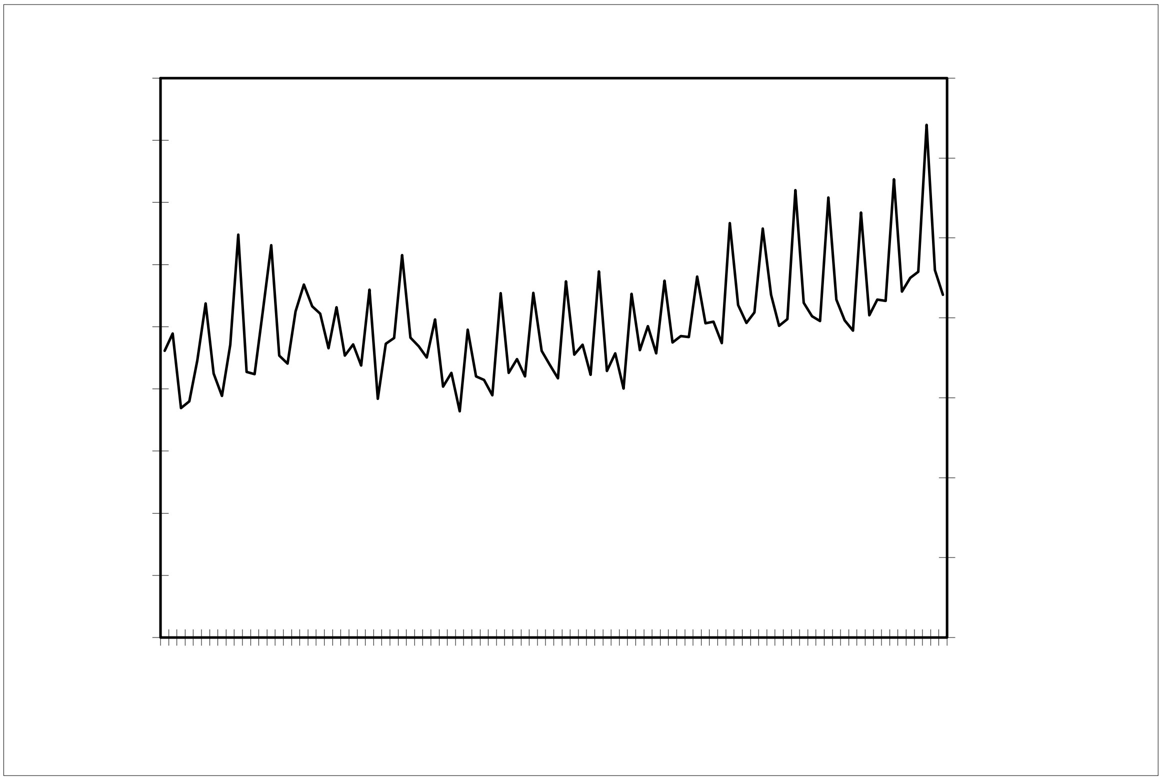
Most previous research studies on the economic effects of oil price shocks on macroeconomic variables have relied on national data, which are easily available from a variety of sources. One of the reasons for paucity in regional/state-level analyses is because reliable sources of state-level information in the preferred format are limited. The data collection efforts in this study were very focused on finding accurate sources of data that are both comprehensive and tenable. The data sources were verified by our in-house databases, those of MMS, and industry trade associations.

In order to establish the robustness of our model, both from statistical and economic theory perspectives, we also used other US macroeconomic aggregate data in the estimation procedures. The national level aggregate economic variables used in the model include quarterly and annual data on real gross domestic product, crude oil producer price index, all commodities price index, interest rates (the 3 month treasury bill rates), and implicit gross domestic product deflator series. These national-level aggregate data are important inputs in the oil and gas industry for making exploration and production investment decisions. For example, given an oil price level, the choice of the levels of investment, and hence potential industry output, may be driven by the prevailing interest rates. With regards to the states, it is also expected that states' economic variables at the state level will to a large extent correlate with important national aggregates such as the overall GDP, which measures national economic output in the U.S.

The data on oil and gas production came from MMS' oil and gas database. The oil price is the crude oil producer price index deflated by the all commodities price index. Both series are available from the U.S. Bureau of Labor Statistics. The natural gas price series used is the wellhead price and is available from the Energy Information Administration. These price series are both deflated by the GDP Implicit Deflator. Data on employment levels for Louisiana is taken from the U.S. Bureau of Economic Analysis (BEA). The BEA also provides a reliable source for the following series: Louisiana personal income and revenue, U.S. real GDP, GDP implicit deflator and interest rates.

