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MMS 2004-052

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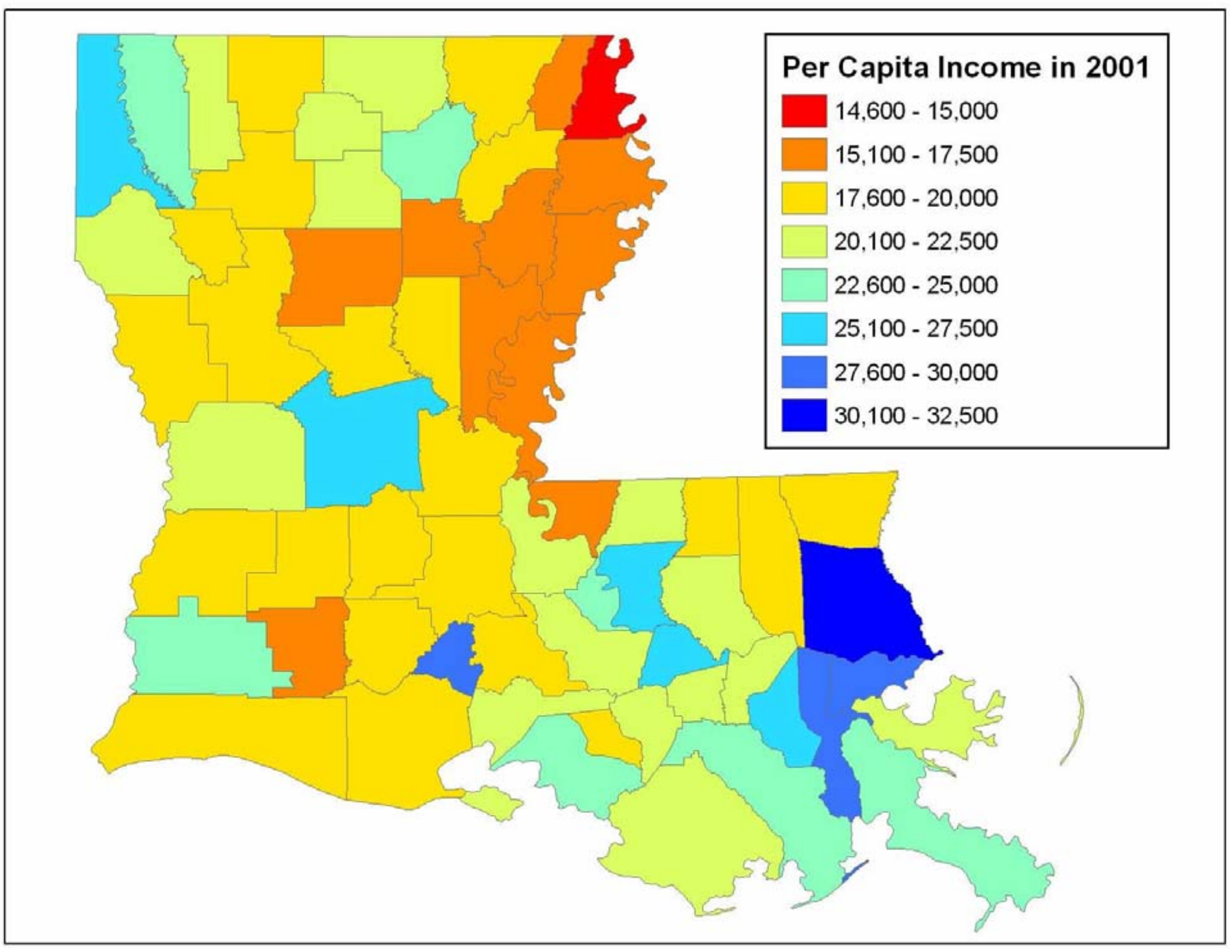
Effects of Changes in Oil and Gas Prices and State Offshore Petroleum Production on the Louisiana Economy, 1969-1999



U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

Cooperative Agreement
Coastal Marine Institute
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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 activities in Louisiana. We estimated a Variable Auto-regression (VAR) model to analyze the impact of changes in oil and gas prices and state offshore production in the Louisiana economy. The main hypothesis is that the impact of oil price on state economic aggregates would mostly be through industry activities. The use of the VAR approach allows us not only to examine the relative importance of prices and production in explaining movement in key indicators of economic activities, but also to study the dynamics of adjustments in these variables over time, given unanticipated changes in petroleum prices and production.

In an overall sense, the study finds that, at least in the case of Louisiana, changes in oil prices are more important in forecasting changes in employment and personal income than changes in natural gas prices in the short-run. Both oil and gas price movements are found to be equally important in explaining changes in Louisiana revenue, although the overall impact on revenue is minimal. It is also noted from the results that irrespective of the resource market, oil or gas, the employment effects of a price shock last longer than the effects of such a shock on personal income or revenue.

The analysis further suggests that the fiscal exposure or vulnerability of the Louisiana budget to oil and gas price changes within the context of state offshore petroleum production has declined over time. The responsiveness of the macroeconomic variables to price changes indicate that if conditioned on state offshore production, it will take a considerably high and sustained change in prices to have an appreciable effect on the economic performance of Louisiana.

Finally, the empirical results also show that the indirect effects of oil and gas price changes are more important than the autonomous direct changes that occur in oil and gas production in state waters themselves. In other words, in the absence of price shocks, autonomous changes in oil and gas production (e.g. technology-induced) have ceased to be very important to Louisiana economic activities. Further, the effects of a gas price shock on the economy are more persistent than oil price shocks. That is, price volatility in the gas market has the potential to be more destabilizing to the economy than the equivalent change in the oil market.

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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 related sectors, wages in the oil sectors are often higher than in the other sectors. As the share of E&P in total employment decreases, the gaps between average wages in the non-petroleum sector and wages per employee in the petroleum sector increases. Downturns or booms in the oil sector do affect quite significantly the overall personal income levels in the state. It is noted that a structural shift in real personal income occurred in the 1980s, such that the growth rates in income in the 1990s were significantly lower than in the 1970s.

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 oil and gas prices is 0.04 and 0.05, in the short run and 0.10 and 0.08 in the long run, respectively.
    - The short run responsiveness of personal income to changes in oil and gas prices subject to state offshore production is 0.06 and 0.08, respectively. In the long run, however, the responsiveness is 0.13 and 0.10, respectively, for personal income.
    - We also estimated the responsiveness of revenue to price shock in the short run to be 0.12 and 0.16, respectively for oil and gas. The corresponding long run responsiveness for oil and gas is 0.12 and 0.08, respectively. The long run price elasticity of revenue in Louisiana, is however, found to be statistically insignificant.

- Quantity equivalence of shocks to oil and gas prices:

    - The quantitative estimates of the impact of 18 percent oil price shock conditional on state offshore production activity, using the 2002 price and aggregate economic data are as follows:

        - Ten thousand jobs in the short run or 26.6 thousand jobs, if the shock persists in the long run.
        - $958 million in personal income in the short run or $2.052 billion if the shocks persist in the long run.
        - $272 million in revenue in an overall sense.

    - The quantitative estimates of the impact of a 20 percent gas price shock, using the 2002 price and aggregate economic data are as follows:

        - 28.5 thousand jobs in the short run or 45.6 thousand jobs in the long run

        - $2.736 billion in the short run or $3.420 billion in the long run

        - $768 million in revenue in the short and long run. There is no difference between the long run and short run effect of a price shock on revenue probably because the shock has to be sustained for a very long period before it could have any tangible effect.

1. INTRODUCTION

The Gulf of Mexico OCS region plays an ever-increasing role in U.S. energy supply. The region produces a significant amount of crude oil and gas needed to meet a relatively good proportion of U.S. domestic consumption. In fact, the region was responsible for at least 25 % of petroleum production in the U.S. in 2002. Much of the economic and social life of the communities in the coastal states bordering the Gulf is strongly tied to the E & P activities of the oil and gas industry operating in the region. Of particular interest to these states and their communities are the production activities occurring within state waters. Apart from providing direct jobs to these economies, these E&P activities also generate severance tax revenue.

Since the late 1970s, policy makers have expressed some concerns about the relationship between oil price changes and the level of economic activities or performance of nations or regions. The accelerated increases in oil prices in the decade of the seventies and the collapse of prices in the mid-1980s and the late 1990s heightened these concerns. Most studies of national economies have concluded that the macroeconomic effects of sustained decline or increase in oil prices can be explained, measured and predicted to some degree (Hamilton, 1985; Hamilton, 1996; Considine, 1988; Mory, 1993; Mork, 1994; Lee et al., 1995; Keane and Prasad, 1996; and Huntington, 1998). The more recent studies at the level of individual firms, industries or the labor force have also established a significant correlation between oil price shocks and macroeconomic aggregates (Davis et al., 1996; Lee and Ni, 1999; Uri, 1996; and Davis and Haltiwanger, 2001).

The effects of oil price changes on the national economy are generally understood, however, the impacts of such changes on state or sub-regional economies are less fully examined. Few studies (Brown and Hill, 1988; Brown and Yucel, 1995; and Yucel and Guo, 1994) have studied the impact of world oil price declines or increases on state economic performance. Most of these studies, unlike national studies, tend to show that rising oil prices stimulate economic growth in oil-exporting states and retard growth in oil-importing states. The converse is expected to be true for declining oil prices. These studies also imply sustained declines or increases and the effects in the economy can be ascertained and policy response designed appropriately.

It is generally agreed that declining oil prices stimulate economic growth while increasing oil prices may tend to dampen economic performance; the effects are not generally conclusive, especially for sub-national economies. Typically, increases in oil and gas prices are expected to induce cost-cutting measures by firms, and often it is labor inputs that are easily affected. To get to equilibrium following an energy price increase and as firms cut output and employment, wages are often cut, and the income of households is negatively affected. Price changes do impact revenue and incomes of communities in many nations where the oil and gas industry looms large in the economy. For most oil producing regions, oil-tax revenue is a major source of general fiscal revenue. A decline or increase in the levels of a firm's profits can influence this tax-base significantly.

The above theoretical description may be true in general, especially for national or cross-national economies; the reality may be different and more complex in specific states or regions. For example, an exporter of oil benefits from an oil price increase, but the non-oil firms located in 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 developed to examine the impact of changes in crude oil prices on both the oil industries and relevant Louisiana macroeconomic aggregates. The research uses recent econometric tools to provide quantitative estimates of the responsiveness and correlation between past and current activities of the oil industries in Louisiana. The analysis is restricted to interaction between oil and gas production from Louisiana offshore waters and Louisiana state employment, personal income, and revenue growths.

This report is organized as follows. Section II presents brief descriptions and descriptive analyses of the data and reports the statistical properties of model variables—employments, personal income and state revenue. Section III reports the general mathematical formulation of the VAR model describing the associations between oil and gas prices and production from state offshore waters and macroeconomic aggregates. Section IV discusses the empirical model results and interpretations. The final section summarizes the conclusions and the implications of the key findings.

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.

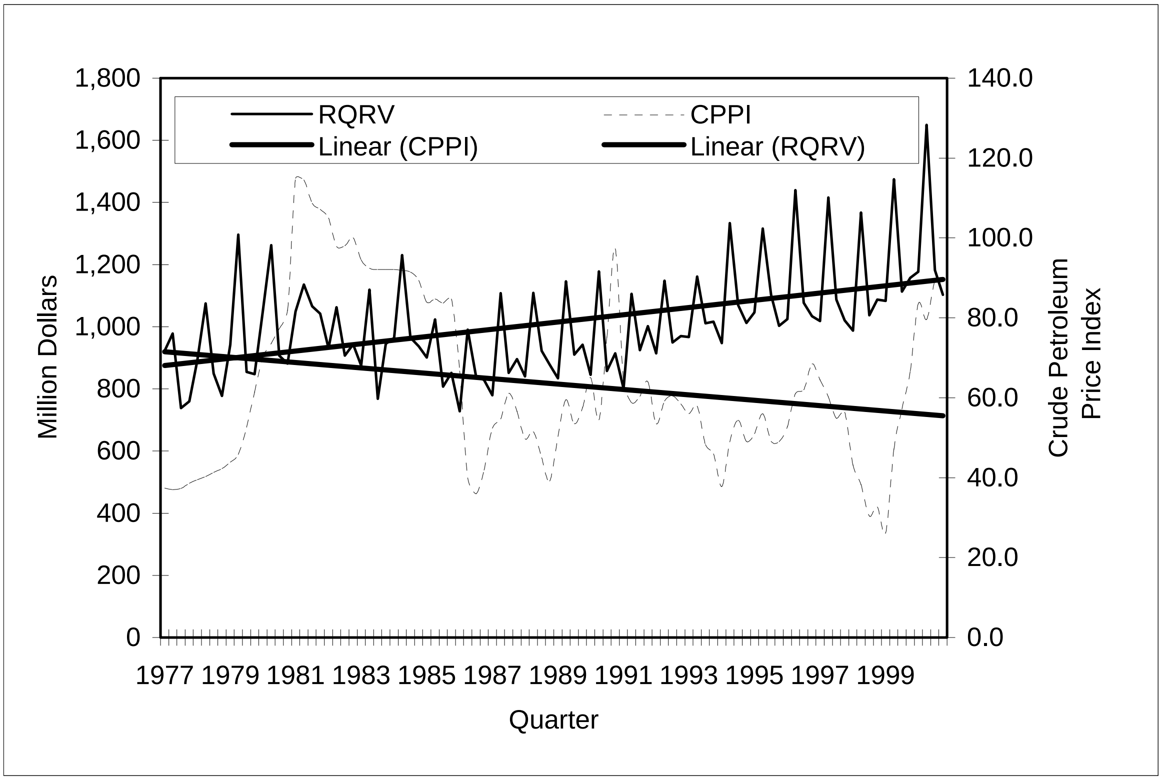

Figure 1a. Trends in State Gross Revenue.

