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Economic Effects of Petroleum Prices and Production in the Gulf of Mexico OCS on the U.S. Gulf Coast Economy

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ABSTRACT

The purpose of this study is to analyze the dynamic interaction between changes in crude oil prices, oil and gas industry activity in the OCS (measured in terms of petroleum production) and selected indicators of the Gulf Coast economies. The scope of the study is expanded to include E&P activity in the deepwater. A vector auto-regression (VAR) model framework showing the interaction between crude petroleum price, oil and gas production, the U.S. interest rates, the U.S. gross domestic product, and selected indicators of the state of the Gulf Coast economy—personal income, unemployment rate and revenue—was developed and estimated. The model framework enables us to establish the direction, symmetry, causation, duration, responsiveness, and correlation between industry activity and state economic activity indicators and oil price changes over time.

The empirical results show that changes in crude oil prices have significant effects on oil and gas production in the Gulf of Mexico OCS and on measures of the Gulf Coast economy. The effects of oil prices on the state of the economy in the Gulf Coast are two-pronged. There is an established direct effect on the macroeconomic aggregates and there is also an indirect effect through production activity. As expected, the results show that the magnitude and duration of a crude oil price shock on the state of the economies in the Gulf States, as well as oil and gas production, differ significantly by state.

In a broad sense, the study shows that while the national economy may have become less sensitive to oil price shocks in the aggregate, the Gulf Coast economies are still prone to oil price shocks, albeit with variations across the states in the Gulf Coast. Thus, the study reaffirms the need to be cautious about policy responses that tend to focus only on the national response to policy issues with regional implications. The assumption that such national response is applicable or appropriate across regions may be erroneous. This demonstrates that understanding the dynamic of oil prices and their impacts on macroeconomic aggregates in and within the regions/states are as important as ever, even as mitigating national policies and response strategies evolve.

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EXECUTIVE SUMMARY

There is a general consensus that declining oil prices stimulate economic growth while increasing oil prices tends to dampen economic performance; the effects are not generally conclusive, however, for sub-national economies. While the effects of changes in oil price structure on the U.S. national economy are generally understood, the impacts of such changes on the state or sub-regional economies are less fully examined. Very few studies have studied the impact of changes in crude oil price on state economic performance, and such studies tend to conclude that a rising oil price more often than not stimulates economic growth in oil exporting states and hinders growth in oil importing states. The converse is true for declining oil prices.

For effective policy and regulatory guidance within the context of the overall national energy policy, agencies such as the MMS need reliable information at the regional levels, where most relevant oil and gas activities take place. This is because each state or region often possesses unique characteristics that are at variance with national outlooks. Therefore, such unique situations require a different policy or regulatory framework. Accordingly, this study is proposed to fill these gaps by extending previous national studies to sub-national economies, especially to areas where MMS has jurisdictional mandates.

This study analyzes the interactions between crude oil prices, oil and gas industry activity in the Outer Continental Shelf (OCS), and selected economic indicators of the Gulf Coast States. Total revenue, personal income, and the unemployment rate of four states in the U.S. Gulf Coast are used as proxies for measuring the strength of the U.S. Gulf Coast economy. The states were selected on the basis of some unique structural and economic characteristics as specified below:

Louisiana: Represents net oil exporter with limited diversified economy;
Mississipppi: Represents net oil importer with limited diversified economy;
Texas: Represents net oil exporter with relatively diversified economy;
Alabama: Represents net oil exporter with limited diversified economy.

Three key indicators for measuring E&P industry activity and performance that are highly and selected indicators of the Gulf Coast States' economies—personal income, unemployment rate and revenue—was developed and estimated. The VAR approach has been used generally for forecasting systems of interrelated time series and for analyzing the impact of a random disturbance on a system of variables. In this formulation, every endogenous variable is modeled to depend on its own lag(s), lags of other endogenous variables, and any exogenous variables that may also be included.

Variance decomposition and impulse response functions represent two complementary ways to characterize the dynamic effects of an unexpected shock to a given economic system that is represented by a VAR model. The variance decomposition procedure provides a way to decompose the effects of a shock on the system to their component parts. The percentage share of the effect of each particular shock provides an indication of its relative potency in explaining the observed variations in each variable experi

On Mississippi Economy: The model results, which describe the interactions between oil price, oil and gas production in the Gulf OCS, and Mississippi economic variables show that the percentage of the variation in the state's unemployment accounted for by price is less than 10 on path can be up to 15.5 percent. The price impact on revenue according to the VAR model results is as high as 16.7 percent. Further analysis of the impulse response results and subsequent adjustment paths to a price shock indicate that unemployment rate takes more than 8 years, personal income takes about 2 years, and revenue takes 5 years to adjust to their initial equilibrium levels. Just as is the case with Louisiana and Alabama, oil and gas production in the Gulf has no direct significant impact on the state unemployment rate.

On Texas Economy: The estimated model results of the effect of oil price interactions with Gulf oil and gas production and state economic variables with respect to the Texas economy show that the impact of a price shock on the Texas unemployment rate is relatively small, although significant. As much as 19 and 18 percent of the variations in personal income and revenue in the state are explained by price shocks, respectively. With regard to the adjustment paths over time, unemployment rate takes less than 10 years, personal income takes approximately 4 years, and revenue takes about 7 years for initial equilibrium to be restored. The effect of OCS production on Texas unemployment rate, unlike in the other Gulf States, is significant, but small.

Economic Effects of Oil Prices and Deepwater E&P Activity in the Gulf OCS:

On Louisiana Economy: The estimated model results for the interactions between oil prices and deepwater oil and gas production show that the effect of a price shock on Louisiana unemployment is relatively small (2 percent). However, deepwater production shows no significant and direct impact on the state unemployment. The model results further show that a price shock, conditioned on OCS deepwater production path, explains as high as 16.5 percent of the variation in Louisiana personal income. The paths of adjustment to price changes if deepwater production is restricted show a lag of 18 quarters for unemployment and 6 quarters for adjustment to price changes subject to deepwater production profile show a lag of 13 quarters for unemployment and 6 quarters for personal income.

On Texas Economy: According to the VAR model results, the response of Texas unemployment to changes in oil price subject to the interactions between oil and gas production from OCS deepwater and price is not statistically significant. However, Finally, there is statistical evidence suggesting significant differences in the duration of the lingering effects of a price shock on the economic performance of the Coastal Gulf States we investigated in this study.

1. INTRODUCTION

1.1. Background

The Minerals Management Service, a federal agency in the U.S. Department of the Interior, manages more than one billion offshore acres and has collected about 4-5 billion dollars in mineral revenues annually over the past five years (USDOI, MMS, 2003). The Gulf of Mexico OCS region accounts for about 25 percent of the oil and gas produced in the U.S. (USDOE, EIA, 2002). Thus, the oil and gas industry in the Gulf Coast is important to the nation's economy, especially to the states in the U.S. Gulf Region. Hence, whatever happens in the oil market portends a certain trend for the national or regional economies, either in the short or long run.

Perhaps the most important variable in the oil market is crude oil prices. Thus, a few economic impact studies supported by the MMS have focused on the effect of oil prices on the economies of Gulf of Mexico (GOM) communities. This is because oil prices, in addition to affecting the revenue base of adjacent states and communities, also have profound effects on the profits of oil companies operating in the region, and consequently, the levels of industry activities in the GOM.

Over the past three decades, policy makers have become overtly concerned with the effects of oil prices on the economic performance of nations or regions. The very high oil prices in the 1970s and the very low prices in the mid-1980s and the early 1990s amplify these concerns. Most studies of national economies have concluded that changes in oil price significantly affect variations in macroeconomic aggregates and hence, the growth of economies.

It is generally agreed that a declining oil price stimulates economic growth while an increasing oil price tends to dampen economic performance. These effects are often exacerbated depending on whether the nation is net oil importing or net oil exporting. The seminal work by Hamilton (1983) laid the foundation for the observed linkage between crude oil price movements and the level of economic activity in th

1.2. Study Objectives

This study develops economic and econometric models that examine the effects of changes in crude oil prices on both the E&P oil industries and the relevant regional economies in the Gulf of Mexico. The research uses recent econometric tools to provide quantitative estimates of the responsiveness and correlation between past and current activities of the oil industries and Gulf States' economic growth and oil price changes and volatility.

Specifically, the following objectives are addressed:

- examine the changes in some specific economic indicators of E&P activities of the OCS oil industries as a result of oil price changes and price volatility over time;
- examine the type of relationships that exist between oil price changes and the level of economic activities of the Gulf Region;
- forecast potential impacts of future changes in oil prices on industry activities and state aggregate economic variables; and
- identify possible policy responses to these changes by the industry and the relevant government in the Gulf.