2.2 Key Indicators of Economic Performance

Measures of the economic strength of Louisiana we included in the model include, real state quarterly revenue (RQRV), quarterly employment and quarterly personal income. The trends in these indicators are presented in Figures 1-6.



Revenue: In the past, Louisiana has derived a significant proportion of its general revenue from oil and gas industry located within its borders and has substantial number of industries that are highly energy-dependent. Figure 1a and 1b present the trends in state total revenue and the proportion of state gross revenue accounted for by prices fell in the mid to late 1980s relative to the previous decade, it has been relatively unstable in the 1990s. Yet, the 1990s still witnessed at least two spikes in oil prices. On the other hand, oil production in Louisiana state offshore waters has been on a declining trend since the 1970s relative to Federal offshore production (Figure 5b). This pattern of production even in the periods of rising oil price is probably a result of

Table 1. Summary Statistics of Quarterly Macroeconomic and E&P Data, 1977-2000

	Unit	Mean	Maximum	Minimum	Std. Dev.	COV
Macroeconomic Statistics						
Unemployment Rate	*%*	8.02	13.38	4.22	2.35	0.29
Total Employment	*Thousand*	1,741	1,969	1,379	133	0.08
Personal Income	*1982$Million*	51,138	66,235	36,317	7,755	0.15
Gross Revenue	*1982$Million*	1,014	1,650	728	171	0.18
Total Wages	*1982$Million*	6,635	8,769	4,568	829	0.12
E&P Data Statistics						
E&P Sector Employment	*Thousand*	62	100	43	17	0.27
E&P Revenue	*1982$Million*	197	461	66	99	0.50
E&P Wages	*1982$Million*	433	715	307	105	0.24
Wages Per E&P Employee	*1982$*	7,082	8,811	5,995	582	0.08
Wellhead Gas price	*1982/Mcf*	3.25	8.56	1.17	1.44	0.44
Crude Oil Price	*1982$/Bbl*	31.42	42.05	21.55	4.15	0.13
State Offshore Liquid Production	*MMBbl*	6.054	8.696	3.285	1.138	0.19
State Offshore Gas Production	*Bcf*					

3. THEORETICAL MODEL AND ESTIMATION

3.1 Model Specifications

As in most studies of macroeconomic impact of oil price volatility, a VAR modeling methodology is adopted in this study. The VAR is a recent development in time series econometric modeling tool. The model framework is a multi-stage process, which involves unit roots tests, co-integration examination, and Granger-causality exploration. It is commonly used for forecasting systems of interrelated time series and for analyzing the dynamic impact of random disturbance on a system of variables.

In its generalized formulation, every dependent variable is modeled as a function of its immediate past values and the past values of other dependent variables in the system. Independent or exogenous variables may also be included in the system equations as explanatory variables. The general mathematical formulation of a VAR system/model usually takes the form[1]:

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

Where y_t is a k vector of dependent variables, x_t is an m vector of independent variables, $A_1,\ldots,A_p$ and B are matrices of coefficients to be estimated. The term, $\varepsilon_{t,}$ is a vector of innovations that may be contemporaneously correlated with each other but is not correlated with their immediate past values and other variables in the right-hand-side.

3.2 Empirical VAR Model Representation

A specific VAR model, which describes the interactions between Louisiana economy, oil and gas production in state offshore waters, and changes in oil/gas price is represented by the

Where:
y_{it} *(i=1, 2,3): 1* = natural log of crude price index or gas price; 2= natural log of crude oil or natural gas production; and 3 = natural log of annual real revenue or real personal income or level of employment[2];

the purpose of this study, we ordered the variables as follows: [oil price → state offshore E&P activity → economic indicators][3].

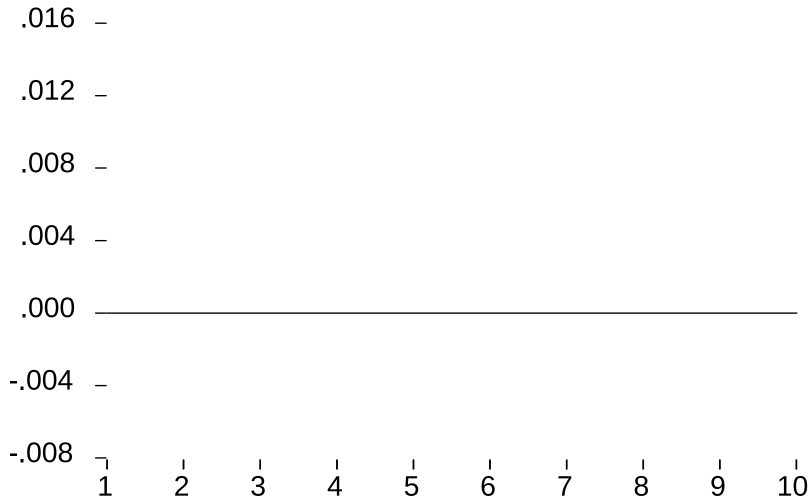
A dynamic formulation of the VAR-type has been found to perform better in macroeconomic forecasting than theoretically based large structural models of the past. Hence, VAR has become a popular means of studying the structural path of dynamic series. Its usefulness for economic analysis also lies in the flexibility offered to test various hypotheses of causation (in the Granger sense) among the variables. In addition, the structure of the VAR can be exploited through what is generally referred to as *innovation accounting*. Two processes in innovation accounting—