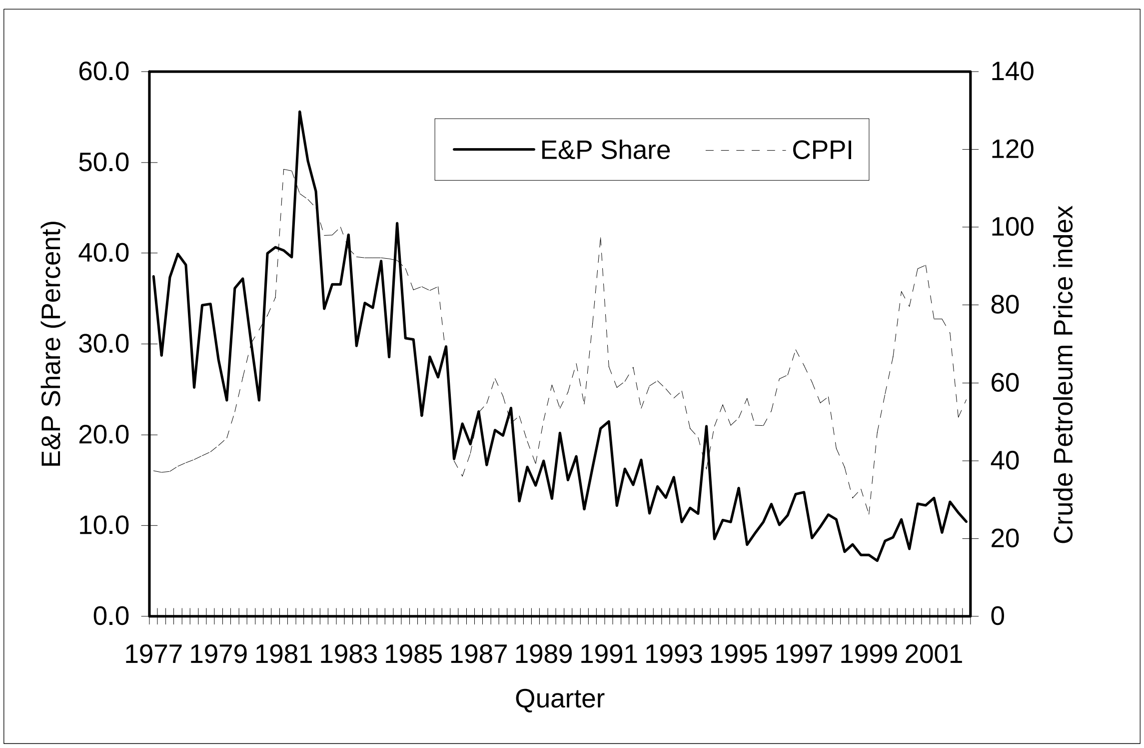

Figure 1b. Proportion of State Gross Revenue Accounted for by the E&P Sector.

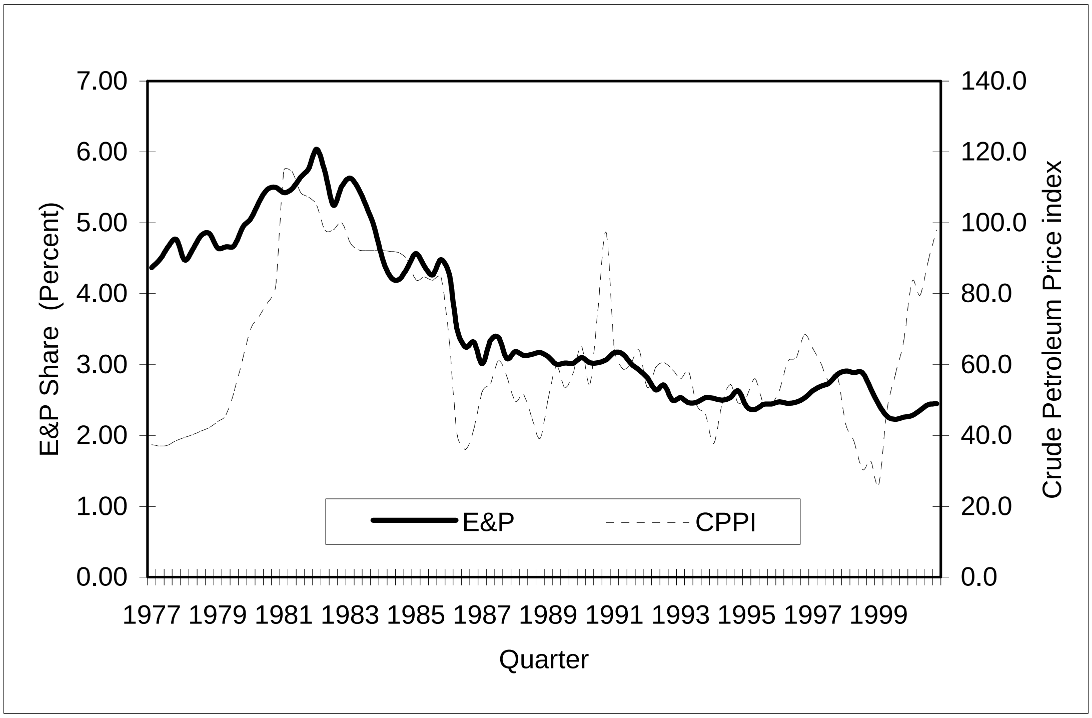

Figure 2a. Trends in E&P Share of Employment and Price Index.

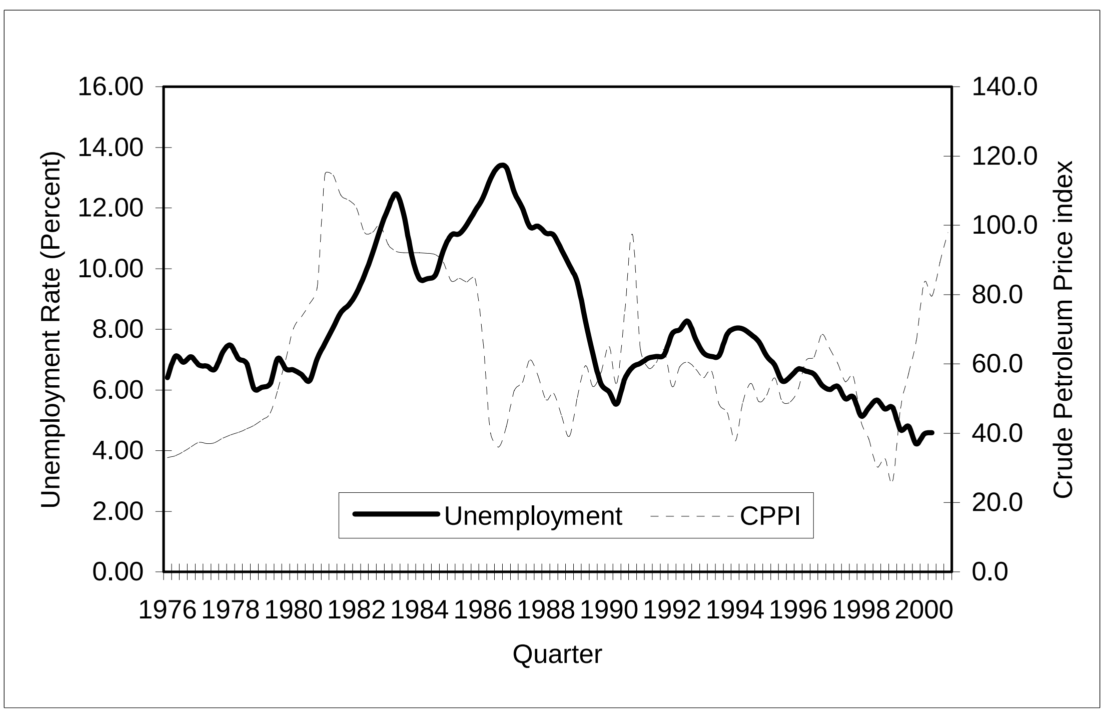

Figure 2b. Trends in Unemployment Rates and Price Index.

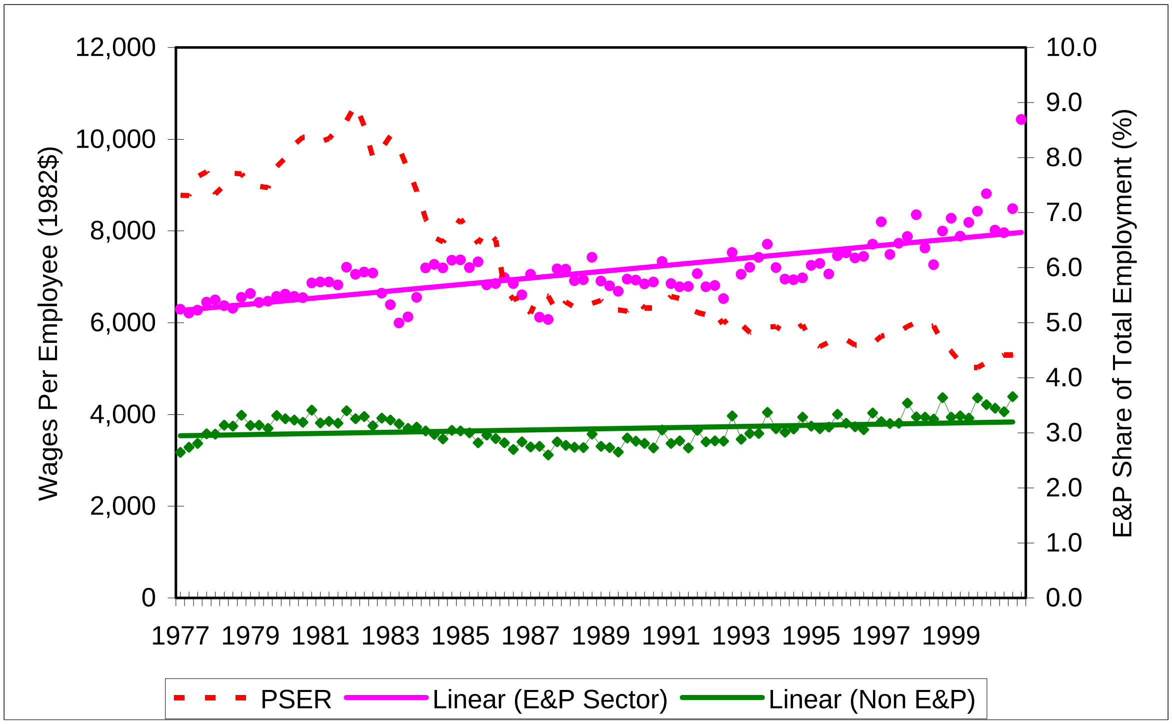

Figure 3. Trends in Wages per Employee.

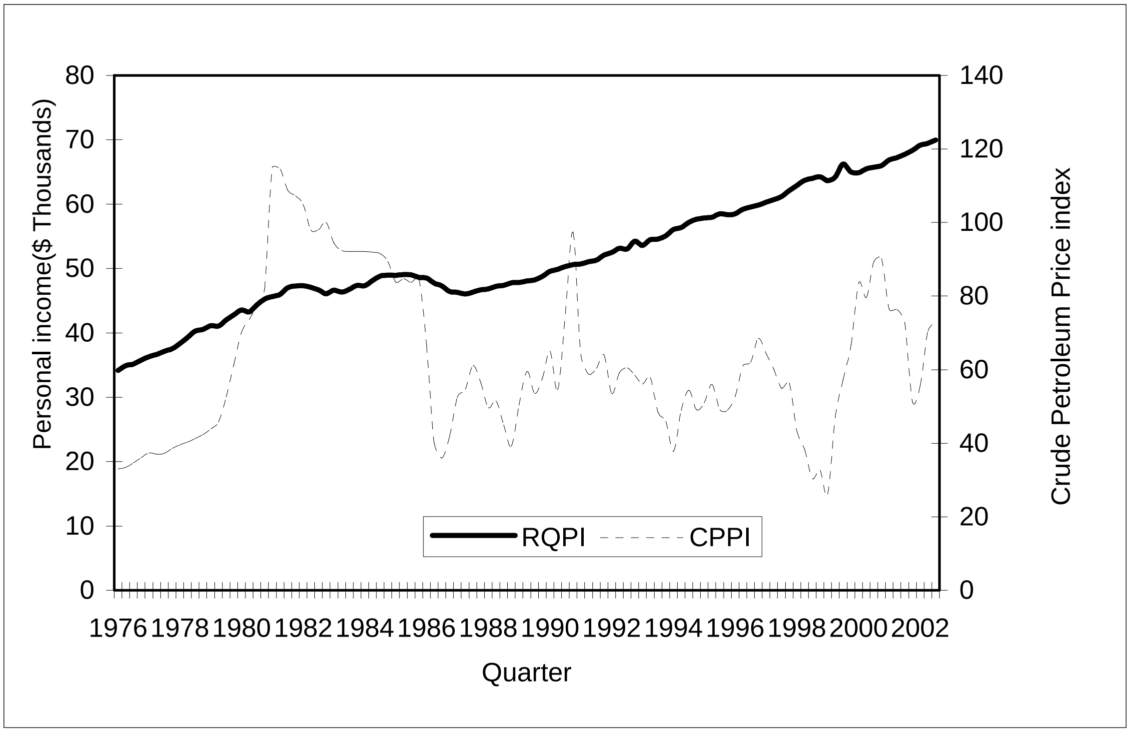

Figure 4. Trends in Real Personal Income and Crude Petroleum Price Index.