In order to meet the above challenges, recent developments in time series econometric modeling tools are employed. These tools enable us to establish the direction, causation, duration, responsiveness, and correlation between industry and states' economic activity indicators and oil price changes over time.

1.3. Regional Scope of Study

This study covers selected representative states in the GOM Region. Specifically, we selected the following states based on their unique structural and economic characteristics specified in each case.

Louisiana: Represents net oil exporter with limited diversified economy;
Mississippi: Represents net oil importer with limited diversified economy;
Texas: Represents net oil exporter with relatively diversified economy;
Alabama: Represents net oil exporter with limited diversified economy.

In terms of industry-level, the project focuses on

2. DATA SOURCES AND DESCRIPTIVE ANALYSIS

2.1 Sources of Data

Most of the previous research 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.

In order to establish the robustness of our mode

2.2. Key Indicators of Economic Performance

The following macro-aggregates[2] or indicators are used as proxies for gauging the economic strength at the state-level:

Revenue: Many GOMR States derived a large percentage of their budgetary revenue from the oil and gas industry located in their areas and some have industry sectors that are highly energy-dependent;
Unemployment: A lot of people in most of the states in the GOMR are employed directly or indirectly in the oil and gas sector, hence, any unusual developments in the sector will reflect on states' welfare; unemployment level is one such closely watched variable;
Personal Income: Apart from the substantial number of jobs produced by the oil and related sectors, wages in the oil sectors are

Table 1

Variable Names, Descriptions, and Transformation Method

Variable	Description	Period*	Length	Seasonally Adjusted	Transformation	Deflated by
ALQPI	AL Quarterly Personal Income	1969:1-2000:2	126	No	Log Difference	GDPI
LAQPI	LA Quarterly Personal Income	1969:1-2000:2	126	No	Log Difference	GDPI
MSQPI	MS Quarterly Personal Income	1969:1-2000:2	126	No	Log Difference	GDPI
TXQPI	TX Quarterly Personal Income	1969:1-2000:2	126	No	Log Difference	GDPI
ALQUR	AL Quarterly Unemployment Rates	1976:1-2000:4	100	Yes	Non Differenced	
LAQUR	LA Quarterly Unemployment Rates	1976:1-2000:4	100	Yes	Non Differenced	
MSQUR	MS Quarterly Unemployment Rates	1976:1-2000:4	100	Yes	Non Differenced	
TXQUR	TX Quarterly Unemployment Rates	1976:1-2000:4	100	Yes	Non Differenced	
QCPPI	Quarterly Crude oil PPI	1947:1-2000:4	216	No	Log Level	QAPPI
CPPIV	Quarterly Crude oil PPI Volatility	1947:1-2000:4	216	No	Non Differenced	
QAPPI	Quarterly All Commodities PPI	1947:1-2000:4	216	No	Non Differenced	
RGDP	Real GDP in 1996 Dollars	1947:1-2000:4	216	Yes	Log Difference	
GDPI	Implicit GDP Deflator	1947:1-2000:4	216	Yes	Log Difference	
TRBR	Three Month Treasury Bill Rate	1947:1-2000:4	216	No	Non Differenced	
GOSHA	Gulf: Oil & Gas Production Shallow. Waters	1948:1-2000:4	212	No	Log Difference	
GODEP	Gulf: Oil & Gas Production Deep Waters	1979:3-2000:4	86	No	Log Difference	
GOTOT	Gulf: Oil & Gas Production Total	1948:1-2000:4	212	No	Log Difference	
ALARV	AL Annual Revenue	1950-2000	51	No	Log Difference	GDPI
LAARV	LA Annual Revenue	1950-2000	51	No	Log Difference	GDPI
MSARV	MS Annual Revenue	1950-2000	51	No	Log Difference	GDPI
TXARV	TX Annual Revenue	1950-2000	51	No	Log Difference	GDPI

* Year:Quarter-Year:Quarter.

Table 2 presents the basic correlation coefficients among macroeconomic aggregates and selected exogenous variables. In general, the crude petroleum price index is shown to be negatively correlated with personal income, but positively correlated with unemployment rates-except in Louisiana. The correlation coefficients between price and unemployment rates are, however, relatively small in value. Personal income is highly and positively correlated with the overall OCS oil production. The correlation coefficients between unemployment rates and OCS production, in general, are similar in magnitude to those between production and personal income, but the signs of the correlation coefficients are reversed. State revenue shows a positive correlation with both price and crude petroleum production in the OCS. 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 a VAR is often required for an in-depth examination of such relationships among variables.

Descriptive statistics of all the variables discussed in the estimation process are shown in Tables 3a and 3b. Average personal income is highest in Texas, followed by Louisiana, Alabama and Mississippi, respectively. However, the range in average personal income between the states is relatively large. Over the period, unemployment rates in these states are quite high, ranging from a mean value of 6.2 percent in Texas to 8.08 percent in Louisiana. The Gulf OCS gross oil and gas production averaged about 287.7 MMB annually. The average distribution of annual revenue in the states also shows a similar pattern to the distribution of quarterly personal income. Texas is considerably ahead of the others in state revenue on both an absolute and per capita basis. The trends in unemployment rates, personal income and annual revenue, macroeconomic indicators of the strength of the U.S. Gulf Coast economy, are discussed briefly below and depicted in Figures 1 through 3.

The trends in annual state revenue as depicted in Figure 1 also show similar patterns to the trends in personal income of the four states (see Figure 2). Louisiana has had the lowest growth rate in revenue, especially since the early 1990s. Prior to the late 1980s, revenue derived from the oil and gas sector accounted for more than one third of the state government aggregate revenue. Presently, however, the oil and gas sector of the economy accounts for less than 12.5 percent of government revenue (Iledare and Olatubi, 2004). Figure 2 shows the trends in quarterly per capita personal income in the four Gulf States over time. It shows that the growth rate in Texas personal income is much higher than the growth in the other three Gulf States. Personal income in Alabama and Mississippi has grown in tandem over this period and the growth is better than the growth in Louisiana.

Figure 3 presents the trends in another important macroeconomic variable--unemployment rates in the Gulf States. Employment levels provide an important indication of the level of economic activity in a state. Unlike personal income and revenue trends discussed earlier, the trends in unemployment rates follow similar patterns in all of the states. Generally, there were low unemployment rates until the early 1980s, when it increased dramatically. It is interesting to note that the net-petroleum importing states—Alabama and Mississippi—experienced the highest reported unemployment rates in the early 1980s. Many people in the Gulf States are employed directly or indirectly in the oil and gas sector, so any unusual developments in the petroleum sector will reflect on the state’s welfare.

The trend in quarterly crude petroleum producer price index (QCPPI), a measure of composite oil prices, is presented in Figure 4. In general, oil price was stable until the mid-1970s. From the mid-1970s, the crude oil price index rose sharply to its historical high in the early 1980s. Although the price fell in the mid to late 1980s relative to the previous decade, it was relatively more volatile in the 1990s. In fact, the 1990s witnessed at least two spikes in oil prices.

Table 2

Correlation Matrix of Model Variables

ANNUAL SERIES: 1954-1999				
	Price Index	**Production**	**Real GDP**	**Treasury Bill**
Revenue, AL	0.577	0.792	0.976	0.164
Revenue, LA	0.607	0.805	0.979	0.188
Revenue, MS	0.554	0.788	0.971	0.153
Revenue, TX	0.550	0.766	0.965	0.126
Production	0.726	1.000	0.896	0.586
QUARTERLY SERIES: 1976:1-1999:4				
	Price Index	**Production**	**Real GDP**	**Treasury Bill**
Income, AL	-0.149	0.833	0.981	-0.451
Income, LA	-0.168	0.835	0.979	-0.467
Income, MS	-0.184	0.854	0.990	-0.433
Income, TX	-0.188	0.871	0.994	-0.422
Unemp., AL	0.103	-0.823	-0.907	0.124
Unemp., LA	-0.156	-0.622	-0.797	0.154
Unemp., MS	0.095	-0.713	-0.890	0.271
Unemp., TX	0.053	-0.796	-0.913	0.032
Production	-0.109	1.000	0.881	-0.245