Table 3. Decomposition of the Variance of Macroeconomic Variables Following Oil and Gas Price Shocks

Equations/Variables	Period (Years)					
	1	**2**	**4**	**6**	**8**	**10**
State Offshore Oil System Equations						
Employment						
Oil Production	0.0088	0.0070	0.0167	0.0239	0.0266	0.0278
Real Oil Price	0.2800	0.4390	0.4245	0.4183	0.4161	0.4150
Personal Income						
Oil Production	0.0293	0.0447	0.0691	0.0740	0.0746	0.0747
Real Oil Price	0.0694	0.2301	0.2442	0.2439	0.2438	0.2437
State Revenue						
Oil Production	0.0723	0.0973	0.1288	0.1377	0.1287	0.1321
Real Oil Price	0.1347	0.1242	0.1401	0.1357	0.1384	0.1380
State Offshore Gas System Equations						
Employment						
Gas Production	0.0064	0.0694	0.9500	0.1054	0.1052	0.1058
Real Gas Price	0.2381	0.3357	0.3317	0.3283	0.3283	0.3281
Personal Income						
Gas *Production*	0.0043	0.0070	0.0196	0.0197	0.0236	0.0237
Real Gas Price	0.1339	0.2831	0.3336	0.3455	0.3448	0.3468
State Revenue						
Gas *Production*	0.0204	0.0234	0.0226	0.0226	0.0227	0.0227
Real Gas Price	0.0005	0.1288	0.1599	0.1603	0.1603	0.1602

plus or minus two-standard error confidence bands[5]. Bands falling on or below the ‘zero line’ signify a statistically insignificant estimate at that point.

Short Run Impact of Oil Shocks on Macroeconomic Variables: Figures 6-8 show the impulse response of employment, personal income and revenue to an oil price shocks, respectively. The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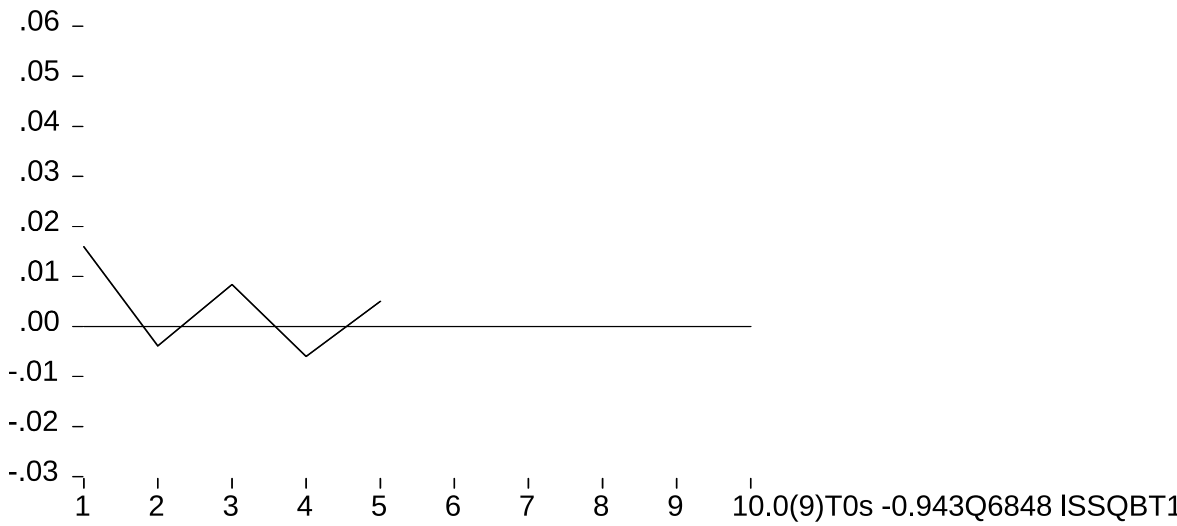