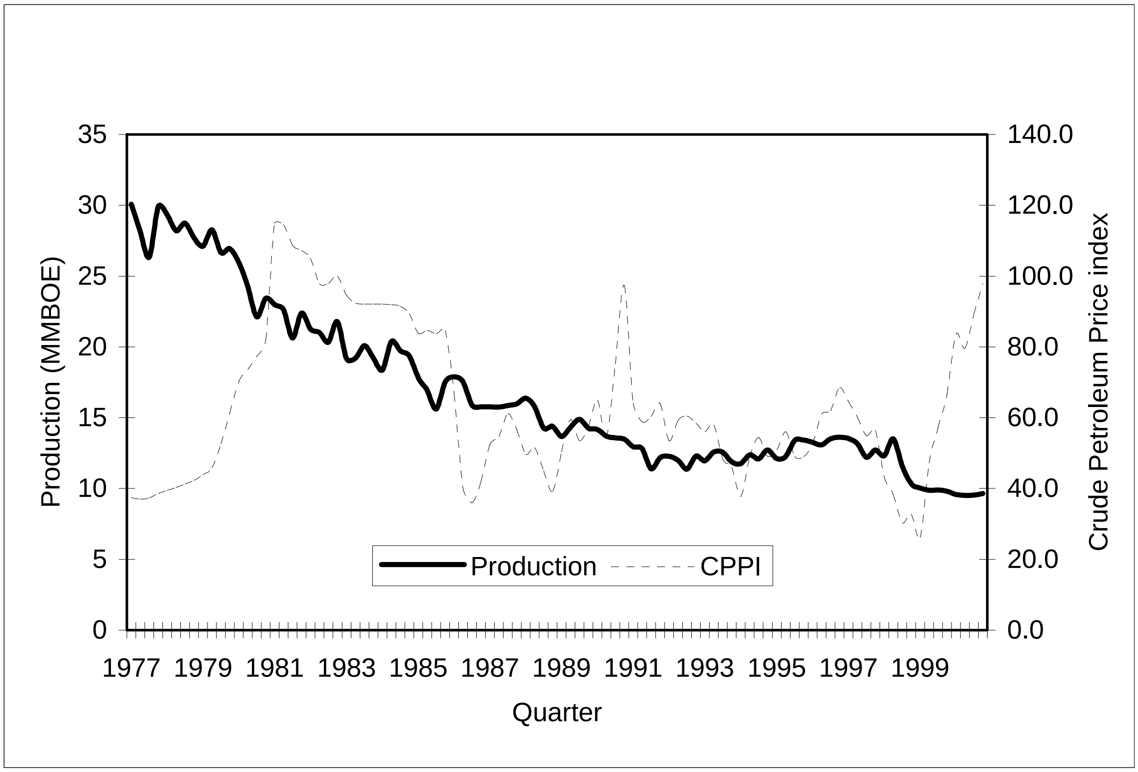

Figure 5a. Trends in State Offshore Production and Crude Petroleum Price Index.

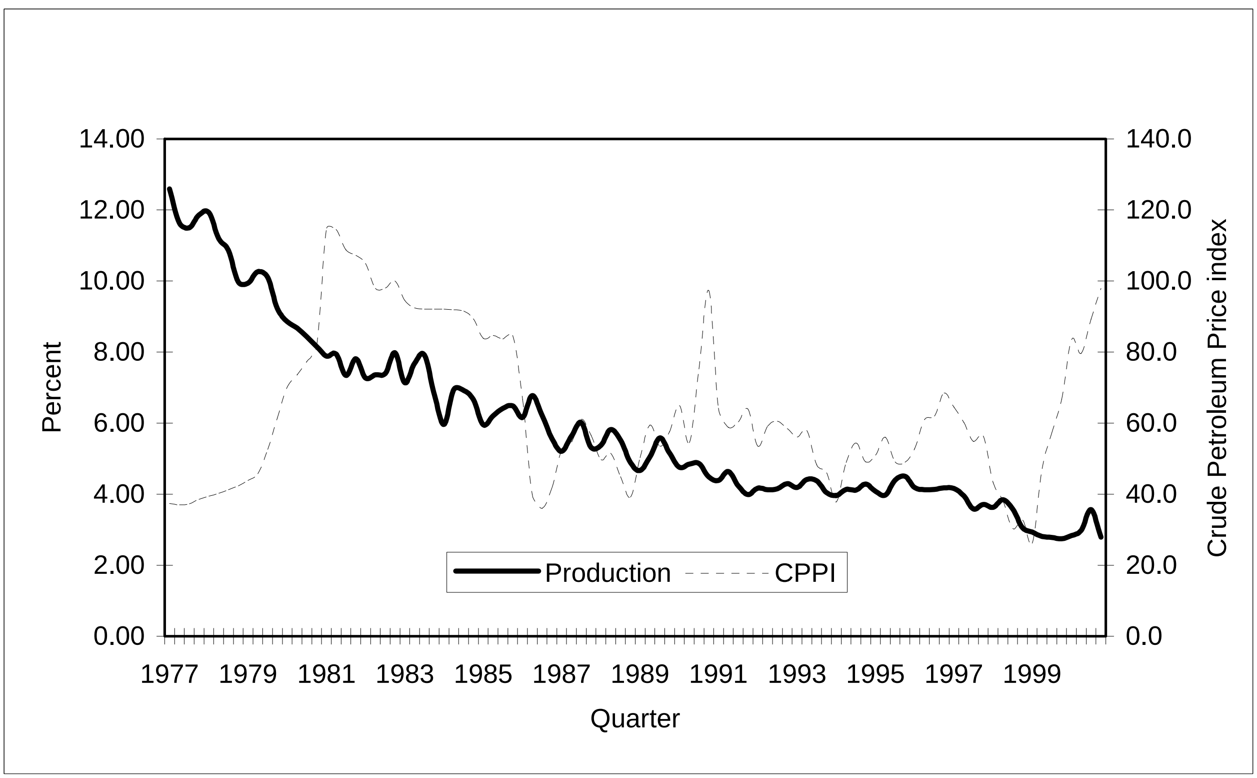

Figure 5b. Ratio of State to Federal Offshore Production and Petroleum Price Index.

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 the E&P sector vis-à-vis the trend in crude petroleum price index. There is a clear growth in revenue over this period, although the path of growth is uneven over the period. This uneven growth pattern is not surprising, given the fact that revenue is conditionally depended on relatively unstable factors such as changing tax rates and petroleum prices, for example.

Employment: Employment is another key indicator of the overall economic activity and a measure quite related to total economic output. In the absence of GSP, employment level provides an important indication of the level of economic activity in the state. A lot of people in Louisiana are employed directly or indirectly in the oil and gas sector. Two patterns of growth in Louisiana employment in the oil and gas extraction sector relative to total employment in the state can be inferred from Figure 2a. The E&P employment data indicate that employment levels in the E&P sector in Louisiana track petroleum price index quite closely. There seems to be a period of rapid rise in employment up to the early 1980s followed by rapid decline up to the mid-1990s. The current level of mining employment is about half of what it was in the peak period of the 1980s. Unlike oil and gas employment, however, total employment for the state has been on the increase over time and the data reveals some structural changes in the mid-1980s.

Although total jobs in Louisiana have been increasing over time, the proportion of jobs accounted for by the mining sector has declined sharply since the early 1980s (Figure 2a). Corresponding to the dramatic turns in employment levels in the oil sector, the low unemployment rates in the late 1970s suddenly increased to high unemployment rates in the early 1980s until 1986 when the rate finally stabilized. Figure 2b shows that the trends in unemployment levels follow similar patterns with petroleum price index. The trend also follows similar pattern with the trends in E&P share of total employment.

Apart from the substantial number of jobs produced by the oil and gas related sectors, because wages in the oil sectors are often higher than in the other sectors (see Figures 3), structural shift in employment distribution could necessarily lead to a noticeable structural shift in personal income. As the share of E&P in total employment decreases, the gaps between average wages in the non-petroleum sector and wages per employee in the petroleum sector increases.

Personal Income. The trends in personal income and crude petroleum price index are presented in Figure 4. A structural shift in real personal income in the 1980s is evident in Figure 4. Thus, the growth rate in income in the 1990s and beyond is lower than in the 1970s. There is, however, evidence of an even growth in personal income in comparison to the uneven growth in revenue. Again this pattern of growth is not surprising, given the fact that personal income is more related to wage levels than it is to the relatively unstable factors, such as changing tax rates and oil prices, which underlies revenue growth.

Petroleum production: Figure 5 depicts state offshore oil and gas production in million barrels of oil equivalent and oil price index (1 BOE = 6 Mcf). In general, oil price was stable until the mid-1970s. In the mid-1970s price rose sharply to its historical high in the early 1980s. Although 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 a combination of factors--available technology, depletion, well completion rate, government regulation, tax regimes, and different price expectation formation by economic agents over the period.

2.3 Descriptive Data Analysis

Descriptive statistics of the data analyzed in this section are presented in Table 1. Some important observations can be made from Table 1. First, oil production appears to exhibit far less variability than gas production, and expectedly, real gas prices appear to show more variability than real oil prices over this period. Second, of the three macro-economic aggregates we evaluated, employment shows the least variability, i.e. most stability. Total wages also shows more stability than personal income and gross revenue using the magnitude of the coefficient of variation (COV)

The degree of dispersion in nearly all selected measures of E&P economy in Louisiana is evident in Table 1. Nearly all the measures we examined for the E&P sector are significantly dispersed around the mean value. Again, using COV for this comparison, we found that E&P revenue and employment levels are highly dispersed with a COV of 50 and 27 percent, respectively. The COV for gas production is also high just as the COV for gas prices reveal the existence of some degree of instability over the period.

Table 2 presents the basic correlation coefficients, which reflects the generic relationship, between states' macroeconomic, E&P activity and the price variables. Oil and gas prices are negatively correlated with their respective production correlates, contrary to our expectation, but this may not be statistically significant. However, the correlation coefficients between prices and measures of oil industry activities in Louisiana offshore waters are comparatively low. Oil price generally shows low positive correlation with all macro-economic variables, except state revenue. On the other hand, gas price has relatively higher but positive correlation with all macro-economic variables except oil price. Furthermore, as expected, oil and gas prices are highly positively correlated.

The negative and often relatively high negative correlation between oil and gas production activities and the three macroeconomic aggregates are also unexpected. These results potentially show the decreasing role of these activities in influencing the direction of economic welfare in Louisiana. However, it should be noted that these results are only indicative of the potential relationships among the variables; correlation is not causation. Therefore, a more robust tool of analysis such as commonly done within a regression framework is often required for an in-depth examination of relationships among economic variables. In the following section, we present one such tool of analysis.

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*	64.301	129.114	32.300	28.824	0.45
State Offshore Pet. Production*	*MMBOE*	16.771	30.078	9.521	5.730	0.34

1 MMBbl = 6 Bcf

COV= the ratio of the standard deviation to the mean of a random variable.

