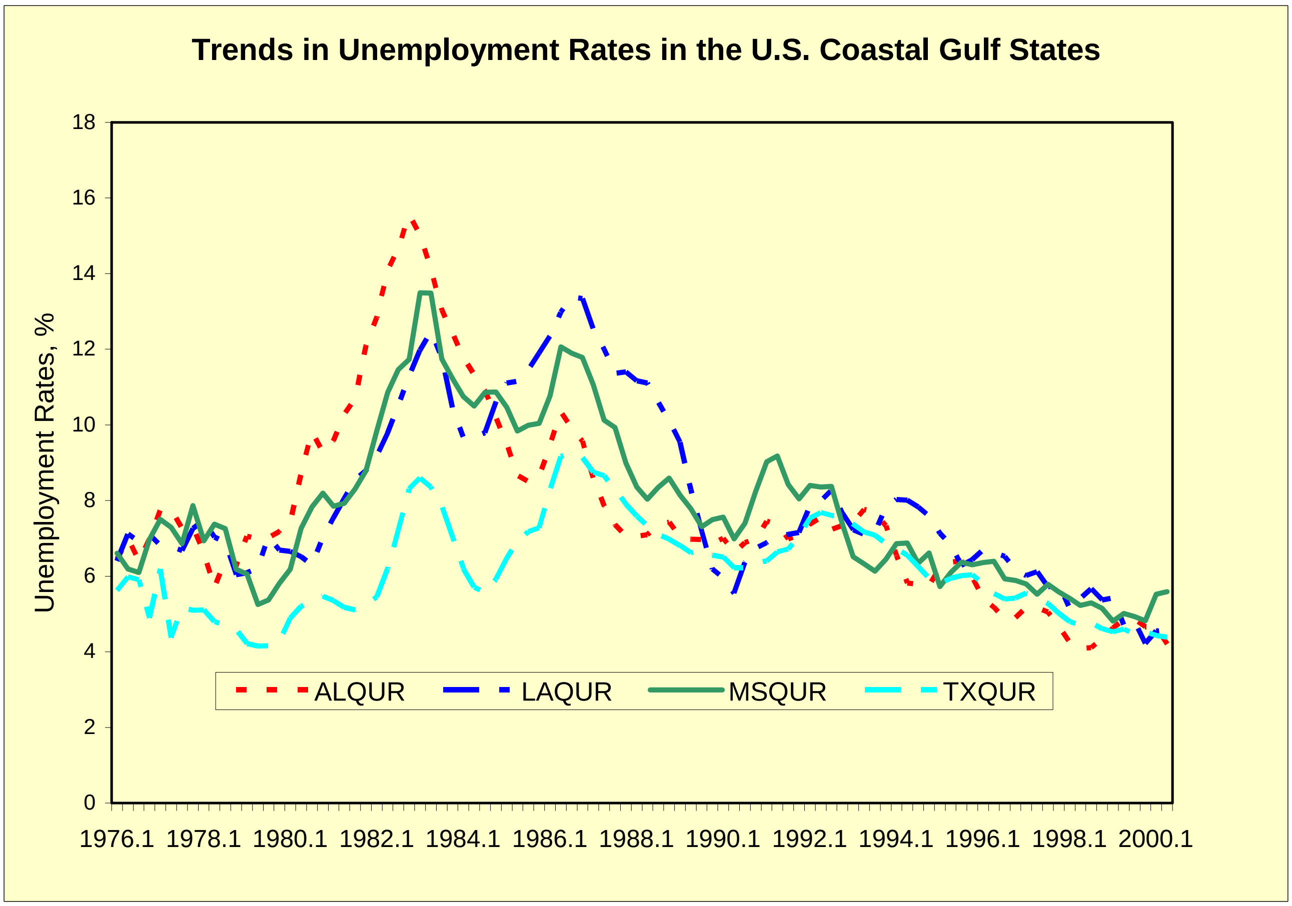
OCS Study
MMS 2006-063

Coastal Marine Institute

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



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

Cooperative Agreement
Coastal Marine Institute
Louisiana State University

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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.

TABLE OF CONTENTS

Page

TABLE OF CONTENTS
(Continued)

Page

LIST OF FIGURES

LIST OF TABLES

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;
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.

Three key indicators for measuring E&P industry activity and performance that are highly correlated with crude oil price movements both in the short run and long run have been identified as drilling rig counts, production, and capital expenditures. However, due to data limitations, oil and gas production was used as a proxy for measuring the trends in E&P industry activity. The scope of the study was also expanded to cover deepwater operations.

Data and Methods: The data used for this study are basically secondary in nature from various sources. The data source for the oil and gas production series is from the MMS oil and gas database. The oil price data is the crude oil producer price index deflated by the all commodities price index series, which is available from the U.S. Bureau of Labor Statistics. Data for unemployment rates are available from the U.S. Bureau of Labor Statistics. The Bureau of Economic Analysis (BEA) is the source of the following data: the quarterly personal income and the annual revenue series for the states, U.S. real GDP, GDP implicit deflator and interest rates.

A vector auto-regression (VAR) model framework showing the interactions between crude petroleum price, oil and gas production, the U.S. interest rates, the U.S. gross domestic product, 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 experiencing the shock. The impulse response functions, on the other hand, provide a way to examine the paths of the effects of an exogenous shock of one variable on other variables and to further characterize the stability and its duration for the variables. The persistence of such shocks reveals the pace and pattern of the adjustment process of the system to its long-run equilibrium. The faster it takes a shock to dampen, the faster the adjustment process back to equilibrium (Brown and Yucel, 1995).

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

On Louisiana Economy: The dynamic VAR analysis of the interactions between changes in crude oil prices, oil and gas production in the Gulf of Mexico (GOM) OCS and Louisiana unemployment rate shows that price is significant and it explains, on average, approximately 11 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 at most 14 percent of the expected variation in personal income and between 11 to 16 percent of the variation in revenue. To our surprise, however, autonomous oil and gas production has no direct significant effect on unemployment according to our VAR results. The impulse response results present the adjustment paths associated with price shocks. The results show that it can take more than 10 years for unemployment, about 3 years for personal income, and up to 20 years for revenue to be restored to initial equilibrium.