Table 3a

Quarterly Summary Statistics of Model Variables, 1976:1-1999:1

	Mean	**Median**	**Max**	**Min**	**Std. Dev.**	**Obs.**
ALQPI*	56,564	53,748	102,073	19,221	24,644	96
LAQPI	59,655	54,557	101,460	21,017	22,686	96
MSQPI	31,506	29,110	58,531	11,141	13,547	96
TXQPI	273,960	246,886	551,782	78,828	129,791	96
ALQUR**	7.78	7.15	15.55	4.09	2.56	96
LAQUR	8.09	7.15	13.38	4.22	2.29	96
MSQUR	7.89	7.45	13.49	4.82	2.13	96
TXQUR	6.22	6.12	9.27	4.15	1.29	96
Price Index	61.35	56.50	114.90	26.20	21.70	96
Real GDP	6,261	6,255	9,084	4,266	1,311	96
Treasury Bill	6.85	5.86	16.30	2.93	2.84	96
OCS Total Prod.	287.70	286.13	356.59	229.23	29.18	96

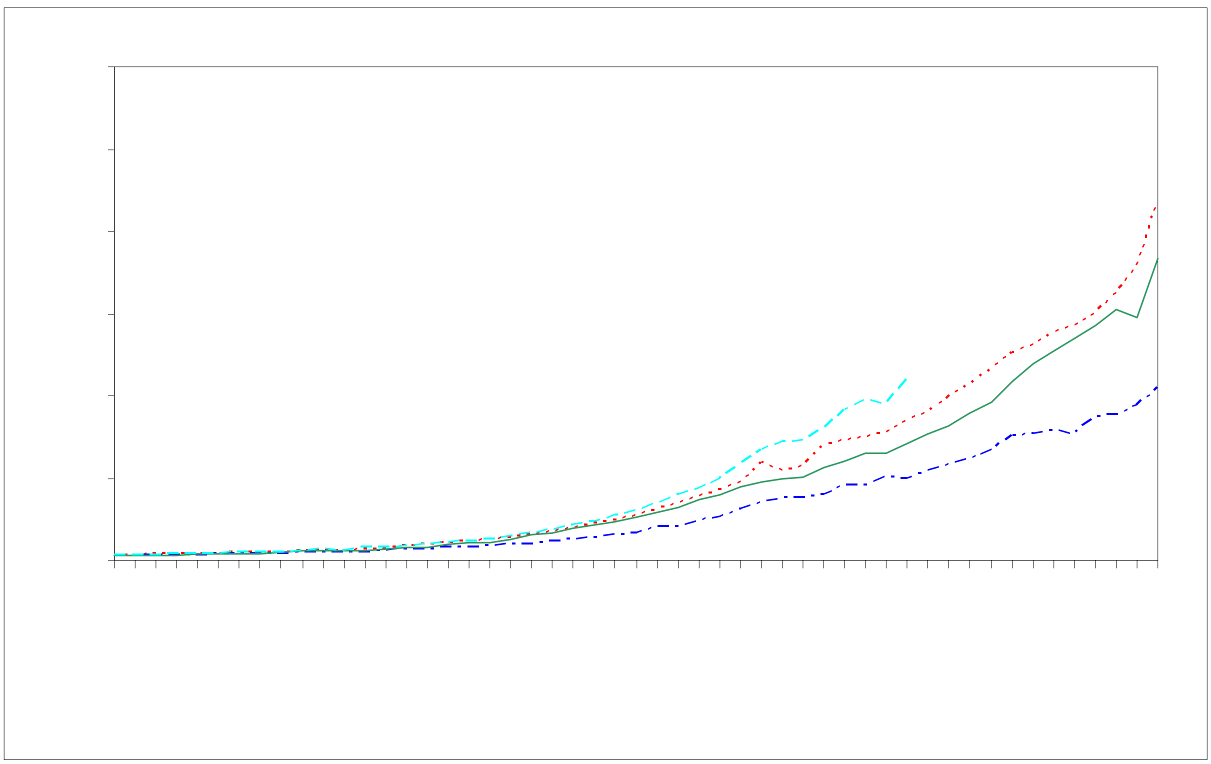
* XQPI represents quarterly personal income measured in millions of real dollars for state X.

Table 3b

Annual Summary Statistics of Model Variables, 1954-1999

	Mean*	Median	Max	Min	Std. Dev.	Obs.
Revenue in AL	4,132.23	2,649.99	13,675.00	313.85	3,919.64	45
Revenue in LA	4,963.84	3,216.15	14,498.00	556.95	4,366.19	45
Revenue in MS	2,644.05	1,759.38	8,399.93	217.10	2,505.38	45
Revenue in TX	14,273.62	8,090.17	47,970.04	855.65	14,584.57	45
Price Index	39.95	35.70	109.60	12.60	27.79	45
Real GDP	4,759.42	4,511.80	8,875.80	2,099.50	1,947.78	45
Treasury Bill	5.61	5.06	14.03	1.73	2.66	45
OCS Production	805.13	962.08	1,406.15	19.57	452.30	45

* Annual revenue is reported in million dollars.