Table 2. Correlation Matrix of Selected Macroeconomic and E&P Variables, 1977-2000

	Symbol	RPGS	RPOL	QOIL	QGAS	EMPP	WGEP	PREV	UEMP
Macroeconomic Statistics									
Unemployment Rate	*UEMP*	-0.145	0.110	0.324	0.123	0.394	-0.452	0.393	1.000
Total Employment	*EMPT*	0.661	0.821	-0.872	-0.850	-0.522	0.799	-0.594	-0.270
Personal Income	*PINC*	0.717	0.718	-0.895	-0.805	-0.611	-0.423	-0.651	-0.452
Gross Revenue	*SREV*	0.287	0.232	-0.450	-0.297	-0.278	0.513	-0.301	-0.433
Total Wages	*WGES*	0.498	0.552	-0.790	-0.493	-0.224	-0.008	-0.311	-0.452
E&P Data Statistics									
E&P Sector Employment	*EMPP*	-0.590	-0.356	0.492	0.728	1.000	0.960	0.937	-0.270
E&P Revenue	*PREV*	-0.657	-0.391	0.544	0.741	0.937	0.895	1.000	0.393
E&P Wages	*WGEP*	-0.467	-0.208	0.317	0.613	0.960	1.000	0.895	0.316
State Offshore Liquid Production	*QOIL*	-0.652	-0.753	1.000	0.774	0.492	0.317	0.544	0.324
State Offshore Gas Production	*QGAS*	-0.655	-0.824	0.774	1.000	0.728	0.613	0.741	0.123
State Offshore Pet. Production*	*QBOE*	-0.679	-0.841	0.847	0.992	0.708	0.577	0.729	0.168
** 1 Bbl = 6 Mcf*									

RPGS = Real gas price; RPOL = Real oil price;

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]:

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

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 following system of equations (2):

$$\begin{aligned}
y_{1t} &= \alpha_{10} + \sum_{i=1}^{p} \beta_{1i} y_{1t-i} + \sum_{i=1}^{p} \gamma_{1i} y_{2t-i} + \sum_{i=1}^{p} \lambda_{1i} y_{3t-i} + \sum_{i=1}^{p} \omega_{1i} X_{1t-i} + \sum_{i=1}^{p} \varphi_{1i} X_{2t-i} + \delta_1 D_1 + \mu_{1t} \\
y_{2t} &= \alpha_{20} + \sum_{i=1}^{p} \beta_{2i} y_{1t-i} + \sum_{i=1}^{p} \gamma_{2i} y_{2t-i} + \sum_{i=1}^{p} \lambda_{2i} y_{3t-i} + \sum_{i=1}^{p} \omega_{2i} X_{1t-i} + \sum_{i=1}^{p} \varphi_{1i} X_{2t-i} + \delta_2 D_1 + \mu_{2t} \\
y_{3t} &= \alpha_{30} + \sum_{i=1}^{p} \beta_{3i} y_{1t-i} + \sum_{i=1}^{p} \gamma_{3i} y_{2t-i} + \sum_{i=1}^{p} \lambda_{3i} y_{3t-i} + \sum_{i=1}^{p} \omega_{3i} X_{1t-i} + \sum_{i=1}^{p} \varphi X_{2t-i} + \delta_3 D_1 + \mu_{3t}
\end{aligned} \tag{2}$$

[1] A brief overview of the VAR procedure is presented in Appendix A.

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];
X_{1t} = the U.S. Feds three-month Treasury bill rate in levels (a proxy for interest rates);
X_{2t} = natural log transformed U.S. real gross domestic product;
D_1 = a deterministic dummy which equals 1 for the period 1979 to 1986 and 0 otherwise; and
p = the number of past values (lags).

The dummy variable D_1 is included in each equation in the system to capture the period when oil prices declined and crashed. The number of past values of the dependent variables (length of lags) in each system of equation is determined statistically using a combination of Schwartz Bayesian Criteria (SBC) and Akaike Information Criteria.

The general formulations represented by the above system of equations in (2) are indeed a *standard* format of VAR model representation. In the primitive forms, the current levels of the other variables are included in the right hand side of the equation defining the evolution of that variable. From a statistical perspective the primitive system of these equations suffers from 'identification' problem. In addition, not all of the parameters of the primitive forms can be recovered from estimating the standard form.

To identify the primitive system, restrictions must be placed on some of the parameters. Such restrictions may be informed by economic theory or the intuition of the researcher. Typically, however, VAR applications are not primarily focused on parameters estimated from the system of equations in (2). Instead the contemporaneous correlation from the system of equations is exploited to generate short-term forecasts and to facilitate the understanding of the dynamic paths and evolution of all the variables in relation to each other.

3.3. VAR Model Estimation and Results

In this section, the VAR modeling framework discussed previously is applied to selected Louisiana macroeconomic economic and state offshore E&P industry performance data in order to ascertain the direction, causation, duration, responsiveness, and correlation among the state macroeconomic variables, state offshore oil and gas production and changes in oil and gas prices over time.

By expressing the system equations in a vector moving average (VMA) format, the dependent variables can be articulated purely as a function of the contemporaneous error terms, u_{it}. Once the system of equations is identified by the imposition of the necessary restrictions, the effects of 'shocks' (or 'innovations') in the error term in a particular equation on other dependent variables can be easily analyzed. One of the common forms of restrictions is to 'order' the variables (and hence, the error terms) according to the effects that are believed to be *'a priori'*. For example, for

[2] Output was originally proposed as one of the indicators but could not be used because of the length of the series at the state level. GSP is only available from 1977 and only on an annual basis.

the purpose of this study, we ordered the variables as follows: [oil price $\rightarrow$ state offshore E&P activity $\rightarrow$ 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—*impulse response* and *variance decompositions*—are adopted to study effects of shocks (i.e. unexpected policy changes) on the system represented in equation (1).

The long-run impact of a policy change affecting one of the variables on other variables in the system can be investigated using the impulse response function and the proportion of these "changes" that are attributable to which variable(s) in the system can be evaluated using variance decomposition analysis. Accordingly, the central focus of VAR analysis is the finding and understanding of the interrelationship among variables over time and not necessarily on the assessment of point estimates.

Thus, the VAR results are discussed generally in terms of the variance decomposition and impulse response functions generated from estimating the VAR model represented by the system of equations in (2). To estimate the system of equations annual data for all model variables were collected, processed and organized into a regression format. The estimation procedures utilized annual data because of a lack of consistent and highly qualitative quarterly data.

3.3.1. Variance Decomposition Results

The empirical results reported in Table 3 have been derived from estimating the system of equations in (2) individually for employment, real personal income, and state revenue in combination with each resource type--oil or gas--one at a time[4] and by using the variance decomposition procedure. This procedure provides a way to decompose the effects of a shock on the economic system to its component parts. The relative proportion of the decompositions indicates the relative potency of the effect of a particular shock in explaining the observed variations in each variable experiencing the shock.

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[3] This type of orthoganalized ordering referred to as Choleski decomposition is commonly used in VAR studies. However, it is also known that this ordering may result in innovation accounting that is not invariant to the order chosen.

[4] This implies estimating six different models/systems: (1) oil price, oil production, and employment, (2) oil price, oil production, and personal income, (3) oil price, oil production, and revenue, (4) gas price, gas production, and employment, (5) gas price, gas production, and personal income, and (6) gas price, gas production, revenue. Interest rate, time dummies, and GDP appear in each model/system as exogenous variables.

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

Accordingly, the dynamic VAR analysis of the interactions among state offshore oil and gas production, oil and gas prices and Louisiana macroeconomic variables—employment levels, real personal income, and real state revenue suggest that oil and gas prices are still important in explaining Louisiana's economic performance. But, the direct effects of oil and gas production in state waters on the economy have waned considerably over time. The relative importance of oil price and production in explaining volatility in economic activity followed by gas price and gas production impacts are discussed briefly as follows.

Table 3 shows that the largest source of variation in employment is oil price. Real oil price accounts for as much as 44 percent of the observed variation in employment over time. State offshore oil production accounts for no more than 2.78 percent over the same period. Crude oil price interacting with state offshore oil production also explains about 6.94-24.42 percent of the variation in personal income between 12.42 and 14.01 percent of the expected variation in gross state revenue. The variations in employment, personal income, and revenue explained by autonomous oil production range from 0.70-2.78, 2.93-7.47, and 7.23-13.83, respectively. However, the VAR results suggest direct effects of autonomous state offshore oil production on state macroeconomic variables are not discernible in a statistical sense.

According to the derived decomposition results from the estimated system equations connecting offshore gas production with gas prices and macroeconomic variables, 23.8-34.1 percent of the observed variation in employment is explained by changes in natural gas prices. However, no more than 10.6 percent of the observed variation in Louisiana jobs is explained by changes in autonomous natural gas production. The results for the VAR model describing the interactions between price, personal income, and gas production following a gas price shock shows that between 13 and 35 percent of the volatility in personal income movements are attributable to the shocks to gas prices and only about 0.4-2.4 percent is due to autonomous gas production. And the system equations connecting revenue with state offshore gas production and prices indicate that gas prices and gas production explain 0.05 –16.05 and 2.04-2.27 percent of the variation in state revenue, respectively.

Further statistical analyses of the results show that the effects of gas prices on employment and personal income are statistically significant, but the effect of gas price on revenue is not statistically significant over the period of estimation. Also, the variance decomposition results seem to suggest that autonomous state offshore oil and gas production direct effects have no statistically discernible effects on selected state macroeconomic variables such as employment, revenue and personal income.

3.3.2. Impulse Response Function Results

Impulse responses provide an avenue to examine the dynamic effects of oil and gas price shocks or innovations on Louisiana economy. It also provides opportunity to examine the paths of adjustment as well as their resilience over time. These shocks are assumed to be of the magnitude of one-standard deviation in each case. In this section we present both short run and long run characterizations of the responses to these stocks. The short run condition is represented by point estimates of the response following a shock. On the other hand, we estimate the long run on the basis of accumulated responses over time. In each case, responses are depicted with 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 response of employment to price is positive until about the fourth year, but only significant to the second year. Initially, the positive shock leads to 0.005 percent increase in employment and then reaches a maximum of 0.009 percent in the second year. The impulse path indicates a relatively fast adjustment back to equilibrium (within 4 years) after the initial shock. The gradual return to equilibrium level also indicates a stable adjustment path.

The response of personal income to a positive price shock is depicted in Figure 7. Changes in personal income reach a maximum of 0.009 percent in 2 years. The response is only statistically significant up to about the third year and stable, since it eventually returns to equilibrium in about 7 years following the shock.

Similarly, Figure 8 shows a positive impulse response of revenue following a positive oil price innovation. The pattern of adjustment clearly indicates a less stable response compared to employment and income. However, revenue response ceased to be statistically significant after the first year of a shock. The initial level of change, which is also the peak response, reaches 0.017 percent. Restoration to initial levels is relatively fast, occurring within 2 years.

Long Run Impact of Oil Shocks on Macroeconomic Variables: In Figures 9-11, we show the accumulated (long run) positive response of employment and state gross revenue to positive shocks in oil prices. As the confidence bands implied, the long run employment responses are statistically significant over time.

Following the shock, employment rises to a maximum of about 0.027 percent in the fourth year and then levels off, indicating long-term stability in the system. The accumulated response of income to a positive price shock is both positive and statistically significant over the entire horizon considered (Figure 10). Following a shock, accumulated responses of personal income show a steady rise that peaked at about 0.02 percent in about the fifth year.

The long run response of revenue following an oil price shock is shown in Figure 11. Although the response eventually stabilized, only the first period is statistically significant as the lower band crosses the zero-line before the end of the second year. The highest significant percentage change reached is 0.017.

[5] The bands are represented by the two 'broken' lines and the actual response by the 'unbroken' lines.

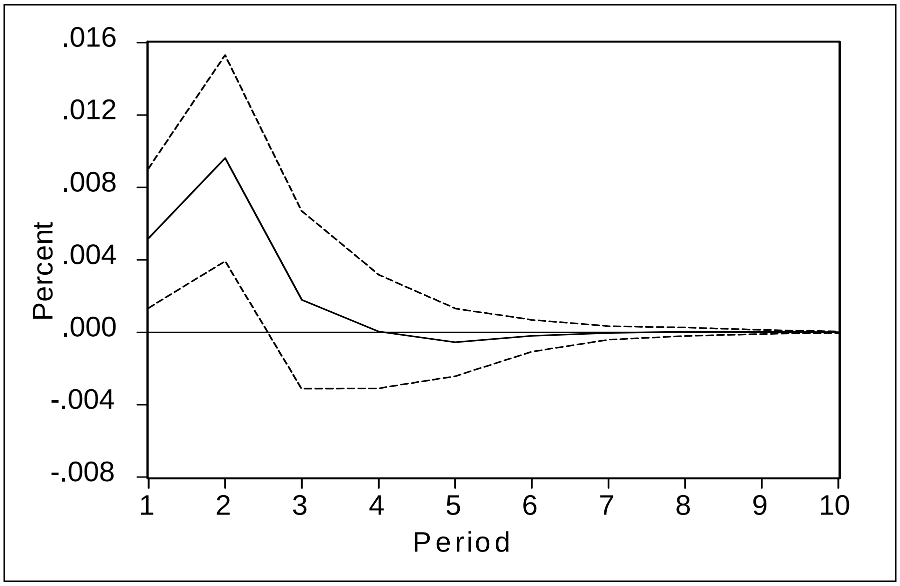

Figure 6. Response of Employment to an Oil Price Shock.

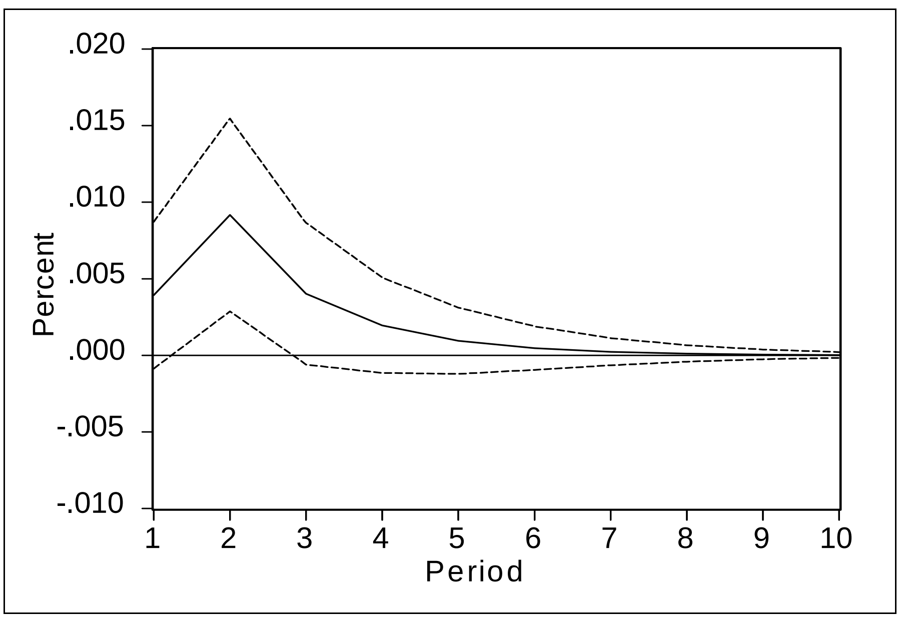

Figure 7. Response of Personal Income to Oil Price Shock.