On Alabama Economy: The model results describing the interactions between oil price, oil and gas production in the Gulf of Mexico OCS and Alabama unemployment rate shows that price explains up to 30 percent of the expected variation in Alabama unemployment. The results also show that a price shock conditional on OCS oil and gas production profile explains up to 11 percent of the observed variation in personal income in Alabama. Further, a price shock exposed to oil and gas production path in the Gulf also has a potential impact of at most 29 percent in the long-term on Alabama revenue. The ensuing impulse response functions reveal the adjustment paths for the interactions between a price shock and gross oil and gas production in the Gulf. The response paths show that it takes approximately 6 years for unemployment, 2 years for personal income, and 12 years for revenue to be restored to their initial equilibriums subsequent to the shock. 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.

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 percent on the average, but significant. Similarly, the empirical results indicate that the effect of price on personal income subject to OCS production 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 personal income.

On Alabama Economy: The model results explaining the dynamic interactions between price and deepwater oil and gas production show that price explains up to 33 percent of the variability of Alabama unemployment. Also, within the same context, but unlike the estimated effect on Louisiana, OCS deepwater production has a highly significant effect on Alabama unemployment. OCS deepwater production explains up to 22 percent of the observed variation in Alabama unemployment. The effect of price shocks on personal income in Alabama is also found to be significant with respect to deepwater production. Under that scenario, a price shock explains up to 5.9 percent of the variation in personal income as well.

On Mississippi Economy: The VAR results describing the effect of a price shock and oil and gas production from OCS deepwater on Mississippi economic variables show that the changes in price explain a relatively small proportion of the observed variation in unemployment (roughly 4 percent). A shock to deepwater production has a significant effect on unemployment. Price shocks explain up to 5.3 percent of the observed variation in personal income. The paths of 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, deepwater production has a direct and significant impact on unemployment. The results further suggest that price shocks explain up to 16.3 percent of the observed personal income variation.

The paths of adjustment to price changes interacting with deepwater production from the Gulf OCS show a lag that is more than 24 quarters for unemployment and 10 quarters for personal income.

In an overall sense, this study suggests that petroleum production in the Gulf of Mexico OCS responds positively to a positive price shock in the economy.

Further, the study shows that:

- Unemployment rates in coastal Gulf States in the U.S. tend to decline in response to increases in petroleum prices. It is interesting to note, however, that the responsiveness of unemployment rates to changes in prices differ significantly across the Gulf States. Texas has the least unemployment responsiveness to a price shock and Alabama has the highest among the four Gulf States.

- According to the VAR model results, personal income tends to increase following a positive shock to petroleum prices in the presence of rising petroleum production. The degree of income responsiveness to price shocks varies across the U.S. Gulf States. In general, personal income responsiveness in Texas is greater than that of Mississippi, Louisiana, and Alabama, in that order. The empirical results also suggest that the Texas economy, because of its size, tends to experience a more lingering path to adjustment for personal income than Louisiana, Mississippi and Alabama. Similarly, personal income in Louisiana tends to experience more lingering effects than Mississippi and Alabama following a petroleum price shock.

- Positive changes in petroleum prices lead to increases in annual revenue in Louisiana, Texas, and Alabama. The responsiveness of revenue to price changes, however, varies across Gulf States just as changes in unemployment and personal income vary across the Gulf States.

- Surprisingly, unemployment rates in the Gulf States appear to be relatively less sensitive to production activities in the Gulf States than expected. In many instances in the U.S. Coastal Gulf States, the direct impacts of changes in production on unemployment rates are insignificant.

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 the U.S. economy. Other studies have since been revealed to debunk or support Hamilton's claim that a sharp increase in oil prices produced the recessions between the end of World War II and early 1980. For example, Considine (1988) shows that gains in output and employment in the U.S. economy were relatively small following the 1986 drop in oil price. Tatom (1988) also shows that changes in oil prices affect real GNP, productivity, and terms of trade and that these effects are asymmetric. A review of several econometric models by Hickman (1984) supports Tatom's conclusions. On the other hand, Prescott (1986) maintains that oil price shocks have little or no effect on national production possibilities. These studies suggest that a sustained decline or increase in oil price and its effects on national economies can be predicted to some degree.

Although the effects of oil price on the national economy are generally understood, the impacts of such movements on state or sub-regional economies are less fully examined. Few studies (Brown and Hill, 1988; Brown and Yucel, 1995; Yucel and Guo, 1994) have studied the effects of crude oil price on state economic performance. Most of these studies, unlike national studies, tend to show that a rising oil price stimulates economic growth in oil exporting states and hinder growth in energy importing states. The reverse is the case for declining oil prices. These studies also imply sustained declines or increases and their effects can be ascertained and policy responses designed appropriately.

For effective policy and regulatory guidance, keeping in perspective the overall national energy policy objectives, agencies such as the MMS desire reliable information at the regional levels, where oil and gas activities take place. This is because each state or region possesses unique operating environments that are at variance with the national outlook. Hence, a different policy or regulatory framework is required. The purpose of this study is to fill these information gaps by extending previous national studies to sub-national economies, especially to areas where MMS has jurisdictional mandates in the Gulf of Mexico OCS region.

Analyses of microeconomic data at the level of individual industries, firms, or workers have established that there is significant correlation between oil price shocks and output, employment, or real wages (Keane and Prasard, 1996; Davis et. al., 1996; Lee and Ni, 1999). For example, an increase in the price of oil leads to an upward shift in firm's cost curve, reducing profit levels, and hence, lowering employment and subsequently output. Such an increase may lead to substitution away from oil to other inputs with potential for further pressure on the cost curves as the prices of those inputs rise. A price decline in the oil market may have the opposite effect, although not likely of a similar magnitude. At the general economic level, because of linkages in the economy among sectors, an increase in oil price may induce inflation, hence, the notion that increases in oil price have preceded most recessions in the U.S. (Carruth et al., 1998).