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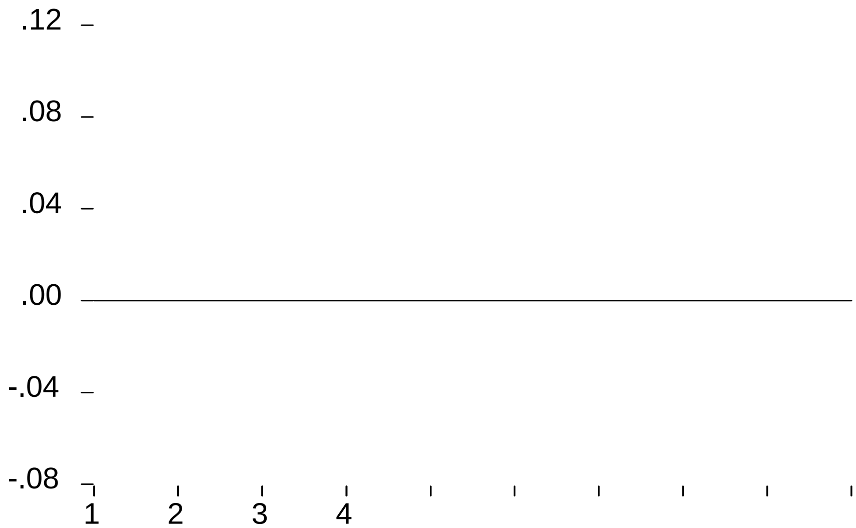

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Short Run Impact of Gas Price Shocks on Macroeconomic Variables: In Figures 12-14 we present the impulse response of employment, personal income and state revenue to positive shocks in gas prices. Employment responds positively up to about the third year, but significant only to about the end of the second year. The initial positive change represents the maximum change ever attained and it leads to 0.007 percent increase in employment above equilibrium levels. The pattern of the impulse response function, as the graph depicts, indicate a relatively long (about 8 years) adjustment back to initial equilibrium employment levels.

The response of personal income to a positive shock in the price of gas is statistically significant up to the third year and fairly stable. It appears that the effect is permanent (i.e. new equilibrium levels), and that the new levels are statistically significant. The maximum level of employment change, attained in the second year, is 0.007 percent. Figure 14 shows a positive response of revenue to a positive shock to gas price. The adjustment pattern indicates a more cyclical movement and thus less stable response compared to the employment and personal income. The maximum change, reached in the second year, is 0.019 percent. Notably, revenue response is not statistically significant throughout the forecast horizon.

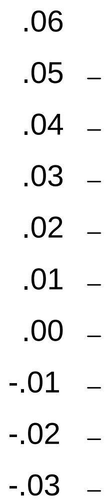
Long-Run Impact of Gas Price Shocks on Macroeconomic Variables: The accumulated (long run) positive response of employment, personal income, and state revenue to positive gas price shocks are is shown in Figure 15-17.

The long run employment responses are statistically significant only up to about the seventh year. Employment rises to about a maximum 0.020 percent above its equilibrium levels in the third year following the gas price shock.

As Figure 16 shows, the accumulated response of personal income to a positive price shock is both positive and statistically significant to about the eight year of the entire forecast horizon. Following the initial shock, accumulated response of income shows a steady rise peaking at about 0.03 percent in the sixth year.

The long run response of revenue to a gas price shock is statistically significant and it is estimated as about 0.018 percent, the highest significant changes attained, in the second year following the shock (see Figure 17). However, the level of change over the entire horizon is highly insignificant. In other words, these changes do not matter to the initial equilibrium levels of Louisiana's revenue.