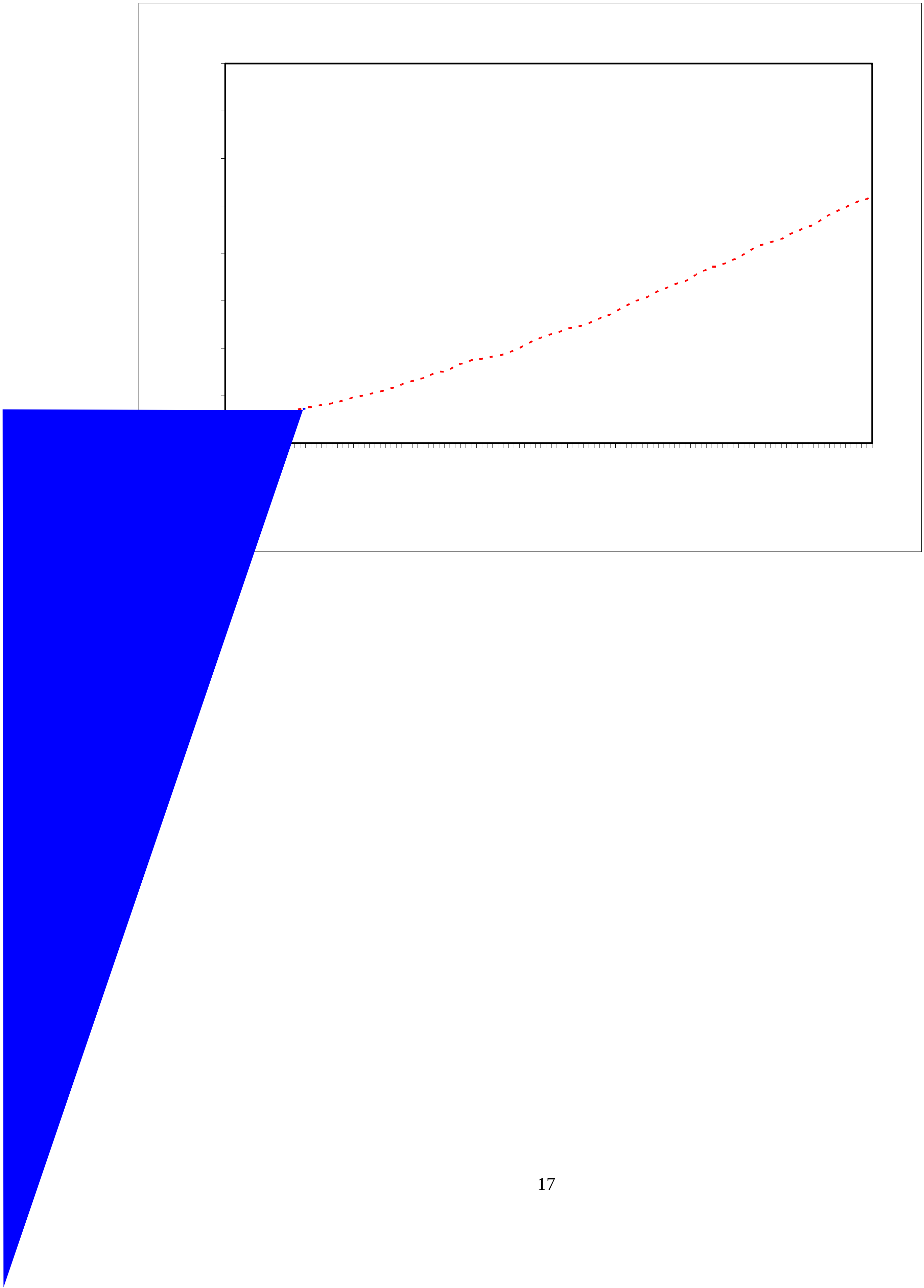
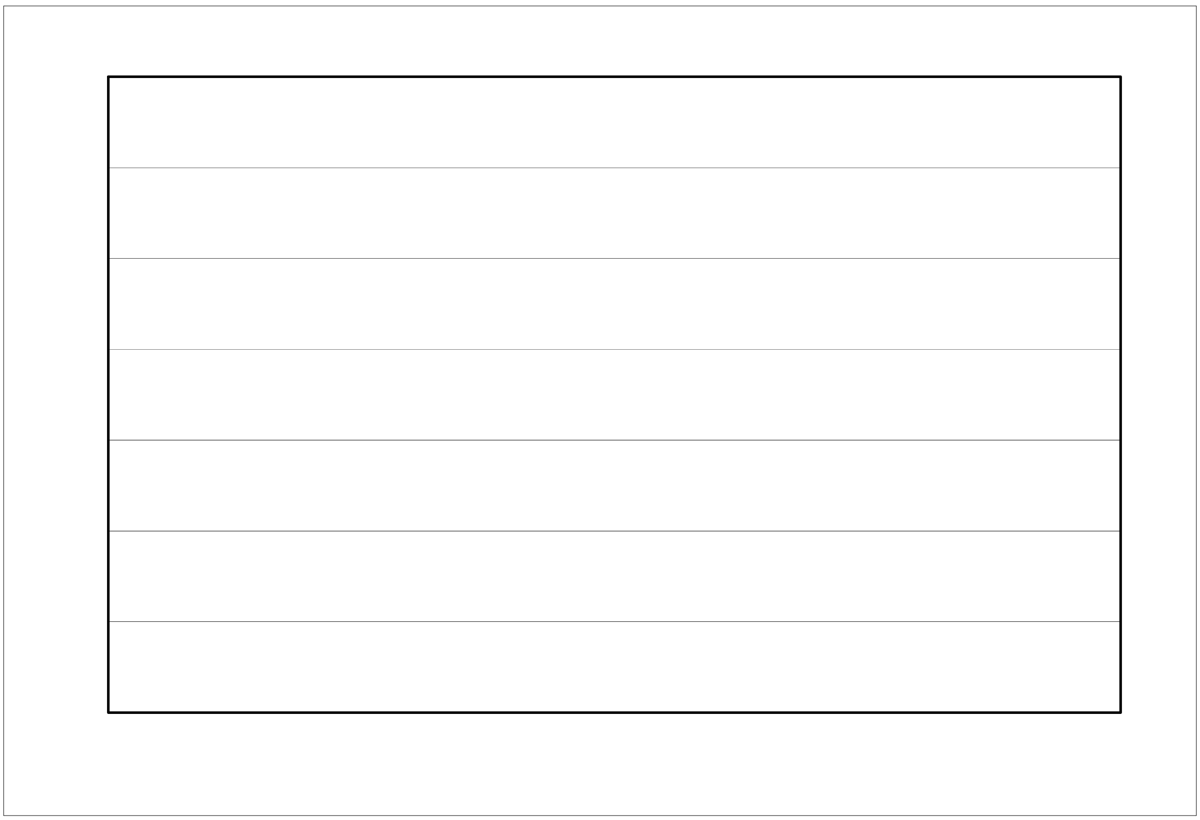
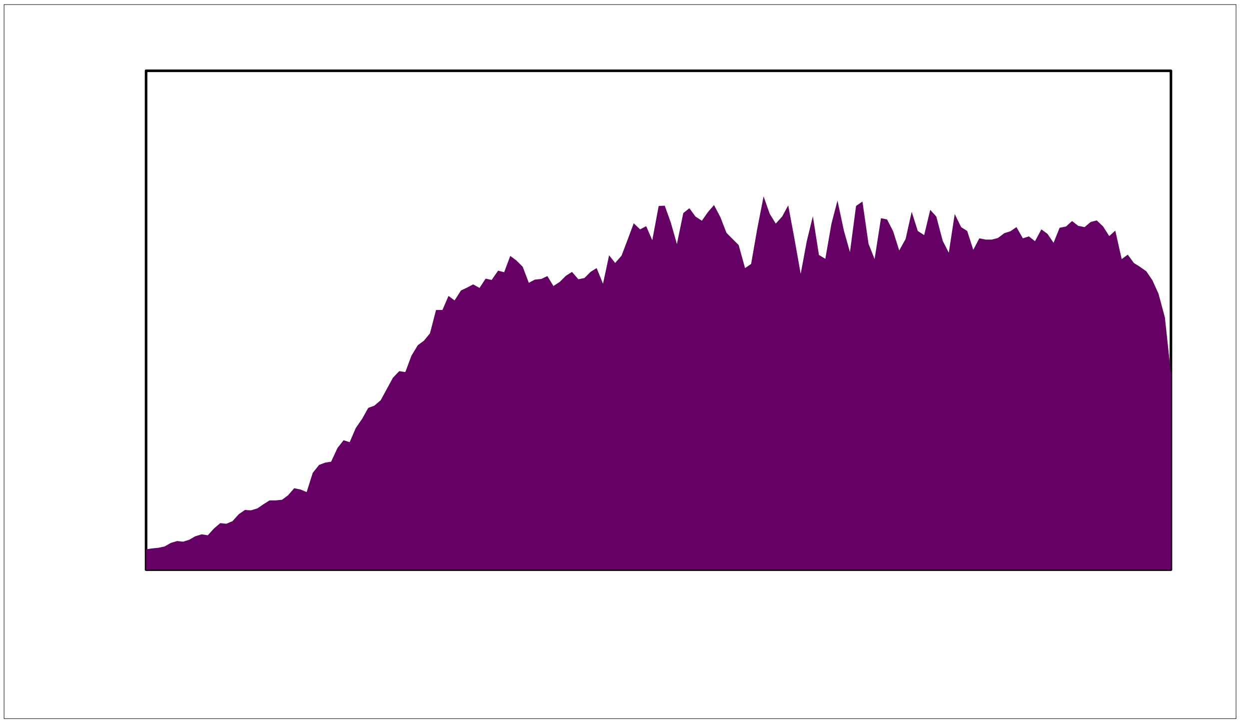


Figure 5 shows that oil and gas production from the OCS has increased significantly since the late 1950s. There was a rapid growth in oil and gas production from 1959 to the late 1970s. However, from the mid-1970s to the late 1990s, the rate of growth in production moderately declined. Since the late 1990s, there appears to be a sharper decline in production rate than any other time in history. In terms of water depth, most of the production activities in the GOM have historically occurred in the shallow waters. However, since the early 1990s, production has declined in the shallow waters while the production in the deep waters has been rising.





3. VAR MODELING OF THE ECONOMIC EFFECTS OF PETROLEUM PRODUCTION AND PRICES

3.1. VAR Model Specification

Recent developments in time series analysis, especially in the theory of co-integration, error-correction and Granger-causality, have extended the opportunities available to analyze, in-depth, economic equilibrium relationships. In this study, as in most studies of macroeconomic impact of oil price change, a VAR modeling approach is adopted. VAR modeling is a multi-stage process—involving unit roots tests, co-integration examination, and Granger-causality exploration[4]. The VAR approach is commonly used for forecasting systems of interrelated time series and for analyzing the dynamic impact of random disturbance on the system of variables. In this formulation, every endogenous variable is modeled as being dependent on its own lag(s) and the lags of other endogenous variables. Exogenous variables may also be included in the specification of the systems.

The general mathematical formulation usually takes the form:

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

where y_t is a vector of *k* dependent variables, x_t is a vector of *m* independent variables, A_1, …., A_p and *B*

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

The dummy variable D_1 is included in each equation of the system to capture the period when oil prices declined and crashed. In addition, the proxy for economic indicator, y_{3t}, does not appear in the price equation because the included measures of the economy in the Gulf States are not expected to have a direct influence on the crude petroleum price index because most economic activities in the Gulf States are price takers in the overall global petroleum economy. The number of past values of the dependent variables (length of lags) in each system of equations is determined statistically using a combination of Schwartz Bayesian Criteria (SBC) and Akaike Information Criteria (Iledare and Olatubi, 2004).

Further, the general formulations represented in the above system of equations (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 an '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 have been imposed on some of the parameters. Such restrictions are based on economic theory or the intuition of the researcher. A common type of restriction is to 'order' the variables (and hence, the error terms) according to the effects that are believed to be *'a priori'*. For example, in this study, we order the variables as follows: [oil price $\rightarrow$ OCS activity $\rightarrow$ economic indicators]. This ordering implies that the shocks on economic variables flow from the shock to oil price and OCS activity in that order. By implication, oil price is not directly affected by either OCS activity or economic variables. A different ordering may produce a different response path, hence, we chose carefully the appropriate ordering based on economic theory or alternative plausible results from different orderings.