Changes in crude oil prices do affect revenue and the personal incomes of communities in many nations where the oil and gas industry looms large in the economy. For most oil producing regions, tax revenue from oil is a major source of general fiscal revenue, hence, a decline or increase in the levels of firm's profits can influence this tax base significantly. Besides, an increase in oil price will generally induce cost-cutting measures by firms. The first casualty in this situation is often labor inputs. To get to equilibrium following an energy price increase as firms cut output and employment, wages are often cut, thus income of households will become negatively affected. In oil importing nations, oil price increases may be inflationary and lead to a dramatic fall in real wages and income.

In a general sense, the above theoretical description may be true for national or cross-national economies, but the reality may be different and more complex in some states or regions. For example, an exporter of oil may receive some benefits from an oil price increase, but the non-oil firms located in that region may face increases in input costs. The converse may be true in an oil importing state. On the other hand, a decrease in oil price may also produce a depressed demand in some sectors of the state economy, and unemployed labor is not immediately shifted elsewhere[1]. This effect may be quite pronounced because states within nations may possess economies with rigidities that are substantially different from their national economies as a whole. The overall net effect in each case is therefore subject to empirical verification and therefore the relevance of our focus on state-level analyses.

[1] Potential structural rigidities and the degree of sectoral dependencies in a particular region's economies will largely influence this situation. A region with a high concentration of oil dependent sectors will be especially complex to analyze.

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 two levels of activities. First, at the aggregate level the study examines oil price impact on industry and state-level macro-aggregates using industry activities for the entire OCS in the GOM. It is hoped that the results of such analysis will provide a broad picture of the potential impact of oil price driven policy variables of OCS activities on the individual state. Second, because MMS policy is often applied by planning area or water depth, the study repeats the same exercise at a more disaggregated level of industry activity in the deepwater.

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 model, both from statistical and economic theory perspectives, we also used other U.S. 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 into the decision making process of the oil and gas industry for making exploration and production investment decisions. For example, given an oil price, the choice of the level 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 the 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 data on unemployment rates for the states also came from the U.S. Bureau of Labor Statistics. The Bureau of Economic Analysis (BEA) is the source for the following economic variables: quarterly personal income and annual revenue data for the states; U.S. real GDP, GDP implicit deflator and interest rates. Table 1 describes the nature of the data used in this study.

Data for the following state macroeconomic aggregates: personal income, unemployment rate, and OCS oil and gas production are reported quarterly. However, for any aspects of the analyses which require the use of state revenue data, we have used annual series of the relevant variables. This was because quarterly data on revenue at the state level was not available. Table 1 shows the data that were available for different time spans for each of the variables. The modeling framework applied is thus restricted by the most time-limiting series. Crude oil equivalence as a measure of oil and gas activities in the OCS was used.

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 often higher than other sectors, thus overall personal income levels in the states may be affected by downturns or booms in the oil sector.

There are several potential indicators of industry activities in the oil and gas industry. Three key indicators of the level of economic activities in the oil and gas industry that may indirectly affect state economic performance and directly mirror the potential performance of the industry itself are drilling rig counts, exploration and development drilling, and production. These indicators are highly tied to the price of oil in the short-run as well as in the long run depending on current and expected profit margins in the industry. However, due to data limitations, especially at the more disaggregated levels of water depths, oil and gas production is used as a proxy for industry activity in our model formulation and estimation.

The modeling approach developed and estimated in this section is premised on our desires to answer the following questions:

a. What have been the general trends in oil prices, industry indicators, and macroeconomic variables over time?
b. Are oil price movements correlated with identified macroeconomic and industry indicators and to what degree?
c. Is there strong causality between oil price movements and identified performance variables in the state?[3]
d. How long does the effect of an oil price change persist before equilibrium is restored in these relevant aggregates?
e. What is the degree of responsiveness (i.e. elasticity), if any, of these economic indicators to changes in oil price?

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[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.
[3] Causality is defined in the Granger-sense here, not in the commonly understood sense. See appendix for details.

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.
** XQUR is unemployment rates in percent for state X. Production is measured in Millions of barrels of oil equivalent and the real GDP is in trillion dollars.

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.