Effects of State Offshore Production on Macroeconomic Variables: The decomposition results presented earlier in section 3.3.1 clearly show that production of oil and gas from state offshore no longer plays a major and statistically discernable role in Louisiana economic activities. To further test the veracity of these results, we study the impact of a direct shock to oil and gas production on employment, personal income and state revenue. As is it is with the case of price shocks, both the decomposed variations and impulse responses of variables were examined. In addition, short and long run imp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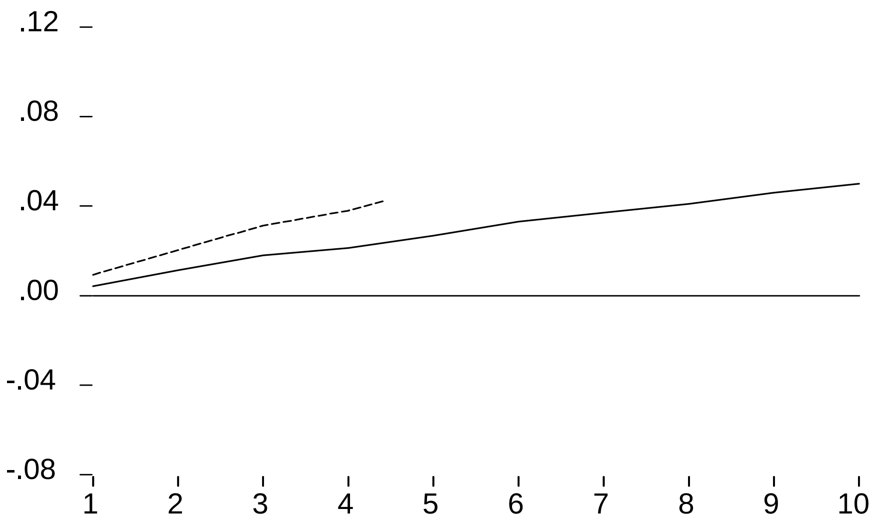
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The impulse response results are illustrated graphically in Figures B1- B6 reported in Appendix B. The results indicate that all the three indicators of economic activities show positive responses to these shocks. In virtually all of these cases, the responses are also relatively fast and stable. However, and most importantly, the results show that, whether in the case of variance decomposition or impulse responses, short and long run, shocks to oil or gas production in state waters are statistically insignificant in explaining Louisiana economic activities. These confirm our previous results.

3.4. Economic Interpretations of the Empirical Results

Table 4 shows the results derived from estimating the system equations in (2) in terms of the short and long run responsiveness of selected macroeconomic variables to relative changes in oil and gas prices. In other words, these are elasticity estimates based on the impulse response functions generated from the system equations in (2). These elasticity measures are calculated by normalizing the maximum change in the relevant macro-economic variable by the maximum change in the relevant prices following the one-standard deviation shock applied (Brown and Yucel (1999)[6].

The results reported in Table 4 indicate that the price responsiveness of these variables to oil and gas price changes is inelastic either in the short or long run. It is, however important to note that these are restrictive or conditional elasticity measures estimated from system equations involving state offshore oil and gas production. As expected, long run elasticity is generally larger than short run because in the long run economic agents

Table 4. Price Elasticity of Employment, Personal Income, and Revenue*

	Short Run (SR)	**Long Run** (LR)	**Relative Size** (SR/LR)
State Offshore Oil System Equations			
Employment	0.04	0.10	2.5

These shocks are estimated to be 18 percent and 20 percent for oil and gas, respectively[8]. Of course, these estimates assume that all other things being equal, including a no-change in the level of price shock over the time horizon considered and they are restrictive or conditional on state offshore oil and gas production dynamics.[9]

According to the results reported in Table 5, the number of jobs provided as a result of that oil price shock would have been up to 26,600. The shock would have added between 1 billion and 2 billion dollars to personal income and up to 272 million dollars to Louisiana revenue in 2002. It is interesting to note that there is no difference in the magnitude of the long run and short run effects of this shock on revenue. The lack of difference appears to indicate that an oil price shock needs to be sustained over a long period of time for the revenue effect to make a difference in the long run.

The effects of a shock in gas price on macroeconomic variables follow a similar pattern of oil price effects. The only difference is in the magnitude, which appears to indicate that, on long-term basis, economic activities in the state benefit slightly more from a shock in oil price than from a similar shock to gas prices. The opposite appears to hold in the periods closer to the shock. For example, the difference would have been as much as 25 percent higher jobs created as a result of oil price shock than under the gas price shock scenario in the long run.

[8] According to EIA's 2002 data, oil and gas prices averaged 26.11$/barrel and 2.95$/mcf, respectively.
[9] See Iledare and Olatubi, 2004 for conditional equivalence estimated from solving the system of equations involving the total Gulf of Mexico OCS petroleum production.

4. SUMMARY, CONCLUSIONS, AND FUTURE RESEARCH

price shock in oil and gas indicate a net-effect that is significant only for employment and personal income. This long run result is understanda

2002). In other words, higher oil and gas prices do not necessarily translate to more revenue for the state unless the high prices are sustained for at least a year.

Third, among the myriad of factors that have helped shape the current status of the oil and gas industry, including resource depletion, technology, regulation and taxes, price remains a major absence of price movements, autonomous changes in production in state offshore waters no longer play a prominent role in Louisiana economic activities.