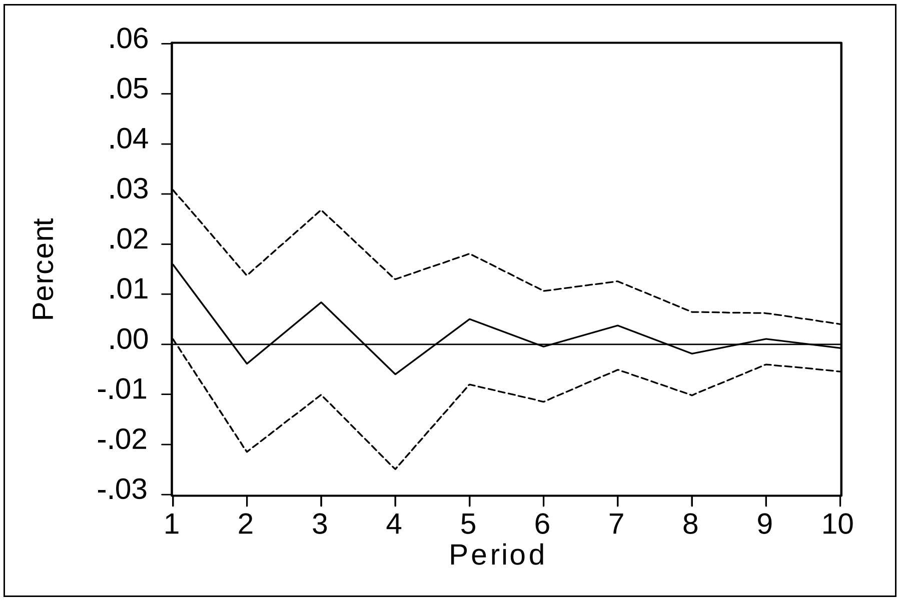

Figure 8. Response of Revenue to Oil Price Shock.

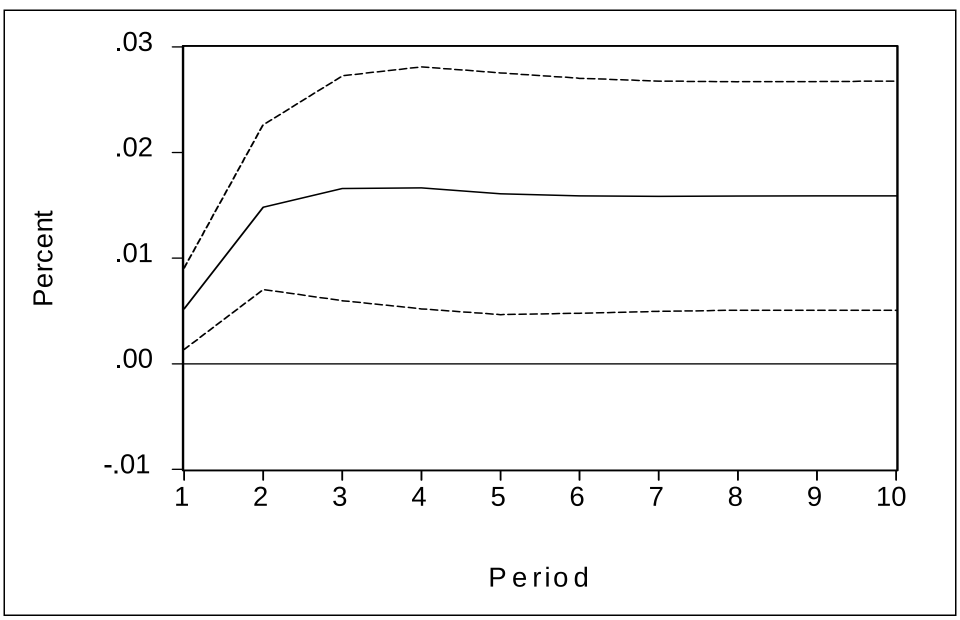

Figure 9. Accumulated Response of Employment to Oil Price Shock.

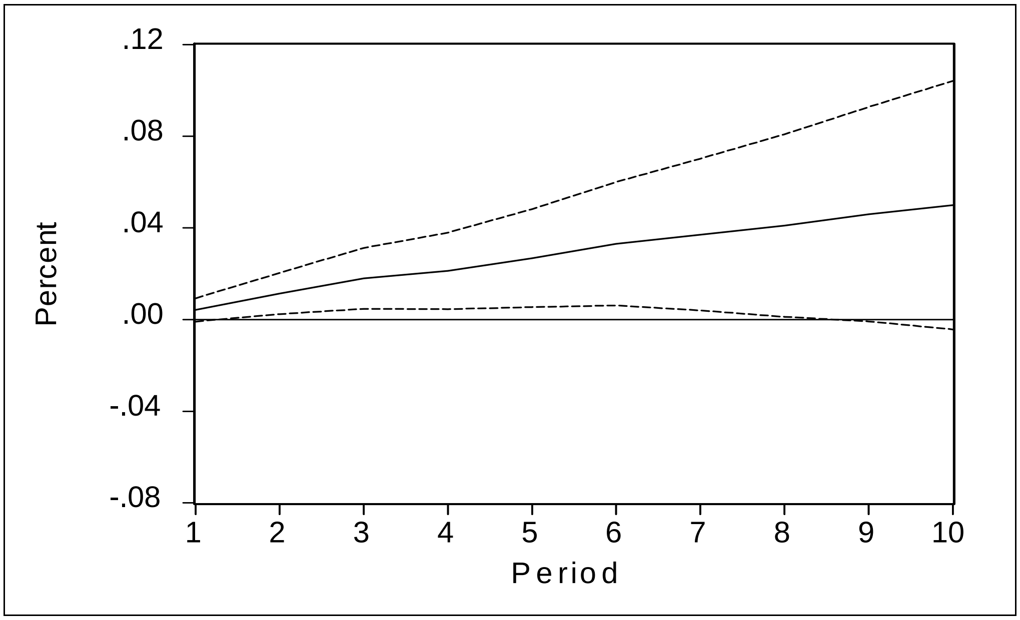

Figure 10. Accumulated Response of Personal Income to Oil Price Shock.

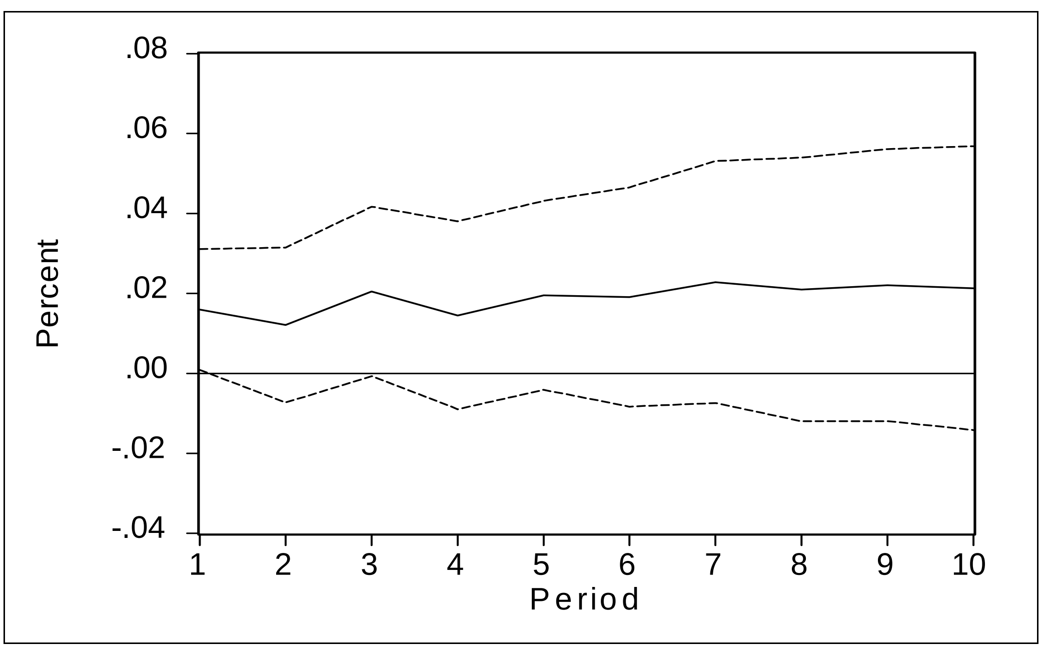

Figure 11. Accumulated Response of Revenue to Oil Price Shock.

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 impacts were also simulated.

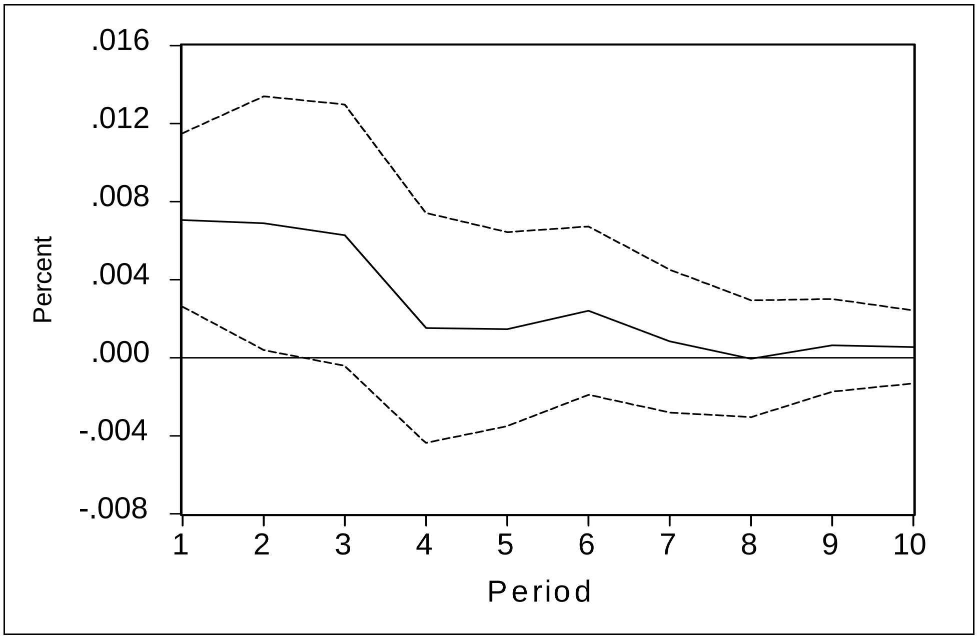

Figure 12. Response of Employment to a Gas Price Shock.

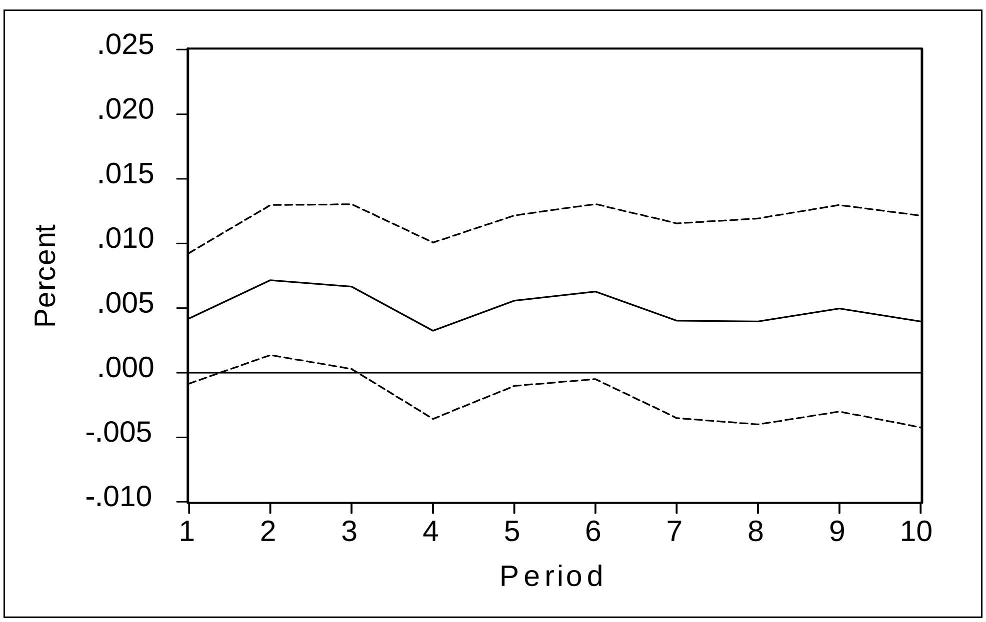

Figure 13. Response of Personal Income to Gas Price Shock.