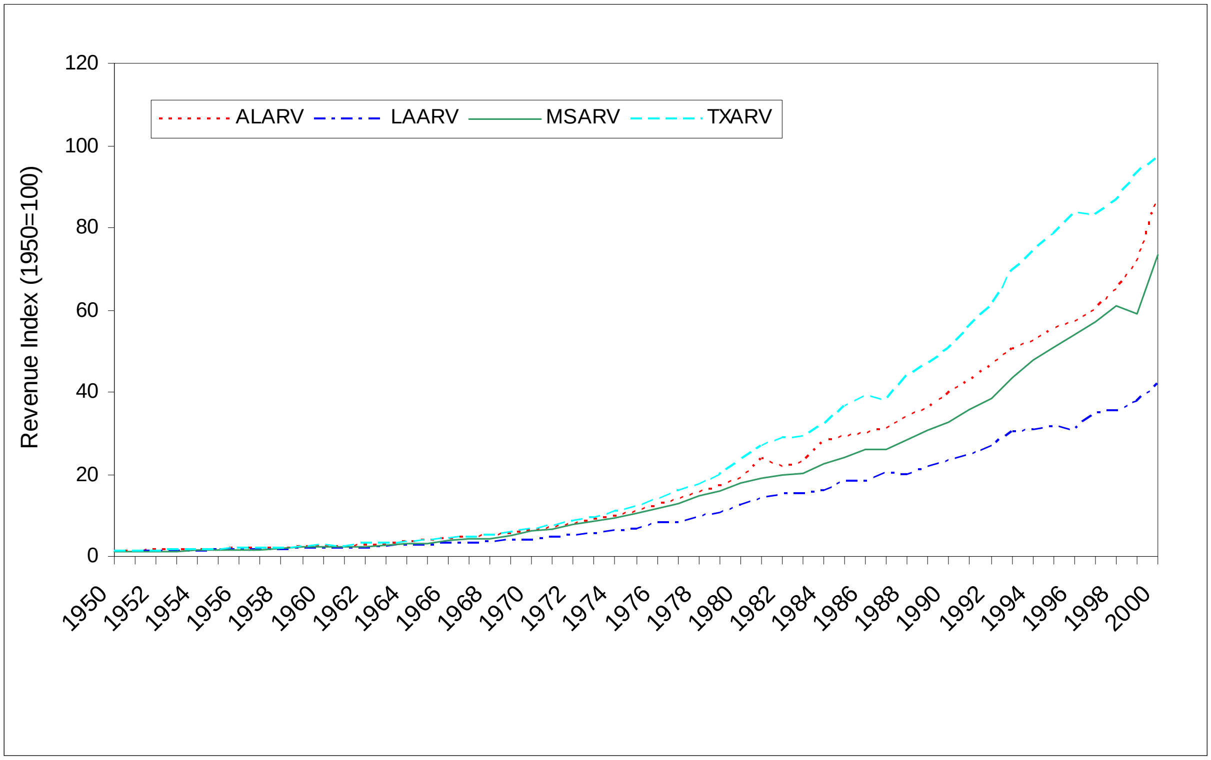


Figure 1: Trends in Annual Revenue of the U.S. Gulf States.

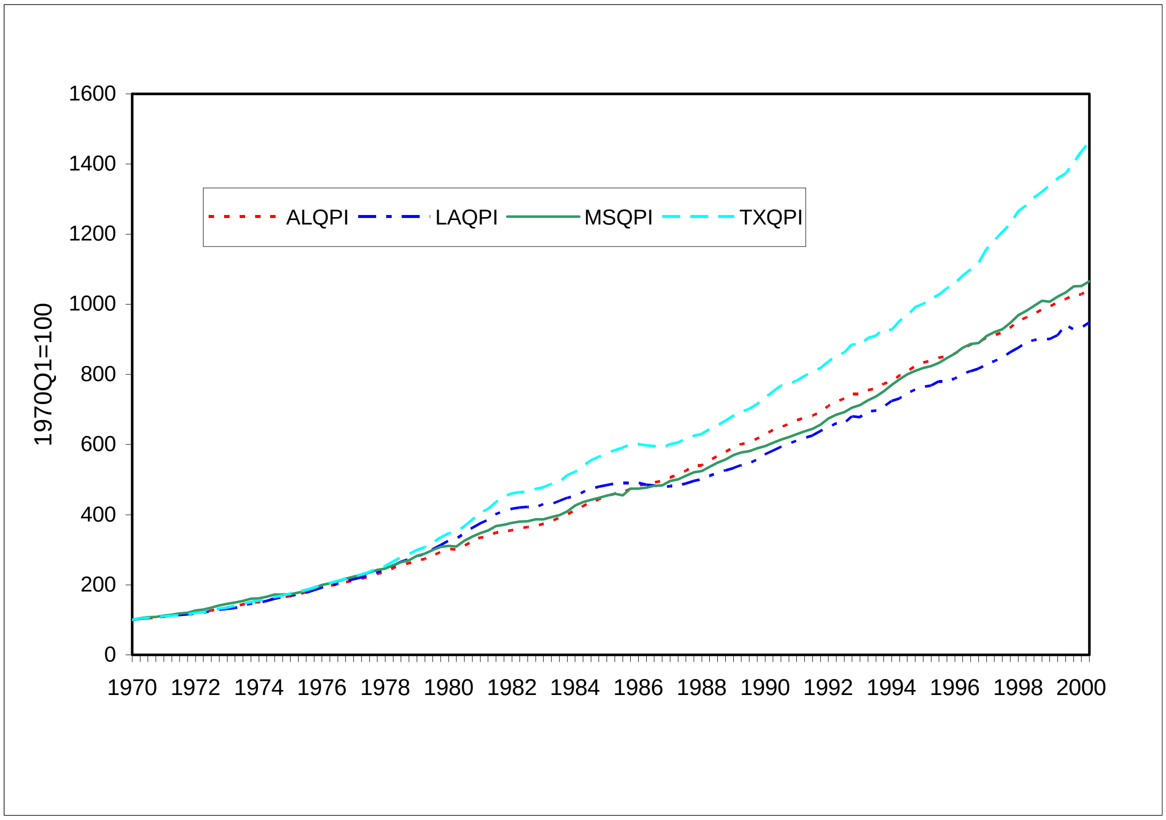


Figure 2: Trends in Quarterly Personal Income of the U.S. Gulf States.