3.3. VAR Model Estimation and Analysis

Generally, a VAR model such as the type we specified in equation (1) can be estimated using ordinary least squares (OLS), if each equation in the system contains the same number of variables and has similar lags on the right-hand-side. OLS in this case provides estimates that are both consistent and asymptotically efficient. The system formulation in equation (2) does not fully meet this criteria; hence, the specification in this paper can be described as near-VAR models. The near-VAR model in each of the cases formulated is estimated using seemingly unrelated regression (SUR) techniques.

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 te stability and duration of such effects. The persistence of such a shock reveals how fast the system will return to its original equilibrium. The faster it takes a shock to dampen, the shorter the adjustment period (Brown and Yucel, 1995).

4. ESTIMATED VAR MODEL RESULTS: VARIANCE DECOMPOSITION ANALYSIS

The empirical results reported in this report have been derived from estimating the system of equations in (2) individually for employment, real personal income, and state revenue in combination with OCS petroleum production in the OCS and deepwater—one at a time.[6] Variance decomposition and impulse response function analyses for each of the Gulf States have been applied to the VAR model results. The variance decomposition procedure provides a way to decompose the impact of a shock on the economic system into its component parts. The relative proportion of the decompositions indicates the relative potency of the effect of a standard deviation price or production shock in explaining the observed variations in each variable experiencing the shock.

4.1. VAR Results from OCS Aggregate Production System Equations

4.1.1. OCS Petroleum Production and the Louisiana Economy: According to the results reported in Table 4, the dynamic VAR analysis of the interactions between changes in crude petroleum prices and oil and gas production in the Gulf of Mexico OCS, and Louisiana unemployment rates shows a significant price effect on unemployment rates. Price explains about 0.45-11.43 percent of the observed variation in unemployment over time. Crude oil price interacting with oil and gas production in the Gulf of Mexico OCS also explains about 5.91-14.61 percent of the expected variation in personal income and between 11.45 to 16.81 percent of the variation in revenue. The autonomous oil and gas production shows no significant direct effects on unemployment according to the VAR results. Nonetheless, a relatively significant variation in personal income and state annual revenue is explained by changes in autonomous production. In an overall sense, both oil prices and Gulf oil production have more impact on revenue than they have on Louisiana unemployment rates and personal income.

4.1.2. OCS Petroleum Production and the Alabama Economy: The model results describing the interactions among oil prices and oil and gas production in the Gulf of Mexico OCS and Alabama unemployment rates indicate that petroleum price variation explains up to 30 percent of the expected variation in Alabama unemployment. The results also show that a price shock conditional on the OCS oil and gas production profile explains up to 11 percent of the observed variation in personal income in Alabama. Further, a price shock interacting with oil and gas production also has a potential impact of at most 29 percent in the long-term on Alabama revenue. The autonomous direct impact of oil and gas production in the Gulf OCS on Alabama unemployment is also not significant, according to the VAR model results.

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

Table 4

Decomposition of the Variance of Macroeconomic Variables Due to Changes in Petroleum Prices and OCS Gross Petroleum Production

	States/Variables	Period				
		1	4	12	18	24
A	**LA Unemployment**					
	OCS Production	0.012	1.273	1.487	1.571	1.600
	Price Index	0.450	1.606	11.393	11.212	11.434
	LA Personal Income					
	OCS Production	2.653	3.141	3.312	3.331	3.335
	Price Index	5.910	14.218	14.609	14.606	14.605
	LA Revenue					
	OCS Production	6.934	10.981	12.601	12.594	12.613
	Price Index	11.456	12.784	16.584	16.789	16.807
B	**AL Unemployment**					
	OCS Production	0.043	0.282	0.524	0.524	0.524
	Price Index	0.052	9.158	29.844	29.873	29.895
	AL Personal Income					
	OCS Production	1.303	3.308	3.993	4.107	4.138
	Price Index	4.296	7.378	10.804	10.837	10.847
	AL Revenue					
	OCS Production	1.111	2.012	2.621	2.632	2.632
	Price Index	14.244	20.785	28.905	28.950	28.953
C	**MS Unemployment**					
	OCS Production	0.780	0.558	0.343	0.321	0.314
	Price Index	1.255	0.947	8.346	9.210	9.448
	MS Personal Income					
	OCS Production	3.376	4.911	5.315	5.404	5.438
	Price Index	9.868	13.949	15.535	15.576	15.583
	MS Revenue					
	OCS Production	41.119	40.89	40.101	40.100	40.100
	Price Index	11.958	15.139	16.747	16.749	16.749
D	**TX Unemployment**					
	OCS Production	1.199	0.956	1.159	1.186	1.190
	Price Index	1.472	1.531	2.285	2.605	2.667
	TX Personal Income					
	OCS Production	0.171	0.908	3.167	3.305	3.331
	Price Index	10.066	18.791	18.607	18.632	18.635
	TX Revenue					
	OCS Production	0.036	1.949	2.143	2.413	2.143
	Price Index	0.133	18.023	18.032	18.033	18.033

4.1.3. OCS Petroleum Production and the Mississippi Economy: The model results, which describe the interactions between oil price and oil and gas production in the Gulf OCS and Mississippi economic variables demonstrate that the variation in the state's unemployment accounted for by petroleum prices is less than 10 percent on average, but significant. Similarly, the empirical results indicate that the effects of petroleum prices on personal income interacting with OCS production may be about 15.5 percent. The price impact on revenue, according to the VAR model results, reaches as high as 16.7 percent. The impact of a change in oil and gas production in the Gulf, as is the case with Louisiana and Alabama, has no direct significant impact on the state unemployment rate. However, the impact of production on revenue and personal income is statistically significant as evident in Table 4.

4.1.4. OCS Petroleum Production and the Texas Economy: The estimated model results reported in Table 4 show that the impact of a price shock on Texas unemployment rates is relatively small, although significant. The variations in personal income and revenue in Texas explained by price shocks are 19 and 18 percent, respectively. The effects of OCS production on Texas unemployment rates, unlike in the other Gulf States, is significant, but small. Production effect on Texas revenue ranges from 0.04 percent in the short-run to 2.14 percent in the long-run. This is a significant departure from the trends observed for Louisiana, Alabama and Mississippi.

4.2. VAR Results from OCS Deepwater Production System Equations

The empirical results reported in Table 5 have been derived from estimating the system of equations in (2) for employment, real personal income, and state revenue in combination with OCS deepwater petroleum production and by using the variance decomposition procedure for each of the Gulf States. The relative importance of changes in petroleum prices and production in explaining volatility in economic activity in these states is discussed briefly as follows.

4.2.1. OCS Deepwater and the Louisiana Economy: The deepwater model results indicate that variation in price and deepwater production has little or no influence on the observed variation on Louisiana unemployment rates over time. This is contrary to expectation in comparison to the other Gulf States. On average, however, price and deepwater production explains about 16 and 2.6 percent of the observed variation in Louisiana personal income, respectively. We did not estimate the deepwater system of equations for revenue because of data limitations.

Table 5

Decomposition of the Variance of Macroeconomic Variables Due to Changes in Petroleum Prices a

4.2.2. OCS Deepwater and the Alabama Economy: The model results describing the interactions among oil prices and deepwater production in the Gulf of Mexico OCS and Alabama unemployment rates indicate that petroleum price variation explains up to 33 percent of the expected variation in Alabama unemployment. The autonomous direct impact of deepwater production in the Gulf OCS on Alabama unemployment is significant, according to the VAR model results, explaining between 13-25 percent of the observed variation in Alabama unemployment. The results also show that a price shock conditional on the OCS deepwater production profile explains 1.95-5.85 percent of the observed variation in personal income in Alabama. The variation in Alabama personal income explained by changes in deepwater production ranges from 0.80 to 7.00 percent.

5. ESTIMATED VAR MODEL RESULTS: IMPULSE RESPONSE FUNCTION APPROACH

To further quantify the responsiveness of the economic performance indicators to price shocks and OCS production in the Gulf States, the impulse response function technique for characterizing the dynamic effects of an unexpected shock in a given economic system is applied separately to data from Alabama, Louisiana, Mississippi, and Texas. Generally, the impulse response function (IRF) shows the dynamic paths of the effects of an independent shock of one variable on another variable and it is also useful for characterizing the stability and duration of such effects.

5.1. IRF Results from OCS Aggregate Production System Equations

5.1.1. Price Shock, Gulf OCS Production, and the Louisiana Economy: The impulse response of Gulf oil production and Louisiana unemployment rate to a one-time positive shock to crude oil price is presented in Figure 7. Unemployment rate falls and oil production increases in response to the shock. Unemployment rate reaches its highest level within 10 quarters after the shock. This corresponds to about 0.6 percent above its initial equilibrium. The minimum level of unemployment rate (0.26 percent in below equilibrium) was attained within three quarters subsequent to the shock. Unemployment rate gradually moves towards equilibrium after reaching its maximum.