Clearly, for Louisiana, a different policy regime should be in play if the findings here hold. While the state has been able to focus on regula

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APPENDIX A
AN OUTLINE OF THE VAR PROCEDURE

Step 1: Model Formulation

A VAR analysis begins with the selection of a suitable model informed by economic theory. Usually, each variable in the system are treated symmetrically. Consider a two-variable case consisting of y_1 and y_2, each affecting the time-path of the other such that:

$$y_{1(t)} + v_{10} + v_{12} y_{2(t)} + a_{11} y_{1(t-1)} + a_{12} y_{2(t-2)} + e_{1(t)} \quad \text{(A1)}$$

$$y_{2(t)} + v_{20} + v_{21} y_{1(t)} + a_{21} y_{1(t-1)} + a_{22} y_{2(t-2)} + e_{2(t)} \quad \text{(A2)}$$

In a general matrix form with *m* variables and *p* lags,

$$y_t = v + A_0 y_t + A_1 y_{t-1} + A_2 y_{t-2} + A_3 y_{t-3} + \ldots\ldots + A_p y_{t-p} + e_t \quad \text{(A3)}$$

Where y_t, v and e_t are m x 1 column vectors and A_0 , A_1 , A_2 , A_3, ... A

$[((I - A_0)^{-1}] D [(I - A_0)^{-1}]'$.

Each of the equation in A6 can be estimated by OLS. However, OLS can only be used if the system contains the same number of variables and lags in the right-hand sides. Otherwise, the appropriate estimator to use is a Seemingly Unrelated Regression (SUR). In this study, as may be observed in equation 4, the right-hand variables in each equation are not the same thus SUR is utilized.

Step 2: Unit Root Tests

Haven formulated an appropriate theoretical model; the next step is to test for *unit roots* (or stationarity) in all the variables. It has been shown that an OLS or SUR regression of the long-run relations implied by each equation in A6 is valid (non-spurious). Non-spuriousness of a long-run relations means that the variables are co-integrated. To be co-integrated there must be unit roots in at least two or more of the variables. A common method to test for unit root in a variable is the Augmented Dickey Fuller (ADF) Test. Equation (A7) is estimated to perform the ADF test:

$$\Delta y_t = \mu + \gamma y_{t-1} + \delta_1 \Delta y_{t-1} + \delta_2 \Delta y_{t-2} + \ldots + \delta_p \Delta y_{t-p} + \varepsilon_t \qquad \text{(A7)}$$

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test for exogeneity is technically different and more restrictive than Granger-causality, however. A necessary condition for the exogeneity of y_1 is that the *current and past values* of y_2 does not affect y_1

$$y_t = C_0u_t + C_1u_{t-1} + C_2u_{t-2} + C_3u_{t-3} + \ldots + C_su_{t-s} + y_0 \qquad \text{(A8)}$$

Where y_0 equals initial value of yt.
Equation (A8) does not give a proper indication of how the system responds to shocks to the individual structural equations. This is because the shocks to the equations contained in the vector u_t are correlated with each other. It is therefore not possible to determine the effects on the m variables of a shock to an individual structural equation would be as the observed u_t represents the combined shocks to a number of equations. It is noted that $u_t = (I - A_0)^{-1}e_t$.

To obtain unencumbered individual shocks in the structural system it is necessary to solve the system for A_0 and thus obtain $(I - A_0)^{-1}$, which will enable us to transform the u_{t-j}'s in into e_{t-j}'s. The transformation is done by selecting an appropriate matrix to orthogonalized the errors so that A_0 is identified. Then

$$y_t = Z_0e_t + Z_1e_{t-1} + Z_2e_{t-2} + Z_3e_{t-3} + \ldots + Z_se_{t-s} + y_0 \qquad \text{(A9)}$$

Where

$$Z_j = CjG \; ; \; e_{t-j} = G^{-1}u_{t-j} \text{ and } G = (I - A_0)^{-1}.$$

The standard approach to identify the elements of $\mathbf{A_0}$ and hence decompose the matrix of reduced form residual in a VAR analysis is by the so-called Choleski Decomposition:

$$u_tu`_t = \Omega = Ge_t.(Ge_t.)` = Ge_t.e`_t.G` = GDG`$$

Where D = **I.**

The Choleski Decomposition of the matrix Ω is obtained such that

$$(I - \tilde{A}_0)^{-1} = G$$

Which implies $\tilde{A}_0 = I - G^{-1}$ and $\tilde{A}_0$ is a representation of A_0 after scaling of the variables in order to obtain D = I. With this G matrix the matrices Z_j in equation (A9) with the errors e_t of unit variance (Floyd, 2001).

The Z_j matrices are called *impulse-response functions*. In this particular method of decomposition, a particular ordering of the variable is imposed on Ω. A different for of ordering will produce a different impulse response. Hence, the analyst must choose a plausible ordering guided by economic theory. In this study we use the ordering: oil price, oil production, and state economic variable. This ordering implies that oil price is not affected by the other variables and the flow of causal relation is from price to production and then state economic variable.