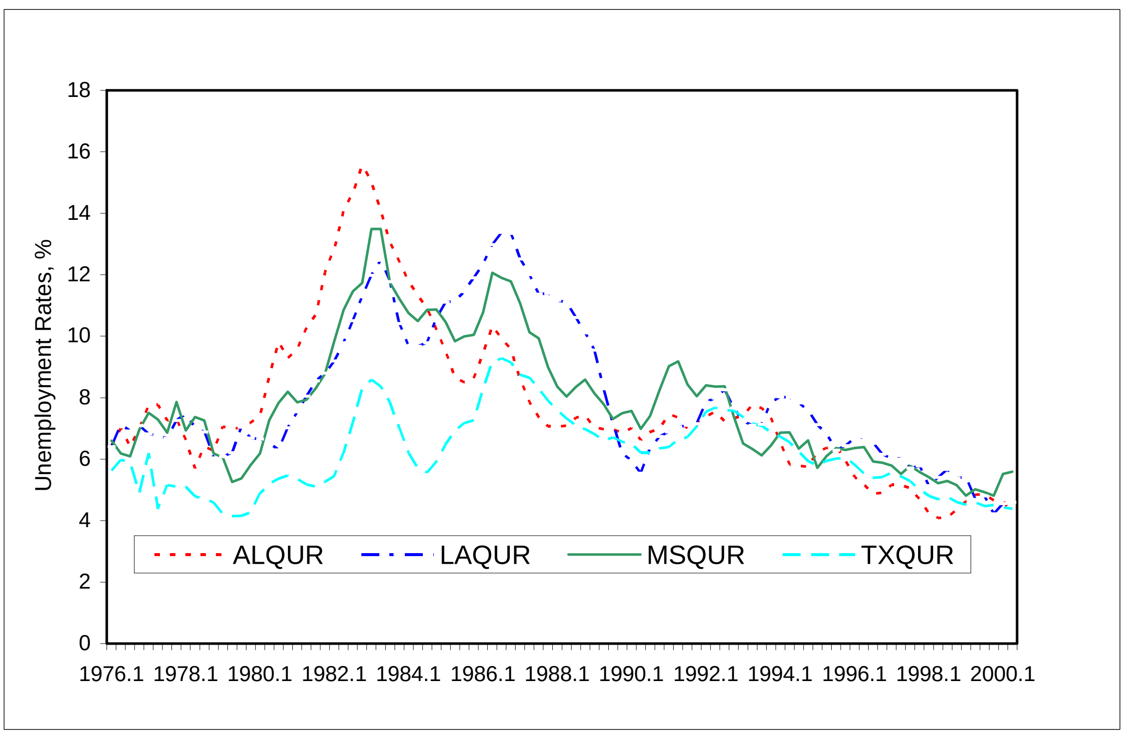


Figure 3: Trends in Unemployment Rates in the U.S. Coastal Gulf States.

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.

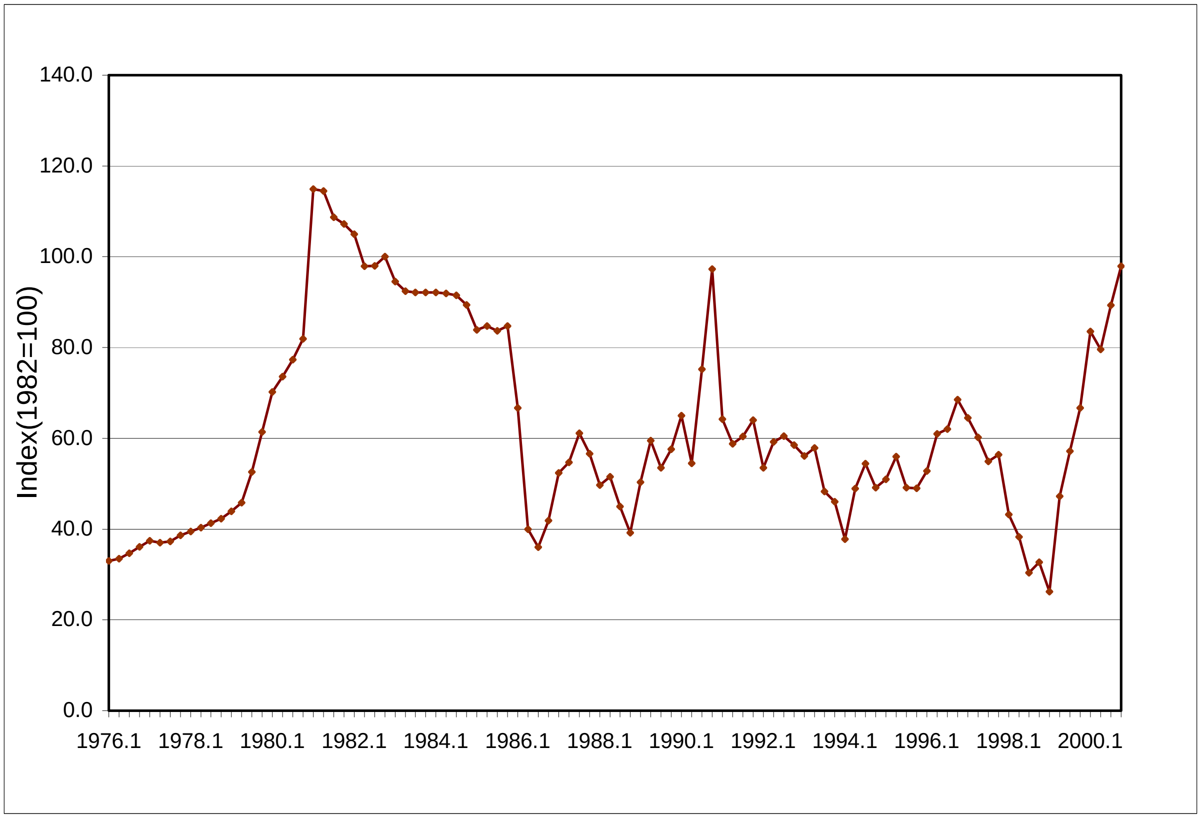
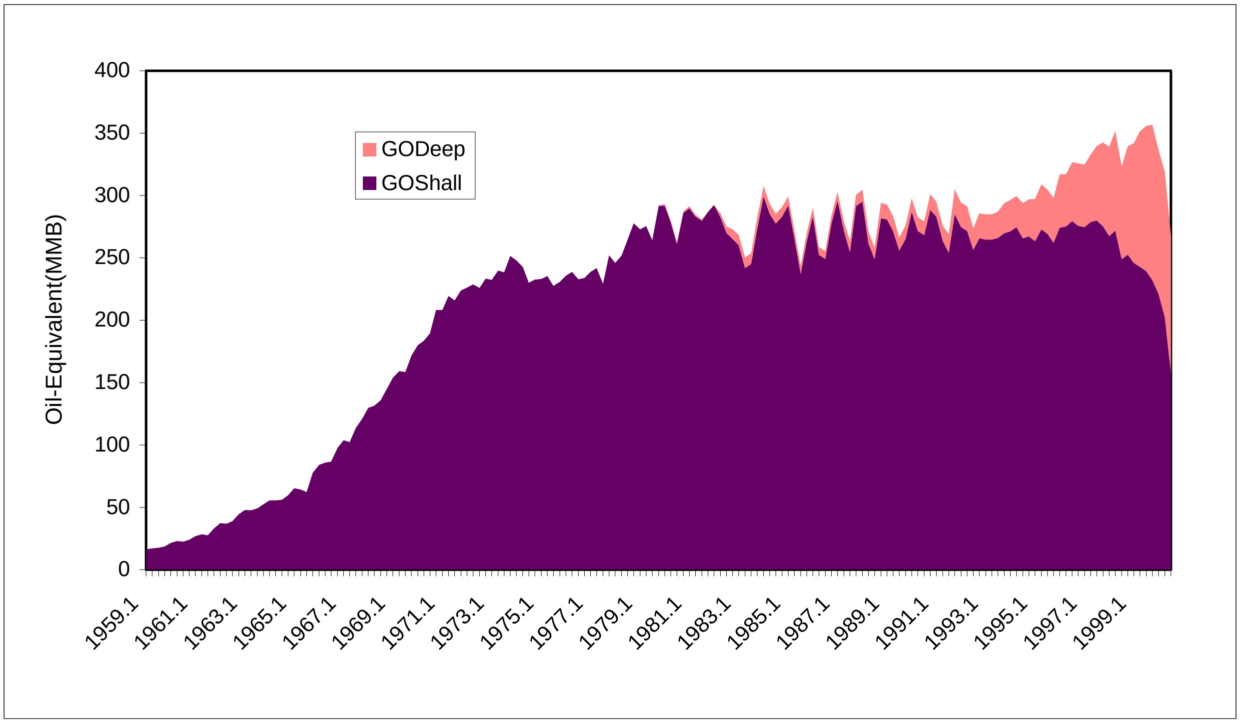