Gulf aggregate production, on the other hand, rises within five quarters to a maximum of 0.35 percent above the initial equilibrium and falls to a minimum of 0.26 percent below its initial level within three quarters. Oil production fluctuates around its equilibrium level over the time horizon. It is also noted that both oil and gas production and the unemployment rate return to their original equilibrium levels, although the dynamic paths to equilibrium are different; oil production fluctuates much more than unemployment rate.

The dynamic response of Louisiana personal income and Gulf OCS production to price is]TJ-26.0006 '

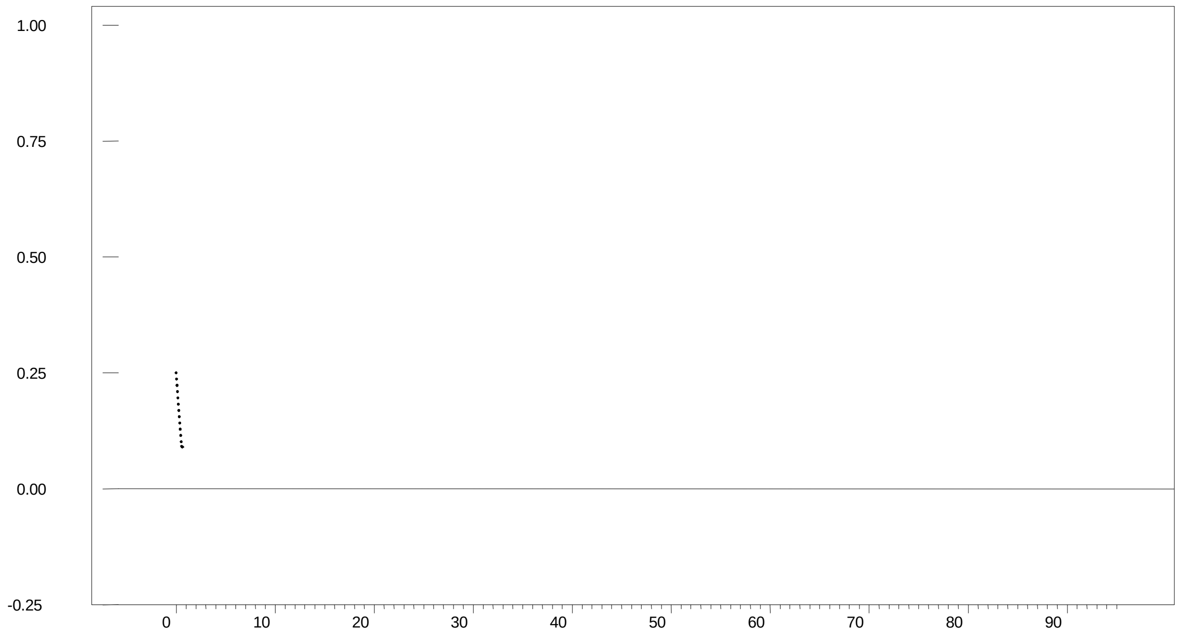

Figure 6: Louisiana Personal Income and OCS Production Dynamic Paths.

Figure 7: Louisiana Unemployment and OCS Production Dynamic Paths.

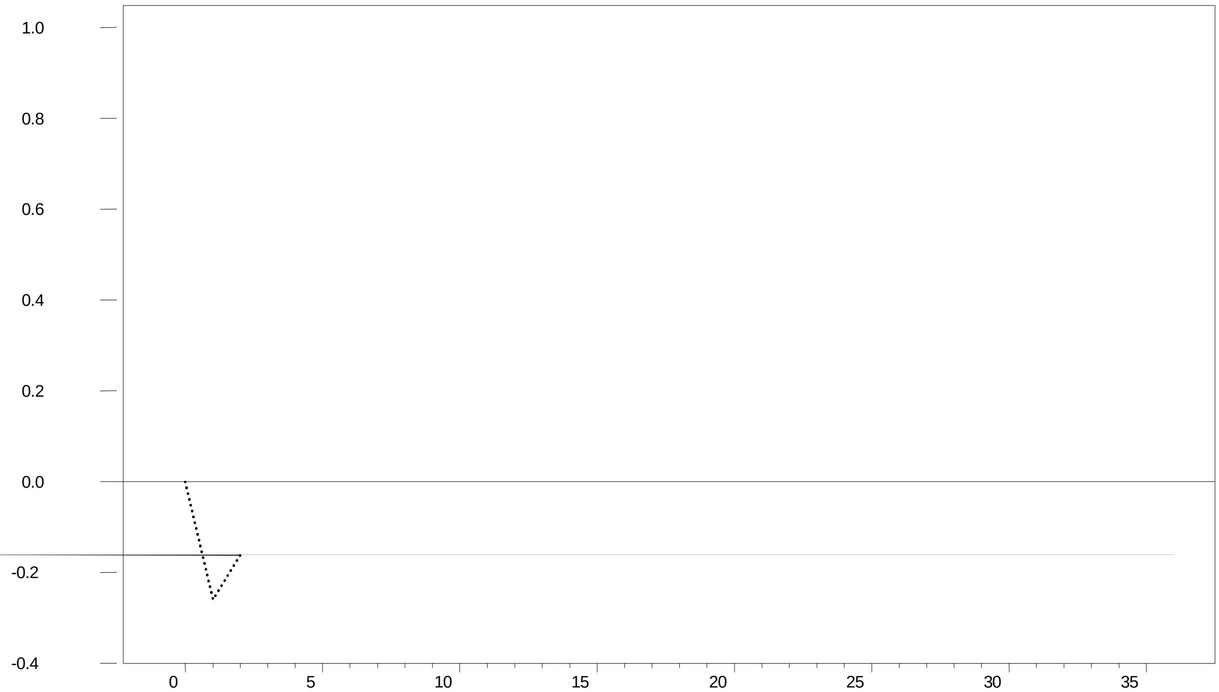

Figure 8: Dynamic Paths of Louisiana Revenue and OCS Production.

Figure 9: Responses of Gulf Production & AL Unemployment Rate to Price.

F[redacted]rsonal Income to Price.

[redacted]

Figure 11: Responses of Gulf Production & AL Revenue to Price.

0 10 20 30 40 50 60 70 80 90

Figure 12: Responses of Gulf Production & MS Unemployment Rate to Price.

Figure 13: Responses of Gulf Production & MS Personal Income to Price.