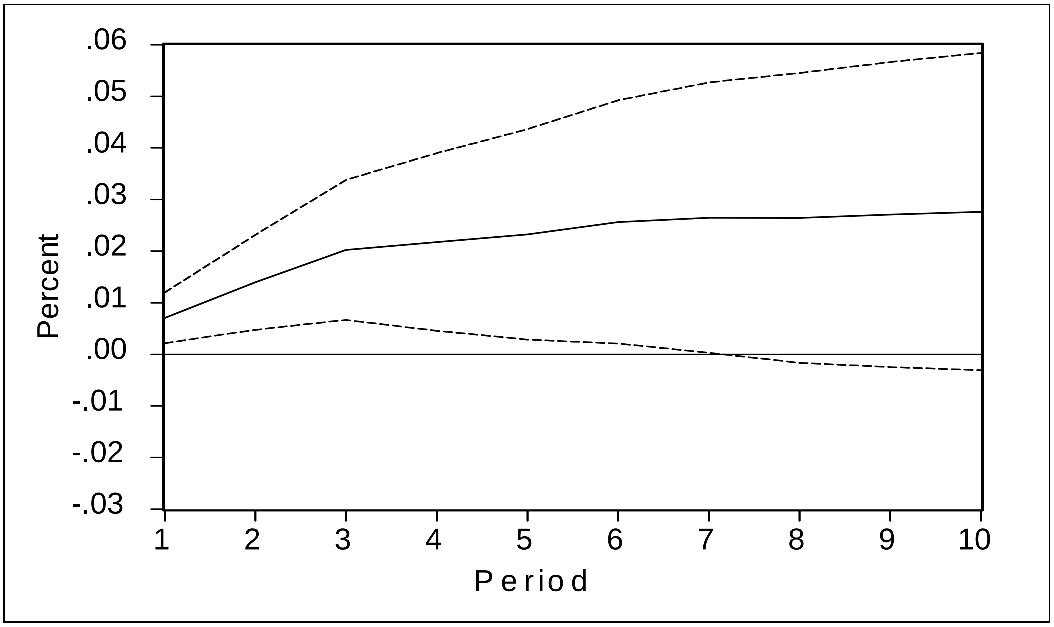

Figure 14. Response of Revenue to Gas Price Shock.

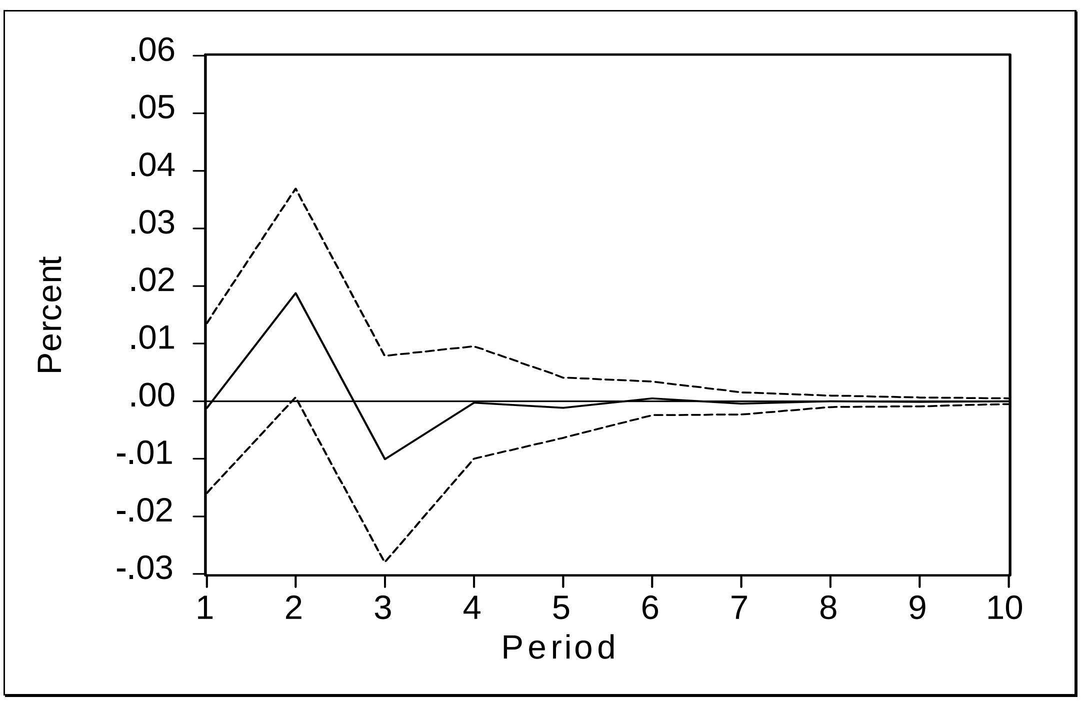

Figure 15. Accumulated Response of Employment to Gas Price Shock.

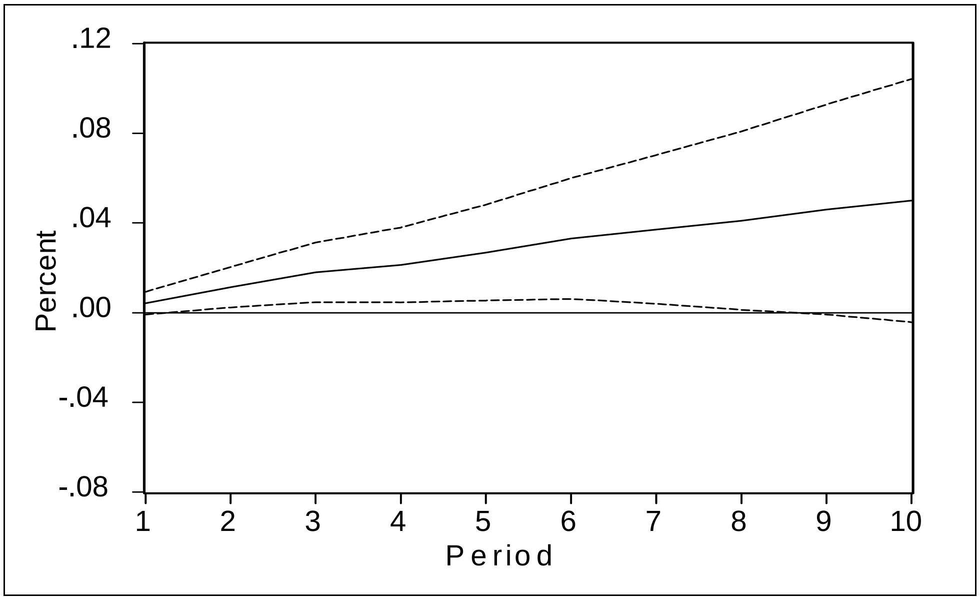

Figure 16. Accumulated Response of Personal Income to Gas Price Shock.

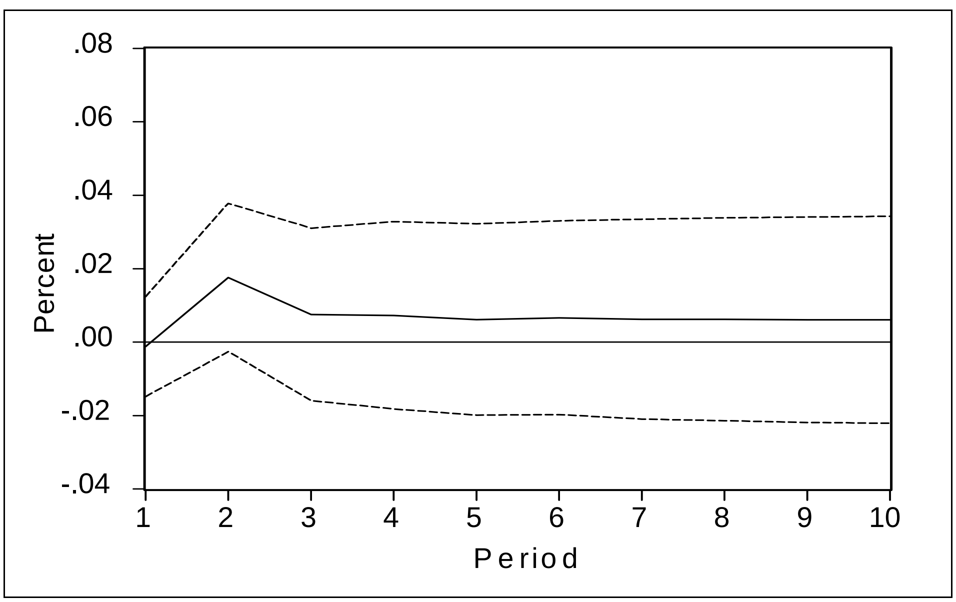

Figure 17. Accumulated Response of Revenue to Gas Price Shock.

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 have more opportunities to adjust to changes than possible in the short run (see column 3, Table 4). Although revenue appears to be the most responsive to price changes, it is not statistically significant using system equations that include gas production. The responses of employment and personal income to changes in oil and gas prices are analogous and significant statistically.

In Table 5 we present estimates of the quantity-equivalence of the responsiveness indicated in Table 4. The estimates were obtained by solving the system of equations involving state offshore oil and gas production. They are restrictive or conditional equivalence of a one standard deviation shock to oil and gas prices using the 2002 price series. The estimates are calculated based on the actual employment, revenue, and personal income figures for Louisiana for the year 2002. For oil and gas price 'shock', we assume the maximum percentage deviation from the expected monthly price for the year 2002[7]. The 'expected' price level is taken as the average price for 2002 in each case.

[6] By implication, since these are estimates from a forecast horizon, we are making an assumption of constant elasticity here.

[7] Oil or gas price shock is defined as max $\{0, (\ln(E(P)) - \ln P_t)\}$, where t is a particular month in the year 2002 and P is either oil or gas price in 2002.

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
Personal Income	0.06	0.13	2.2
Revenue	0.12	0.12	1.0
State Offshore Gas System Equations			
Employment	0.05	0.08	1.6
Personal Income	0.08	0.10	1.3
Revenue	0.16	0.08*	0.5

Note: * Denote non-significance at 95%.

Table 5. Quantitative Estimates of the Effects of Maximum Price 'Shock' in 2002

	Short Run (SR)	**Long Run** (LR)
State Offshore Oil System Equations		
Employment (Million)	0.0106	0.0266
Personal Income ($billion)	0.958	2.052
Revenue ($billion)	0.272	0.272
State Offshore Gas System Equations		
Employment (Million)	0.0285	0.0456
Personal Income ($billion)	2.736	3.420
Revenue ($billion)	0.768	N.A.

Note: N.A. Not applicable, since the corresponding elasticity is not significant.

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

This study examines the inter-relationships between petroleum price changes and economic activities in Louisiana in the context of oil and gas production in the state offshore waters. The goal is to provide some baseline information that will be useful to policy makers and resource managers, such as, MMS to enhance their decision-making capability.

The results obtained here are useful not only to Louisiana but to other similarly situated states as well. By using current analytical methodologies we are able to provide key findings that are similar to the findings in other studies. The use of VAR approach allows us not only to examine the relative importance of prices and production in explaining movement in key indicators of economic activities, but also to study the dynamics of adjustments in these variables over time, given an unanticipated change in petroleum prices.

As technology and prices push the frontier of oil exploration and development to deeper waters in the Gulf, a study of the impact of changes in petroleum prices given the current trends in production is warranted and timely. This is especially true for regional economies and communities near the GOM. The Louisiana results presented here are one of such unique opportunities to begin to examine these issues so as to fashion appropriate policy response in the future.

4.1. The Underlying Operating Mechanism

The results seem to follow the pattern economic theory would have predicted given that oil and gas producers are profit- maximizers. Thus we expect, as the results show, that as prices increase (assumed positive shock), more oil and gas is produced. To produce more, more workers are hired. Because such price shocks often occur in boom periods in the oil and gas industry, competition in the labor market forces up the wage rate. Given that the oil and gas industry usually pays higher than average wage, the overall effect is to raise the take-home pay of workers, and hence, the average personal income of Louisianans. At the given severance tax rates, but with increases in production and price, revenue derived by the government should rise.

The analysis above probably also extends to other non-oil sectors of the Louisiana economy in the short run. However, in the oil and gas-dependent sectors the situation may be mixed, even in the short run. For example, refineries and other chemical and allied industries may experience increases in input costs as a result of price increases, if the price shock is high enough. Thus, in these oil-using sectors, job losses may occur. This may reduce personal income and tax-base of the government as well. In the long run, this shock may lead to decline or even recession in the U.S. economy, which implies a reduced demand for goods and services, including oil and gas. The result of such a development is the reverse of the previous scenario—job losses, reduced income, and less government revenue. In other words, all economic activities in Louisiana may eventually return to their equilibrium levels, as this study finds.