Figure 4: Trends in Crude Petroleum Price Index, 1976-2000.



Note: For this report, a lease is considered to be located in deepwater if the average water depth is at least 200 m.

Figure 5: Gulf of Mexico OCS Petroleum Production by Water Depth Category.

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 are matrices of coefficients to be estimated. The term ε_t is disturbance term that may be correlated with each other but may not be correlated with their immediate past values (ε_{t-1}) or other variables on the right-hand-side.

3.2. Empirical VAR Model Representation

The VAR model, which describes the interactions among the Gulf Coast economic indicators, oil and gas production in the Gulf OCS, and changes in crude petroleum price index is represented by the following system of equations (2):

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

where:

y_{it} *(i=1,2,3):* 1= natural log of crude petroleum price index; 2= natural log of oil and gas production; and 3= quarterly unemployment rates or natural log of annual state revenue or natural log of quarterly personal income;

[4] A brief outline of a typical VAR procedure is given in Appendix A.

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 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 function (IRF)* and *variance decompositions*—are adopted to study effects of shocks (i.e. unexpected policy changes) on the system represented in equation (1).

To estimate the system of equations which involve personal income or unemployment rates, quarterly data for all model variables for Alabama, Louisiana, Mississippi, and Texas were collected, processed and organized into a regression format. However, all estimation procedures involving state revenue data utilized annual data for the estimation procedure because of a lack of quarterly data for state revenue. As mentioned earlier, Louisiana (LA) represents a petroleum producing and net petroleum exporting state with a limited diversified economy. Mississippi (MS), on the other hand, represents a net petroleum importing state with a limited diversified economy and Texas (TX) is a relatively more diversified economy than Louisiana. The economic base of Texas is also considerably larger than Louisiana. Texas is also a net exporter of natural gas but a net oil importer. Lastly, Alabama (AL) is a borderline net petroleum importer (high net oil importer and low net gas exporter) and its economy is less dependent on petroleum than Texas or Louisiana.

The long-run impact of a policy change affecting one of the variables in the system can be investigated using the impulse response function and the proportion of these “changes” that are attributable to each variable 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).

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 by planning area and water depth—one at a time.[5] 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 particular shock in explaining the observed variations in each variable experiencing the shock.

On the other hand, the impulse response function technique characterizes the dynamic effects of an unexpected shock in a given economic system. It 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

[5] 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.

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

<u>4.1.3. OCS Petroleum Production and the Mississippi Economy:</u> 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.

<u>4.1.4. OCS Petroleum Production and the Texas Economy:</u> 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.

<u>4.2.1. OCS Deepwater and the Louisiana Economy:</u> 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 and OCS Deepwater Petroleum Production

	States/Variables	Period				
		1	4	12	18	24
A	**LA Unemployment**					
	OCS Production	0.006	1.282	1.412	1.432	1.434
	Price Index	0.636	1.637	2.196	2.078	2.012
	LA Personal Income					
	OCS Production	2.350	2.533	2.610	2.612	2.612
	Price Index	5.895	15.357	16.497	16.494	16.494
	LA Revenue					
	OCS Production	-	-	-	-	-
	Price Index	-	-	-	-	-
B	**AL Unemployment**					
	OCS Production	13.005	19.826	22.570	22.320	22.311
	Price Index	0.020	10.523	32.025	33.071	33.119
	AL Personal Income					
	OCS Production	0.813	4.630	6.912	6.973	6.991
	Price Index	1.952	3.922	5.660	5.843	5.852
	AL Revenue					
	OCS Production	-	-	-	-	-
	Price Index	-	-	-	-	-
C	**MS Unemployment**					
	OCS Production	0.073	5.168	7.848	7.899	7.923
	Price Index	2.426	5.462	4.225	4.066	3.997
	MS Personal Income					
	OCS Production	1.494	2.158	2.476	2.483	2.483
	Price Index	3.337	5.167	5.366	5.367	5.368
	MS Revenue					
	OCS Production	-	-	-	-	-
	Price Index	-	-	-	-	-
D	**TX Unemployment**					
	OCS Production	2.618	1.903	7.564	7.792	7.827
	Price Index	0.958	0.302	0.973	1.083	1.099
	TX Personal Income					
	OCS Production	3.180	5.095	5.826	5.811	5.866
	Price Index	7.705	14.644	16.359	16.360	16.361
	TX Revenue					
	OCS Production	-	-	-	-	-
	Price Index	-	-	-	-	-

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.

4.2.3. OCS Deepwater and the Mississippi Economy: The VAR results describing the effect of a price shock and oil and gas production from OCS deepwater on Mississippi economic variables show that the changes in price explain a relatively small proportion of the observed variation in unemployment (roughly 4 percent on average). A shock to deepwater production also has a significant effect on unemployment. The results show that approximately 8 percent of the observed variation in unemployment is explained as a result of production shocks. Price shocks also explained up to 5.368 percent of the observed variation in personal income over the period. Production impact, on the other hand, explained less than 2.5 percent of the variation in personal income over the period.