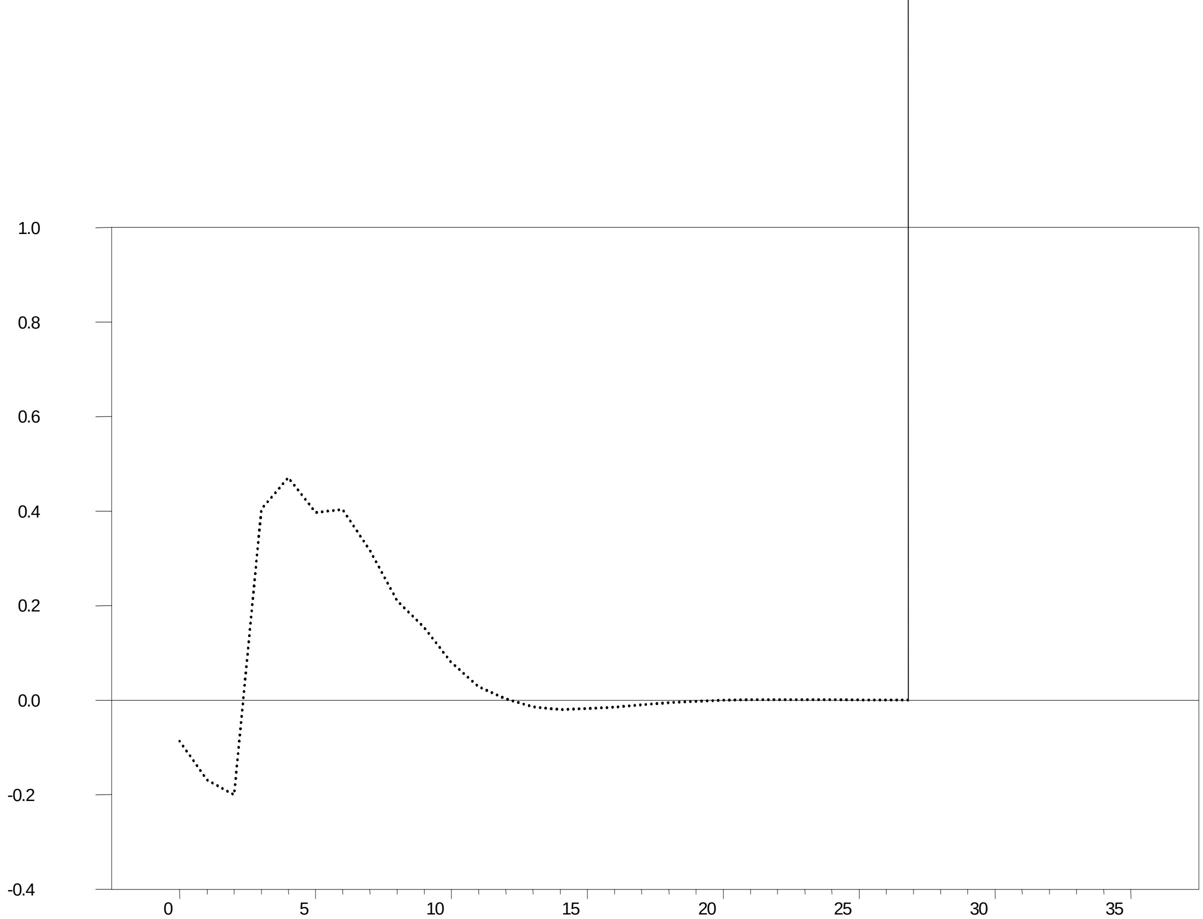

Figure 14: Responses of Gulf Production & MS Revenue to Price.

Figure 15: Responses of Gulf Production & TX Unemployment Rate to Price.

Figure 16 depicts the response of Texas personal income to a price shock. A positive price shock leads to positive response from both oil production and personal income. Both variables fluctuate, but the pattern is more pronounced for oil production than for income. The former is more cyclical. Texas revenue increases initially in response to a positive price shock in the context of Gulf oil and gas production. However, all variables quickly trend toward equilibrium although the path to equilibrium is faster for revenue than production (see Figure 17).

5.2. IRF Results from OCS Deepwater Production System Equations

5.2.1. Price Shock, OCS Deepwater Production, and the Louisiana Economy: The impulse response of OCS deepwater production and Louisiana unemployment rate to a one-time positive shock to crude oil price is presented in Figure 18. Louisiana unemployment and deepwater production decrease following a positive price shock. The negative production response is contrary to our expectation. However, this response is small and probably transitory, reflecting a lagged responsiveness. The response path for unemployment is also relatively short. Further, the response paths for deep OCS petroleum produc

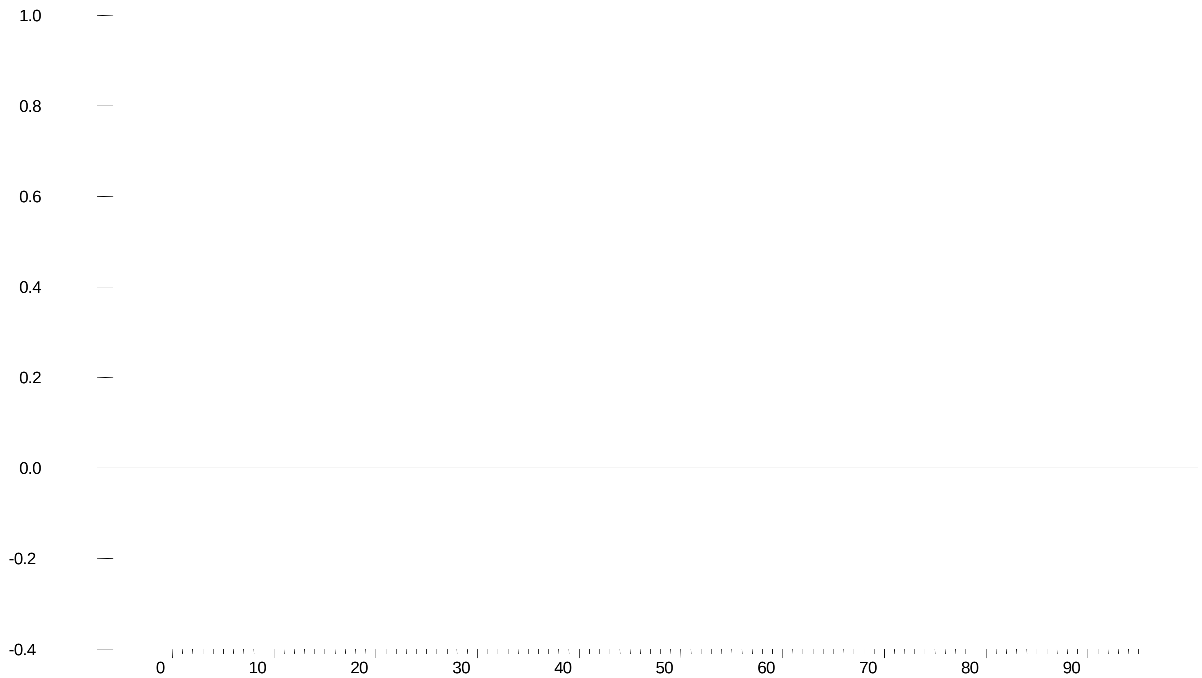

Figure 16: Responses of Gulf Production & TX Personal Income to Price.

Figure 17: Responses of Gulf Production & TX Revenue to Price.

0 6 12 18 24 30 36 42 48 54 60 66 72 78

Figure 18: Responses of Deepwater Production & LA Unemployment to Price.

Figure 19: Responses of Deepwater Production & LA Personal Income to Price.

Figure 20: Responses of Deepwater Production & AL Unemployment Rate to Price.

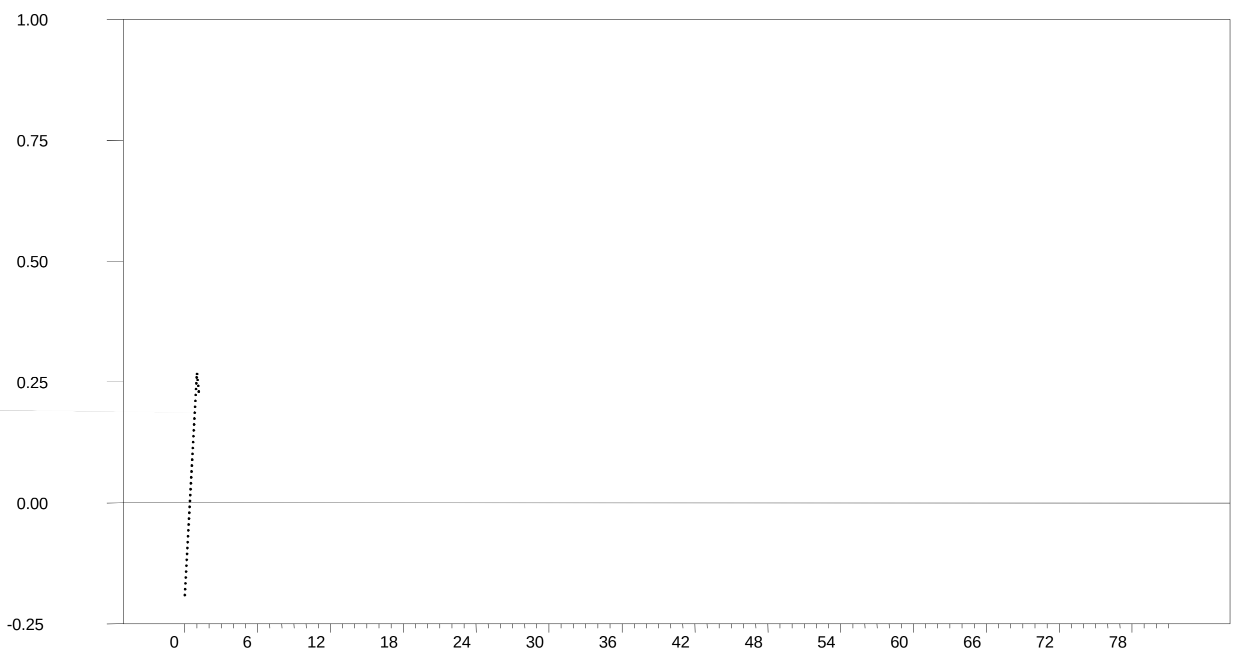

Figure 21: Responses of Deepwater Production & AL Personal Income to Price.

0 6 12 18 24 30 36 42 48 54 60 66 72 78

Figure 22: Responses of Deepwater Production & MS Unemployment Rate to Price.