The upper-left-corner of Z_0

A plausible way to determine the importance of different exogenous shocks in explaining the dependent variables is by calculating the fractions of the forecast error variance of these variables attributable to such shocks. That is the fractions of these forecast errors that are due to individual shocks can be obtained from equation (A9). In the two-variable case considered here the *variance decomposition* may be estimated as described below.

Let z_{ij}^0 be the *ij*-th element of Z_0**,** we can express the current-period forecast error thus:

$$y_{1t} = z_{11}^0 e_{1t} + z_{12}^0 e_{2t}$$
$$y_{1t} = z_{21}^0 e_{1t} + z_{22}^0 e_{2t}$$

Then,

$$Var\{y_{1t}\} = (z_{11}^0)^2 + (z_{12}^0)^2$$
$$Var\{y_{1t}\} = (z_{21}^0)^2 + (z_{22}^0)^2$$

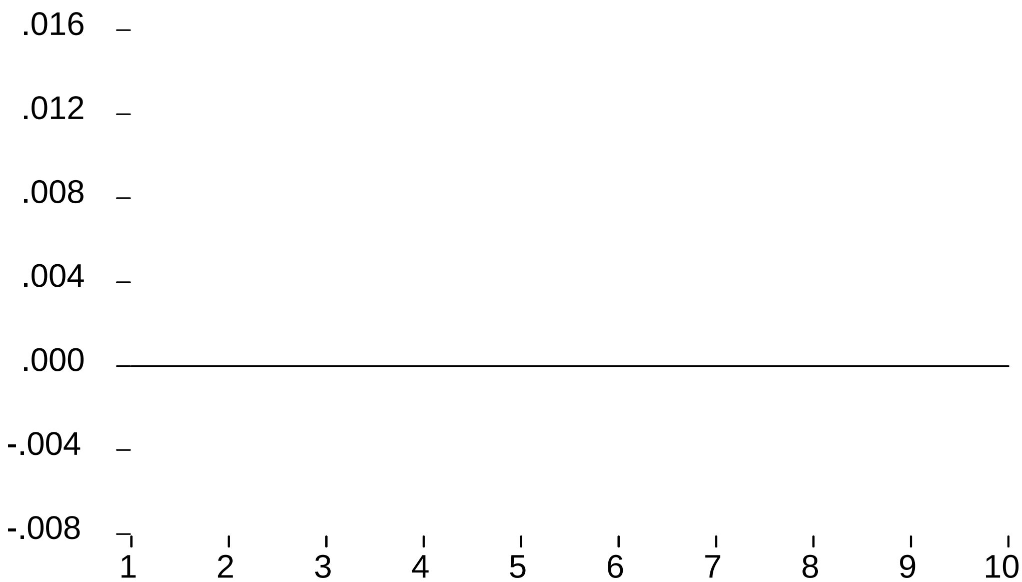
For e_1 and e_2 are independent shocks with unit variance. The standard deviations of these estimates are their respective square roots and the fraction of the error variance attributable to the shock to the first and second equations are

$$\frac{(z_{11}^0)^2}{(z_{11}^0)^2 + (z_{12}^0)^2} \text{ and } \frac{(z_{12}^0)^2}{(z_{11}^0)^2 + (z_{12}^0)^2}.$$

Similar calculations and logic is followed for t-steps ahead forecast and their respective decompositions obtained.

APPENDIX B

(Displayed for illustrative purposes only)