4.2.4. OCS Deepwater and the Texas Economy: According to the VAR model results, the impact of changes in oil prices on Texas unemployment subject to variation in OCS deepwater oil and gas production is not statistically significant. However, deepwater production has a direct and significant impact on Texas unemployment. The results further suggest that price shocks explained up to 16.3 percent of the observed personal income variation, and deepwater production explained a little less than 6 percent of the observed variation in Texas personal income.

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 depicted in Figure 6. A positive shock to price initially leads to a positive response from both oil production and personal income. The affected variables return to the initial equilibrium levels quickly. Figure 8 shows that the dynamic paths of production and revenue rose following a price shock. Revenue rose to a maximum 0.35 percent of its initial level before the shock. However, all variables fluctuated widely, albeit towards equilibrium restoration, and movements in production and revenue were much more in tandem during the period.

5.1.2. Price Shock, Gulf OCS Production, and the Alabama Economy: The impulse responses of aggregate OCS petroleum oil production and Alabama unemployment rate, personal income and gross revenue to a one-time positive shock to crude oil price are presented in Figures 9 through 11. Figure 9 presents the response of Gulf oil production and Alabama unemployment rate to a one-time positive 1-standard deviation shock to crude oil price. The immediate effect is a decrease in unemployment rate and an increase in oil production. The highest level of unemployment reached is about 0.85 percent (in 6 quarters) above its initial equilibrium level while the minimum reached is 0.15 percent (in 16 quarters) below equilibrium.

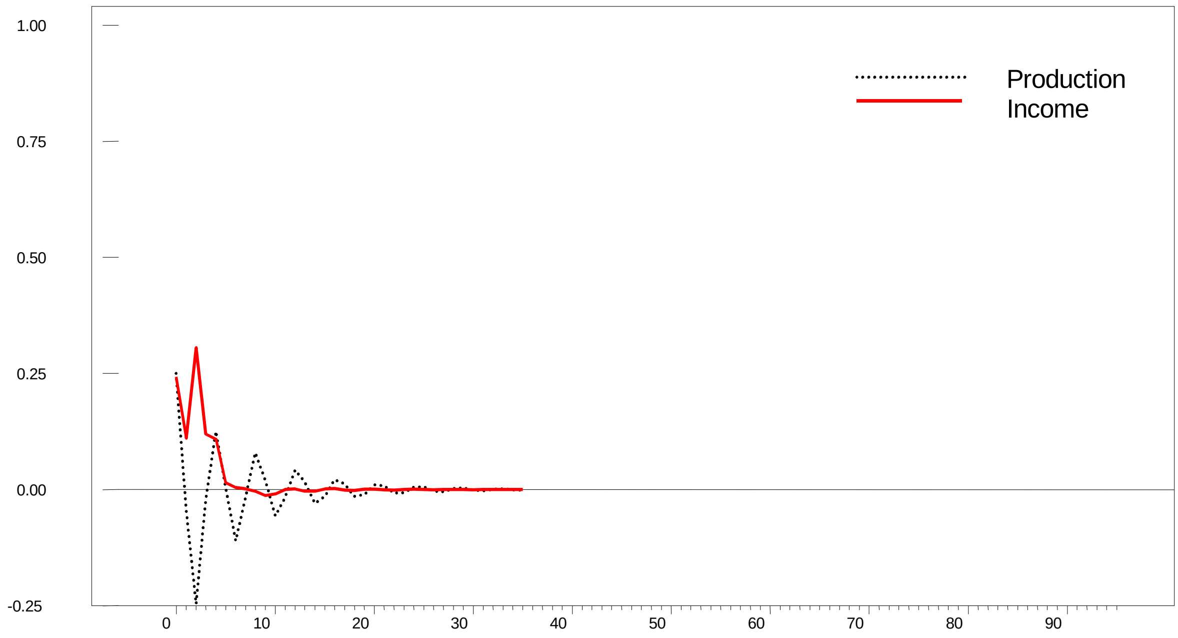

Figure 6: Louisiana Personal Income and OCS Production Dynamic Paths.

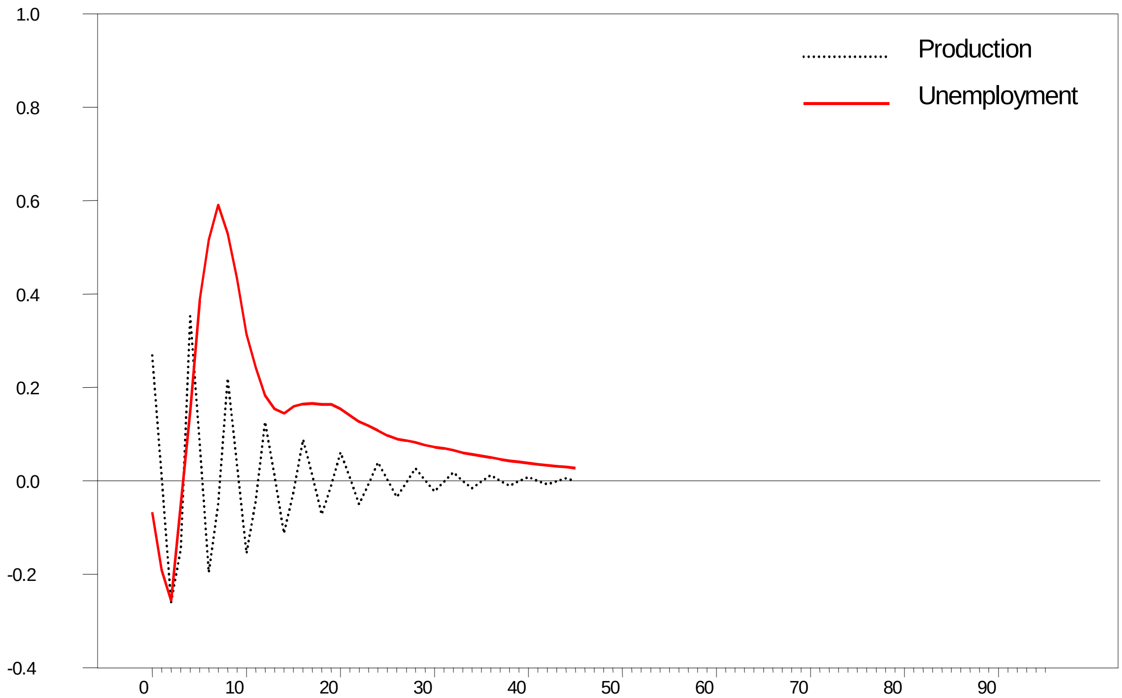

Figure 7: Louisiana Unemployment and OCS Production Dynamic Paths.