Thus, the analyses above imply that what is finally observed following a positive price shock are overall net-effects. Our study shows that these net-effects in the short run are clearly positive for employment and personal income but mixed for revenue. The long-term prospects for a positive price shock in oil and gas indicate a net-effect that is significant only for employment and personal income. This long run result is understandable because, while industries may be forced to reduce output, in practice, it is not often easy to reduce wages and employment. Economic theory suggests stickiness in wages and rigidity in jobs market characterized by contracts, as is often the case in the oil and gas industry.

Our empirical results also indicate some salient findings that will be of interest to policy makers and oil and gas resource managers. These findings point to differences and similarities as well as general conclusions, which are conditional on the interactions between state offshore oil and gas production and Louisiana economic activity. The salient features are highlighted as follows:

- Changes in oil prices are more important in forecasting changes in employment and personal income than changes in natural gas prices in the short run.
- Both oil and gas price movements are equally important in explaining changes in Louisiana revenue, although the overall revenue impact is minimal.
- The indirect effects of oil and gas price changes are more important than the direct, autonomous, changes that occur in oil and gas production in state waters themselves. In other words, in the absence of price shocks, autonomous changes in oil and gas production (e.g. technology-induced) have ceased to be very important to Louisiana economic activities
- In general, the effects of a gas price shock on the economy are more persistent than oil price shocks. That is, price volatility in the gas market has a potential to be more destabilizing in the economy than equivalent change in the oil market.
- Irrespective of the market, oil or gas, the employment effects of a price shock last longer than personal income or revenue.
- The fiscal exposure or vulnerability of the Louisiana budget to oil and gas price changes in the context of offshore production in state waters have declined over time.
- The responsiveness of the macroeconomic variables to price changes indicate that when considering state offshore production, a considerably high and sustained change in prices is required to have an appreciable effect on Louisiana economic performance.

4.2. Policy Inferences from the Key Findings

These features bring certain policy issues to the fore. First, when designing intervention strategies following innovations in the oil or gas markets, it is important to distinguish between the source(s) and potential time-dimension of the shock(s). The analyses above clearly show that there are some differences in response between oil and gas, and whether the innovation is technology-driven (e.g. autonomous production changes), or price-driven. A shock that is potentially short term may require little policy intervention; in fact, such may be counter-productive. On the other hand, shocks that are potentially long term may invite appropriate interventions.

Second, in terms of oil and gas production in Louisiana offshore state waters, the findings here indicate that the state can hope to benefit from petroleum price increases only if those changes in prices are high and sustained for a significant time period. Therefore, relatively modest changes in petroleum prices can no longer be relied upon to assuage a short-term fiscal crisis (Scott, 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 determinant. However, in the light of our findings and with the current declining trends in oil and gas production in Louisiana state waters, tax increases or more regulation of state offshore production will likely be counter-productive because it raises costs in an environment of declining production and inelastic price responsiveness. On the other hand, incentives that shorten the time frame for the adoption of new technologies, or even reward innovations may encourage exploration or exploitation of marginal wells. Thus, the future policy direction at the state or federal level must focus on production-enhancing incentives.

Fourth, legislative debates often pitch oil-producing states, which favor policies that support higher oil and gas prices, against non-producers, who often take the opposite position. Our findings suggest that erstwhile regional tone of energy policy in the U.S. may be disappearing as states wield less and less control on declining production within their jurisdiction. In essence, more of the current net oil producing states will themselves become like the rest of the nation, making it less plausible to argue for discriminating federal policies across states in response to petroleum market instability. If our findings hold and current production trends prevail, Louisiana must begin to focus on strategies and policies that recognize the implications of her changing status.

Finally, the relative resilience of state revenue to these price shocks may be an indication of a progressive diversification of the state economy. This may be in itself welcome news to state fiscal planners. The oil and gas industry is often characterized by boom and bust, and since it is difficult to manage a budget based on volatile revenue streams, a more predictable revenue base offered by a well-diversified economy may be a more attractive position to be. However, the state also has a relatively high concentration of petrochemical, refinery, and other oil and gas-dependent sectors. Even if the trends in oil and gas production in state jurisdiction continue, the state economy will still be exposed to the vagaries of the oil and gas market in the foreseeable future.

4.3. Concluding Remarks

In an overall sense, the study finds that, at least in the case of Louisiana, oil and gas prices are still important with respect to short-term fluctuations in employment and personal income, but less so with respect to the variation in state revenue. In addition, the empirical results show that while there are some differences between the effects of oil and gas prices on Louisiana economy, the pattern of the effects is similar in many respects. Not withstanding this finding, it is noted that inferences from the dynamic paths of adjustment support the contention that changes in natural gas prices have a more destabilizing effect on the economy in the long run than oil prices. It is also obvious from this study that only a sustained high positive movement in petroleum prices can have a long-lasting impact on Louisiana economy if the economy is conditioned on changes in state offshore oil and gas production. Finally, the study also shows that, in the 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 regulation and tax increases to enhance significant oil and gas contributions to the state economy, in the past, especially state revenue, the current trends warrant new strategies. For example, given that prices are exogenously set, a range of production-enhancing incentive regimes might be the way to go.

There is ample opportunity and justification to extend these analyses to other regions with economies similar to Louisiana. The MMS manages oil and gas resources in several state waters; therefore, it would be an important and worthwhile exercise to extend this study to those states. Such research would not only identify trends in those states, but similarities and differences among them as well. In addition, a study with a wider scope may help to identify strategies that have been used to mitigate price effects and lessons that may be learned across states. The results from such an exercise could then provide MMS with a more holistic view of the dynamics of the price-offshore-production interactions and regional economies. This is important because we may be witnessing a paradigm shift in exploration and drilling activities in the Gulf as industry players move farther and farther into deep waters for more profitable prospects, leaving coastal communities with new challenges.

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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_p are m x m matrices of coefficients. The m-element vector e_t are white noise residuals that are *iid* satisfying $E\{e_t e_t`\}= D$, where D is a diagonal matrix. Note also that $e_{1(t)}$ and $e_{2(t)}$ are uncorrelated and are pure innovations (or shocks) in $y_{1(t)}$ and $y_{2(t)}$, respectively.

Equations (A1) and (A2) are referred to as *primitive* or *structural* form of a VAR. Often this primitive form are either over-identified or under-identified and the presence of the current levels of the other variable in own equations implies correlation of the regressed with the error terms. Hence, consistent estimation of these forms cannot be obtained. To estimate each of this equation by OLS, one must obtained the reduced forms. The system of equations is solved simultaneously to extract the *reduced* or *standard* VAR form:

$$(I - A_0)y_t = v + A_0 y_t + A_1 y_{t-1} + A_2 y_{t-2} + A_3 y_{t-3} + \ldots\ldots + A_p y_{t-p} + e_t \quad \text{(A4)}$$

Which reduces to

$$y_t = (I - A_0)^{-1} v + (I - A_0)^{-1} A_1 y_{t-1} + (I - A_0)^{-1} A_2 y_{t-2} + (I - A_0)^{-1} A_3 y_{t-3} + \ldots\ldots + (I - A_0)^{-1} A_p y_{t-p} + (I - A_0)^{-1} e_t . \quad \text{(A5)}$$

In a general matrix form equation A5 becomes:

$$y_t = b + B_1 y_{t-1} + B_2 y_{t-2} + B_3 y_{t-3} + \ldots\ldots + B_p y_{t-p} + u_t \quad \text{(A6)}$$

Where

$b = (I - A_0)^{-1} v$, $B_1 = (I - A_0)^{-1} A_1$, $B_2 = (I - A_0)^{-1} A_2$ $B_3 = (I - A_0)^{-1} A_3$ . . . . . etc., and $u_t = (I - A_0)^{-1} e_t$.

The variance-covariance matrix of residuals of the vector u_t equals

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

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:

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

Where $\Delta y_t = (y_t - y_{t-i})$, $\gamma = \rho$-1, while the null and alternative hypotheses are

Unit root: H_0: $\gamma = 0$
No Unit Root: H_1: $\gamma < 0$

There is no consensus as to what should be done to the variable(s) subsequent to VAR estimation if a unit root is confirmed. Some have suggested that the variable be differenced to remove the unit root(s). Others argue otherwise. Those who argue for non-differencing believe that since the goal of a VAR analysis is not to determine parameter estimates, but uncover dynamic interrelationships among variables, differencing "throws away" valuable information. However, the majority view is for differencing because a VAR should mimic the true data generating process. In this study, we adopt the majority view.

Step 3: Exogeneity and Exclusion Tests

Although in theory we have formulated A6 such that every endogenous variable are present in each equation and the lag length are also equal across equations. In reality, it may be that a variable or some lags of it does not really add to the forecasting performance of another variable and may therefore be excluded from the determination of that variable. The procedure to determine if a variable is a *causal* factor in predicting another is often the Granger causality and exclusion tests. If y_1 does not improve the forecasting performance of y_2, then y_1 does not Granger-cause y_2 and therefore nothing is gained by including it in the equation determining y_2. The common F-test can be used to evaluate Granger-causality causality for a single equation. A 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. A multivariate approach to carrying out the exogeneity and exclusion test is to use the so- called "block causality" test.

To perform the test, run the system of equation with all the lags and variable as is (unrestricted form, *U*), and obtain the variance-covariance matrix, Σ_u. Then regress the system again excluding all the lags of the variable from the equations where it is theorized to be exogenous, and obtain the restricted Σ_r. The results are evaluated using the likelihood-ratio test $(T-c)(log|\Sigma_r - log|\Sigma_u|$, which is distributed as a Chi-square with the degrees of equal to the number of restrictions. T is the number of observations and c, the number of parameters estimated in the unrestricted form. This logic may be extended to the question of the inclusion of dummy variables as well.

Step 4: Lag-Length Selection

The selection of the appropriate lag-length in the system of equation is an important consideration. As in the selection of the appropriate variable(s) in the right hand sides, the likelihood-ratio test is often used to select the appropriate lag length. The goal here is to ensure a parsimonious system with errors that are white noise as the theoretical model presumed. This test may also use the Akaike Information Criteria (AIC) and or the Schwartz-Bayesian Criteria (SBC). In the case of the AIC and SBC, we look for the model with the lowest value of the AIC or SBC estimates.

Step 5: Estimation

With steps 4 and 5 completed, the system of equation may still be symmetric. In this case, OLS is still the appropriate choice estimator applicable to each of the equations. However, it is possible that the resulting system after the previous two-steps produce a non-symmetric system such that either the right-hand variables are not the same across equations, or the lag-lengths differs across equations. In the non-symmetric situation, OLS is no longer an appropriate estimator as pointed out previously, we have to use another estimator such as an SUR.

Step 6: Innovation Accounting

Because of the restrictions implied in the reduced system in (A6), not all of the parameters of the primitive forms can be recovered without even further restrictions. In addition, further restriction may be necessary to obtain consistent estimates of (A6). Thus the main focus of a VAR is not on parameter estimates, rather it is to understand the time-path and dynamic interrelationships among included (endogenous) variables. One approach to obtain useful information from a VAR is to focus on the error terms in (A6) since by design these are contemporaneously related across equations. In essence, we want to see what happens to a variable and to the other variable to which it is related if there is an innovation (or shock) to it.

One method to accomplish this is to use a *moving average representation* of the system. For example, the system given by (A6) is transformed such that:

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

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

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

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 **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 gives the response of y_1 to a one-standard-deviation shock to the first equation in the current period. Thus, the response of the first variable to a one-standard-deviation shocks to the second variable in the current and previous periods given by the second elements from the left in the top rows of the Z_j matrices. In the same manner the response of the second variable to a one-standard-deviation shocks to the other variable is given by the elements of the second rows of the Z_j matrices, and so on.

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)

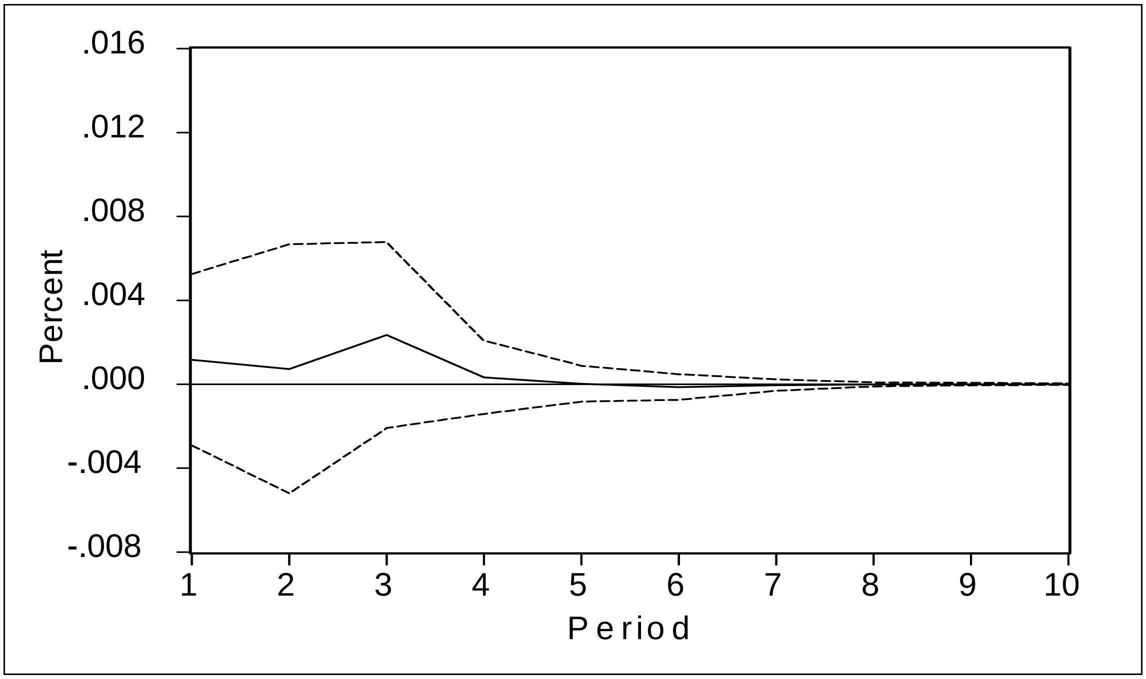

Figure B1. Response of Employment to an Oil Production Shock.