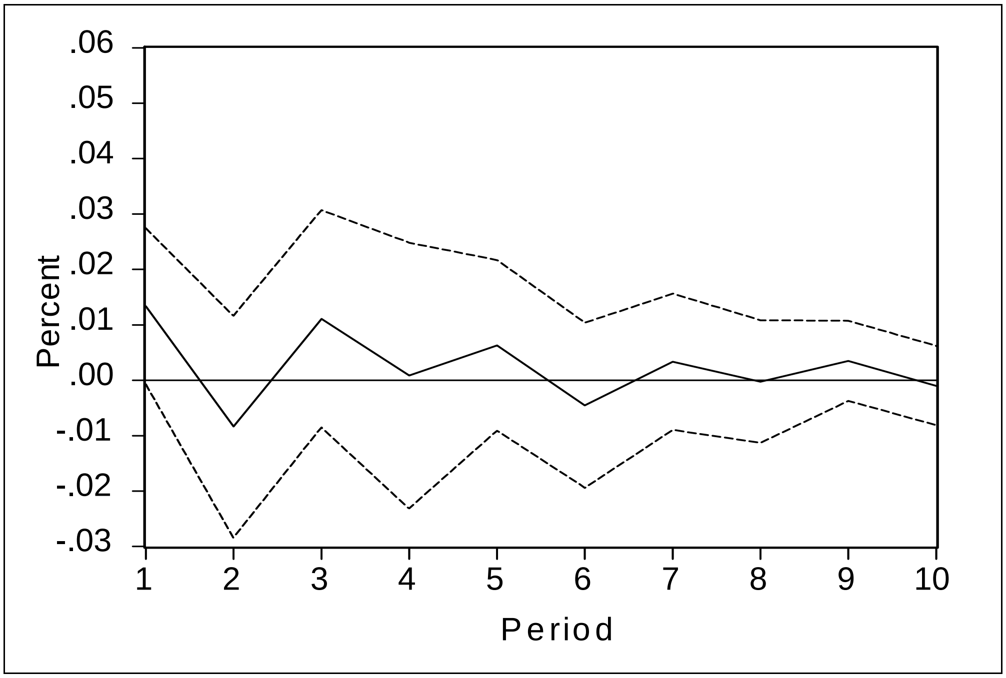
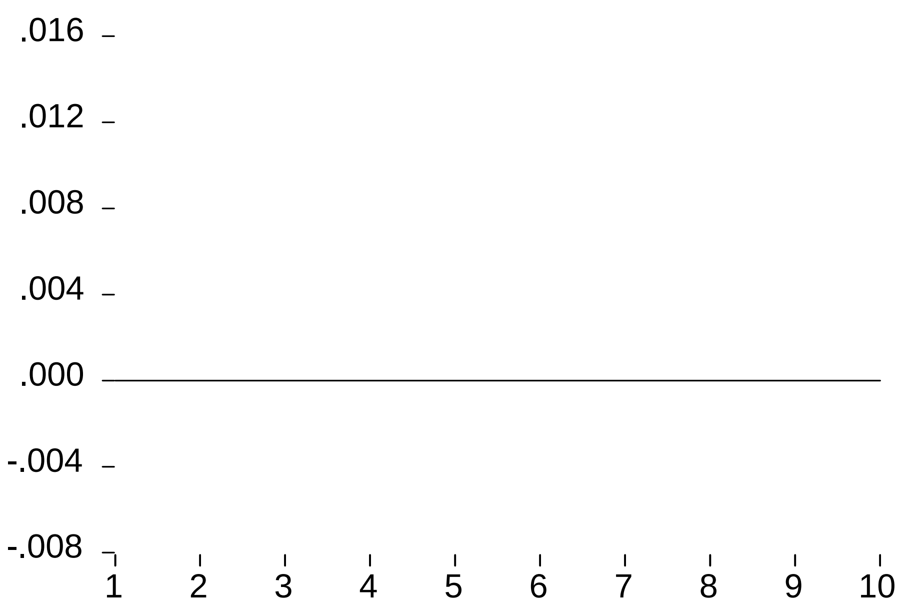
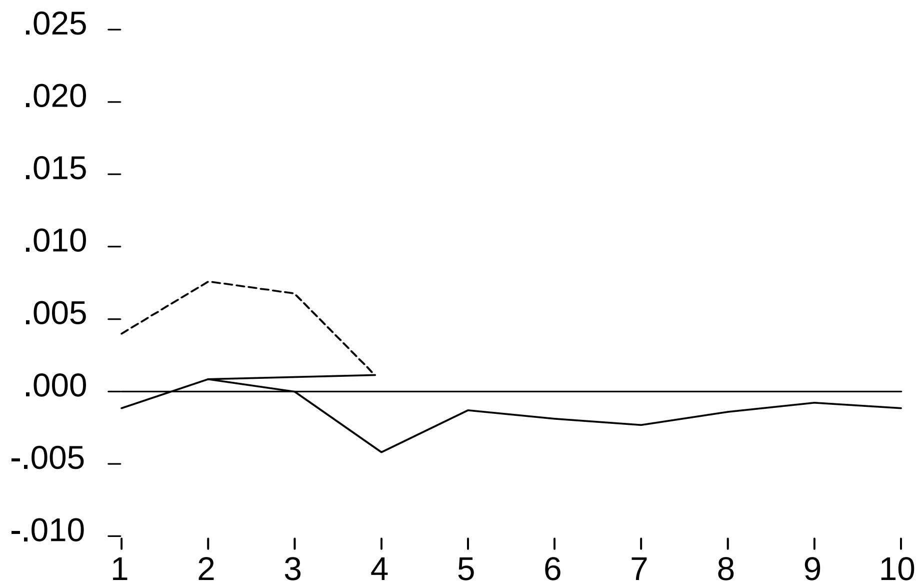


Figure B3. Response of Revenue to Oil Production Shock.

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.