Figure 23: Responses of Deepwater Production & MS Personal Income to Price.

<u>5.2.4. Price Shock, OCS Deepwater Production, and the Texas Economy:</u> The impact of a positive price shock on Texas unemployment rate and deepwater production is presented in Figure 24. The figure shows that unemployment and production fall initially in response to a price shock. Unemployment rate rises to a maximum of about 0.26 percent and production declines at a similar magnitude in the opposite direction. The restoration to equilibrium takes at least 24 quarters for unemployment rate in Texas. The dynamic paths for OCS deepwater production interacting with Texas quarterly personal incomes are depicted in Figure 25. The Figure shows that personal income rises to about 0.3 percent of its initial state and a positive deviation from deepwater production equilibrium is at a slightly smaller level.

0 6 12 18 24 30 36 42 48 54 60 66 72

Figure 24: Responses of Deepwater Production & TX Unemployment Rate to Price.

Figure 25: Responses of Deepwater Production & TX Personal Income to Price.

6. ECONOMIC INTERPRETATIONS OF THE VAR MODEL RESULTS

The impulse response function results and the corresponding graphical representations have been used in quantifying the price responsiveness of state macroeconomic variables. The results are shown in Tables 6 and 7. Each elasticity repor

Table 6

Estimated Range of the Impact of Changes in Price and OCS Production on Macroeconomic Variables Using the Impulse Response Function Technique (%)

		Price Effect		Production Effect	
	Variables/VAR system	High	Low	High	Low
A	Louisiana (LA)				
	Unemployment	11.40	0.45	1.60	0.01
	Personal Income	14.60	5.90	3.30	2.65
	Revenue	16.80	10.90	12.61	6.90
B	Alabama (AL)				
	Unemployment	29.90	0.05	0.52	0.04
	Personal Income	10.85	4.30	4.14	1.30
	Revenue	29.95	14.24	2.63	1.02
C	Mississippi (MS)				
	Unemployment	9.45	0.84	0.78	0.31
	Personal Income	15.58	9.87	5.44	3.33
	Revenue	16.75	11.96	42.50	40.10
D	Texas (TX)				
	Unemployment	2.67	1.47	1.20	0.83
	Personal Income	18.64	10.07	3.33	0.17
	Revenue	18.03	0.13	2.14	0.04

Table 7

Estimated Range of the Impact of Changes in Price and Deep OCS Production on Macroeconomic Variables Using the Impulse Response Function Technique (%)

		Price Effect		Production Effect	
	Variables/VAR system	High	Low	High	Low
A	Louisiana (LA)				
	Unemployment	2.20	0.64	1.43	0.06
	Personal Income	16.50	5.90	2.60	2.00
	Revenue				
B	Alabama (AL)				
	Unemployment	33.12	0.02	22.32	13.00
	Personal Income	5.85	1.95	6.99	0.81
	Revenue\				
C	Mississippi (MS)				
	Unemployment	5.46	2.43	7.92	0.07
	Personal Income	5.37	3.34	2.48	1.49
	Revenue				
D	Texas (TX)				
	Unemployment	1.10	0.29	2.83	1.36
	Personal Income	16.36	9.71	5.89	2.47
	Revenue				

Table 8

Price Elasticity of Macroeconomic Variables and the Quantity Equivalence Conditional on the Dynamics of OCS Petroleum Production and the Gulf Coast Economy

Quarterly
Unemployment

Although the unemployment rates across the states tend to decline following an increase in petroleum prices, the highest oil price elasticity of unemployment rates occurs in Alabama (2.575), while Texas shows the least responsiveness of unemployment rates to price shocks (1.917). These represent a quantity equivalence of 0.200 and 0.119 percent change with respect to the mean value of unemployment rates in Alabama and Texas, respectively. Table 8 presents price elasticity of macroeconomic variables and the corresponding quantity equivalence. The elasticity estimates are conditional upon the interactions among OCS petroleum production, changes in petroleum prices, and the economy.

Further analysis of the impulse response functions also reveals different adjustment paths to equilibrium for the Gulf States following a price shock (see Table 9). The empirical results indicate that it may take unemployment rates, personal income and government revenue more than ten years, about 3 years, and up to 20 years, respectively to be restored to initial equilibrium in Louisiana. For the Alabama economy, the response paths show that it may take approximately 6, 2, and 12 years, respectively, to restore unemployment, personal income, and revenue to their initial equilibrium subsequent to any price shock.

The adjustment paths to a price shock to the Mississippi economy indicate that unemployment rates take more than 8 years, personal income takes about 2 years, and revenue takes 5 years to adjust to their initial equilibrium levels. The adjustment paths over time for unemployment rate take less than 10 years, personal income takes more than 4 years, and revenue takes about 7 years for initial equilibrium to be restored in response to a price shock to the Texas economy.

The fact that it takes longer for the employment levels in Texas and Louisiana than Alabama and Mississippi to return to initial equilibrium after a price shock is most likely due to the fact that oil and gas production and oil and gas related businesses are more prevalent in Texas and Louisiana than Alabama and Mississippi. However, because Texas has a larger and more diversified economic base than Louisiana, it is more able to dampen the likely destabilizing effects of a price shock on employment levels than Louisiana. On the other hand, the economic size of Texas seems to cause the effects of changes in crude petroleum prices on personal income to linger longer than in Louisiana, Alabama and Mississippi, in that order. The gross annual revenue in Louisiana seems to be the most susceptible to an unexpected price shock and Mississippi annual revenue is more resilient than Louisiana, Alabama and Texas in this regard. The decline in petroleum revenue in Louisiana as a result of declining oil prices has tended to push Louisiana to the brink of a budget deficit in the more recent time than Texas (Brown and Yucel, 1995). The results for Alabama and Mississippi are also consistent with the declining relative exposure to the petroleum industry vagaries over time (Scott, 2002).

Table 9

Estimated Adjustment Paths to Equilibrium Following a Price Shock Impact on Aggregate OCS Petroleum Production and the Economy

Indicators	Alabama	Louisiana	Mississippi	Texas
Unemployment (Quarters)	25	45	35	38
Personal Income (Quarters)	8	12	8	18
State Revenue (Years)	12	20	5	7

7. SUMMARY AND CONCLUSIONS

This study examines the interactions between oil price changes, oil and gas production and selected macroeconomic variables of each economy of the Gulf States. Rather than focus on point estimates from regression analyses, we employed a VAR approach to understand both the composition of potential effects of a price change and the adjustment paths of the economic variables and oil and gas production over time. By decomposing and examining the impulse responses of forecast errors, we are able to predict the relative magnitude and the dynamic adjustments of the selected variables to oil price shock.

Specifically, the study shows that:

- Oil and gas production in the Gulf as a whole responds positively to a positive shock in crude oil price. This is an expected result given that firms operating in the Gulf OCS desire to maximize return on investment, hence, an increase in the price of output is a signal from the market of a higher demand for oil and gas products. Likewise, a decrease in price will have the opposite effect.

- Unemployment rates across all the states tend to decline following an increase in price of crude oil. This result is consistent with the fact that an increase in price of oil and gas industry output will spur the industry to expand output, and *ceteris paribus*

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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 is 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,

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

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 is either over-identified or under-identified and the presence of the current levels of the other variable in its own equation implies correlation of the regressed with the error terms. Hence, consistent estimation of these forms cannot be obtained. To estimate each of these equations by OLS, one must obtained reduced forms. The system of equations is solved simultaneously to extract the *reduced* or *standard* VAR form:

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

Which reduces to

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

In general matrix form, equation A5 becomes:

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

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 $u_t = (I - A_0)^{-1} e_t$

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

Each of the describing equations of 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. In this study, as may be observed in equation A4, the right-hand variables in each equation are not the same thus SUR is utilized.

Step 2: Unit Root Tests

Having formulated an appropriate theoretical model, the next step is to test for *unit roots* (or stationary) in all the variables. It has been shown that an OLS or SUR regression of the long-run relations implied by each describing equation of A6 is valid (non-spurious). Non-spuriousness of 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 a unit root in a variable is by 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 suggest 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 is present in each equation and the lag length is also equal across equations, in reality, it may be that a variable or some of its lags 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 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 adopt the majority vie 0 12.0504 4942rfac

To perform the test, run the system of equations with all the lags and variables (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 $\Sigma_{r.}$ 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 th

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

$$y_t = Z_0 e_t + Z_1 e_{t-1} + Z_2 e_{t-2} + Z_3 e_{t-3} + \ldots\ldots + Z_s e_{t-s} + y_0 \qquad \text{(A9)}$$

Where

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

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

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