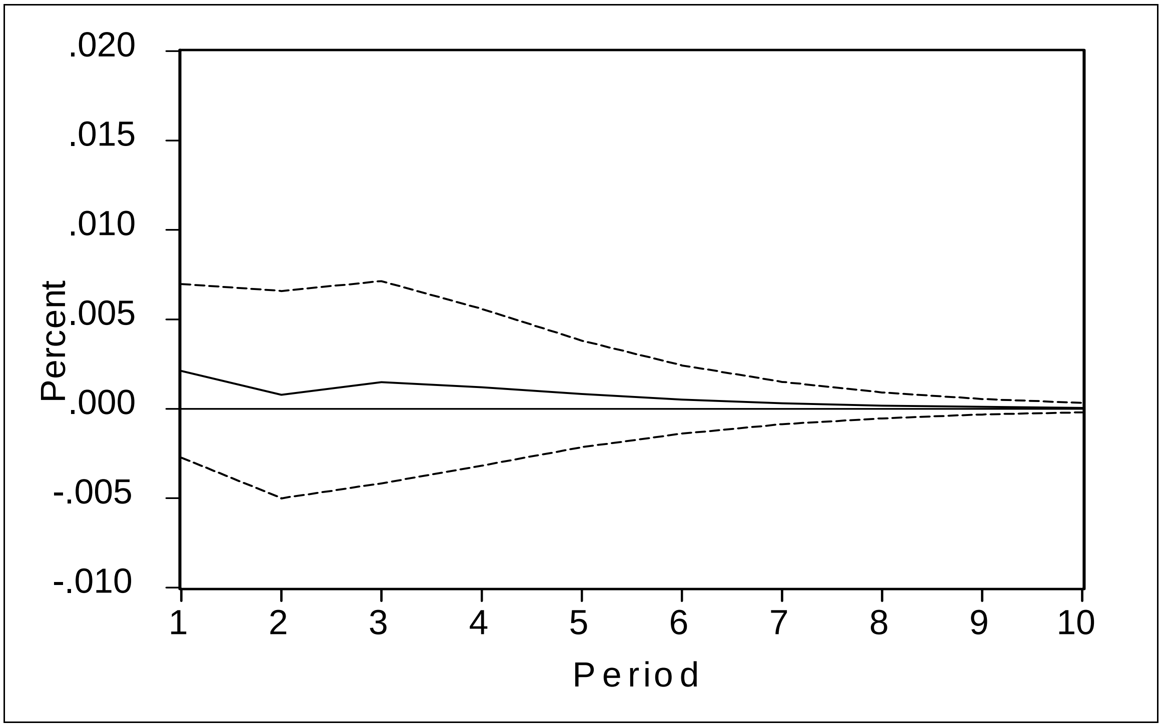

Figure B2. Response of Personal Income to Oil Production Shock.

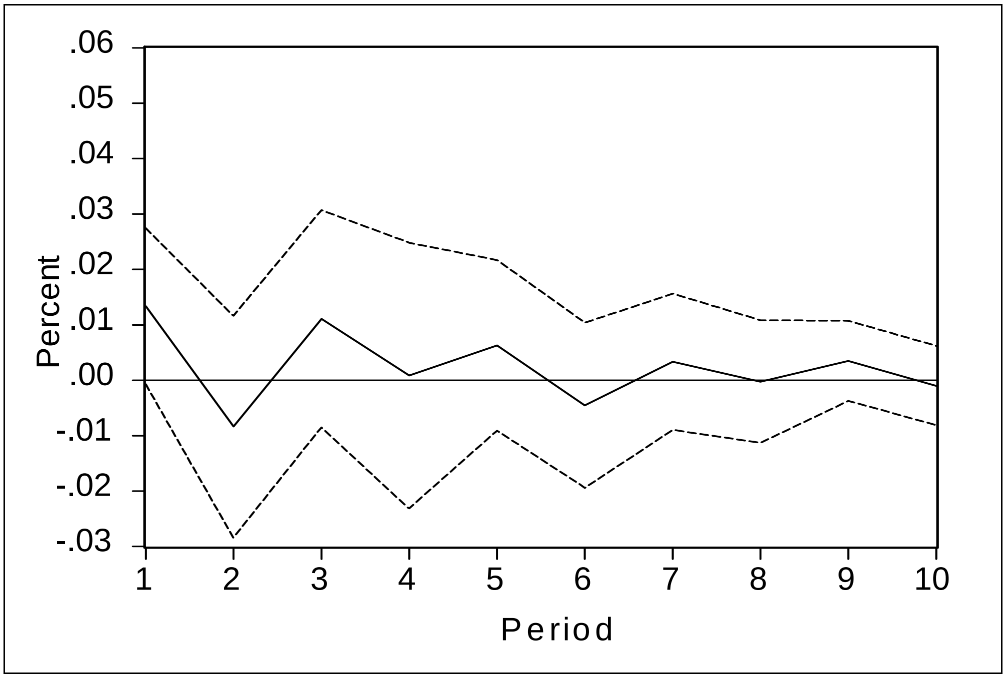

Figure B3. Response of Revenue to Oil Production Shock.

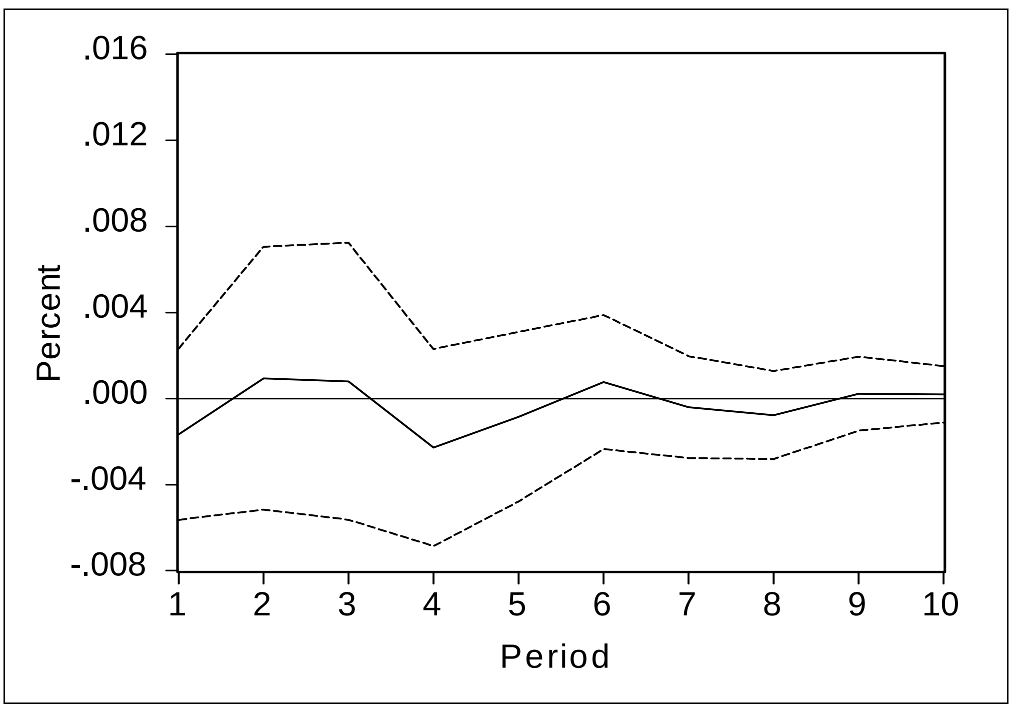

Figure B4. Response of Employment to Gas Production Shock.

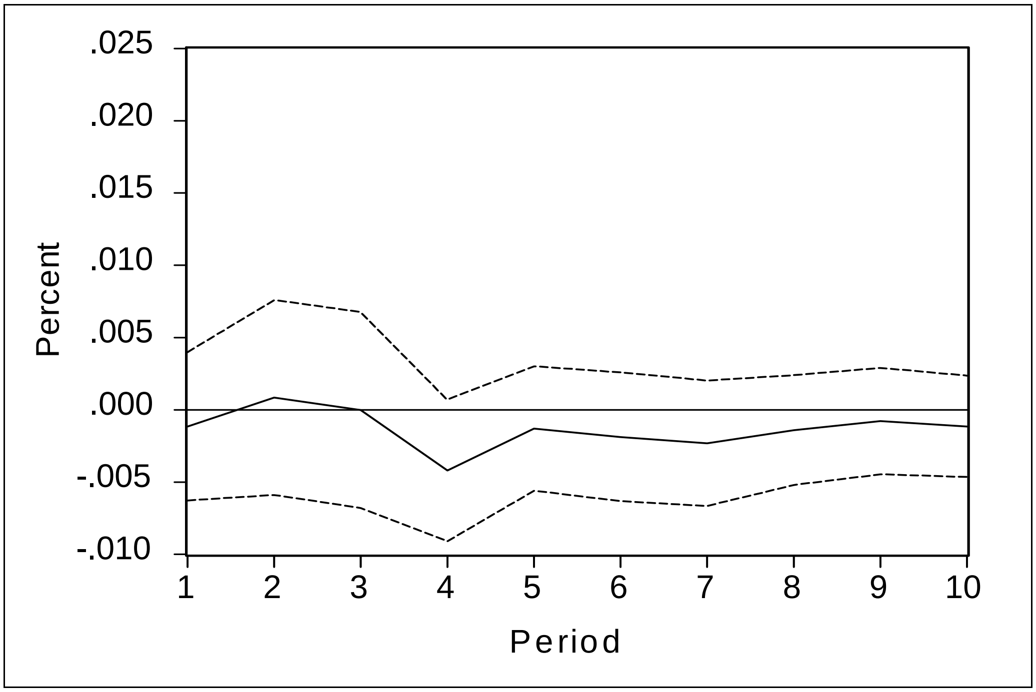

Figure B5. Response of Personal Income to Gas Production Shock.

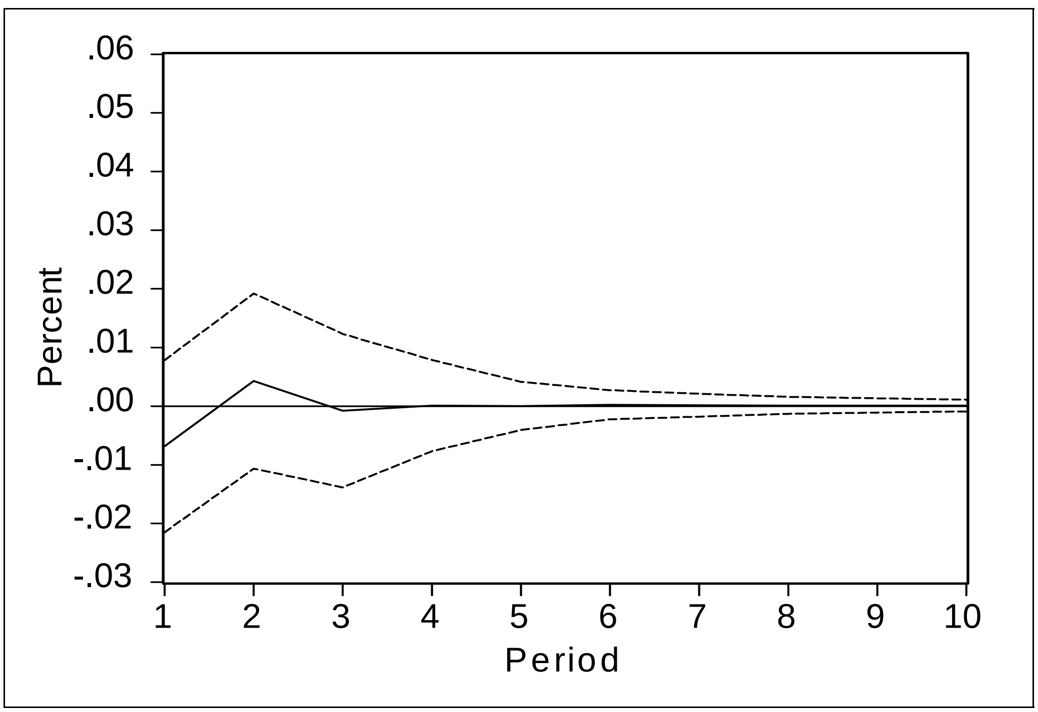

Figure B6. Response of Revenue to Gas Production Shock.

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.