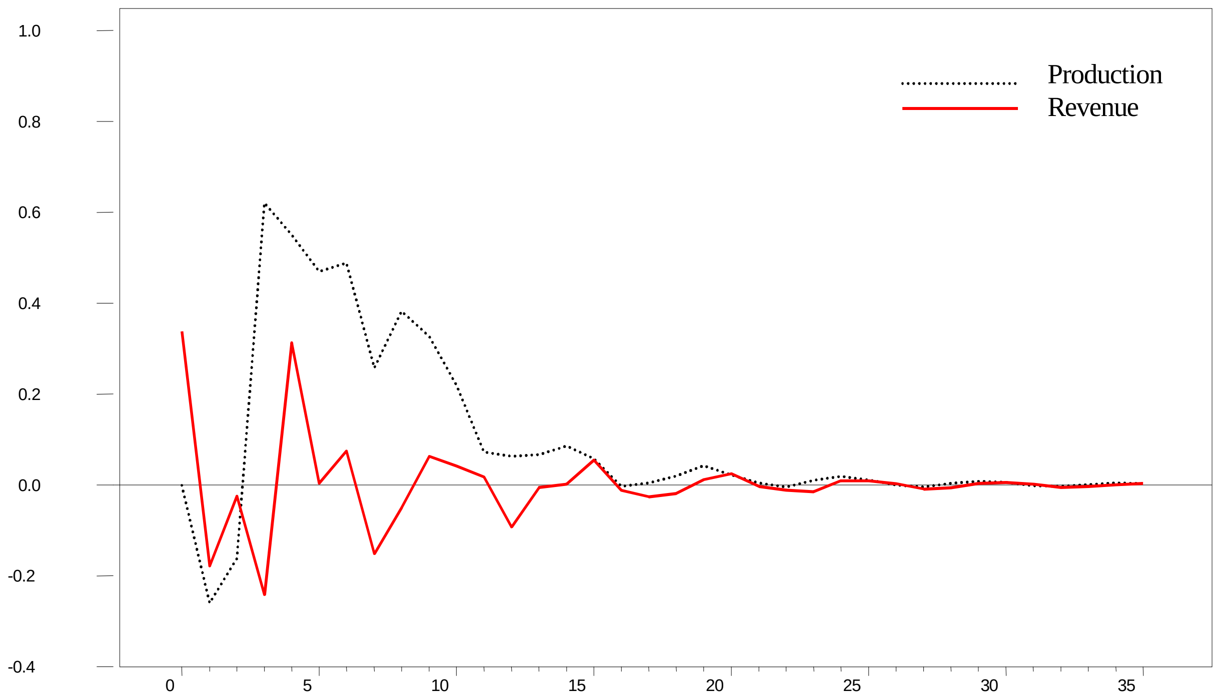

Figure 8: Dynamic Paths of Louisiana Revenue and OCS Production.

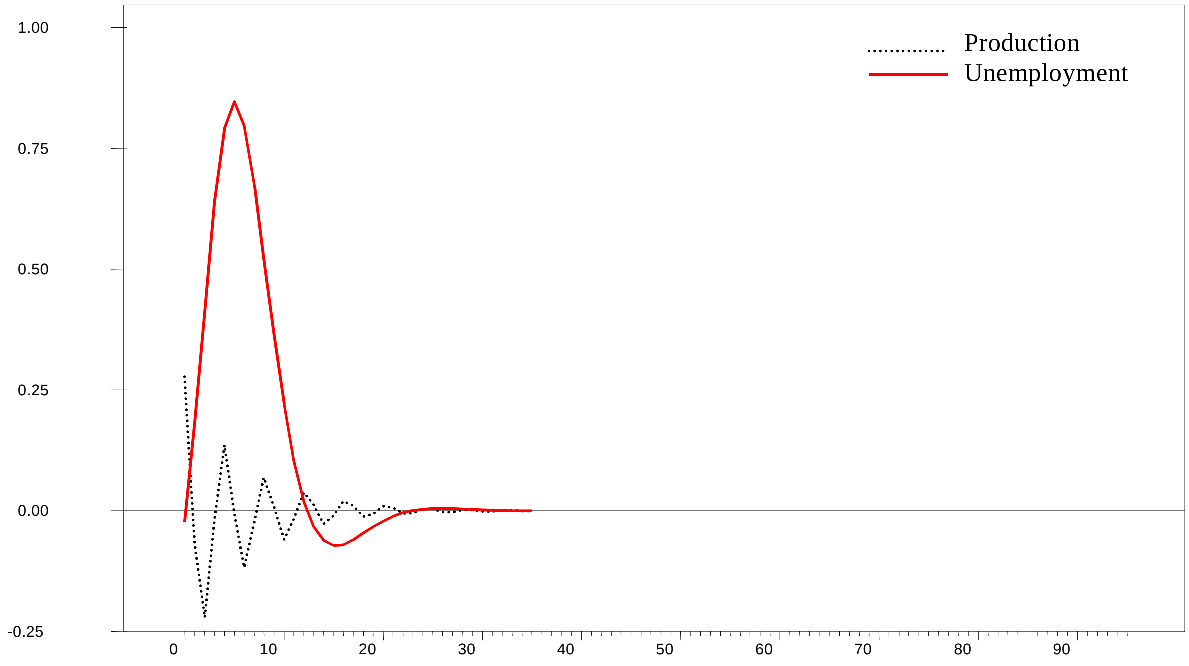

Figure 9: Responses of Gulf Production & AL Unemployment Rate to Price.

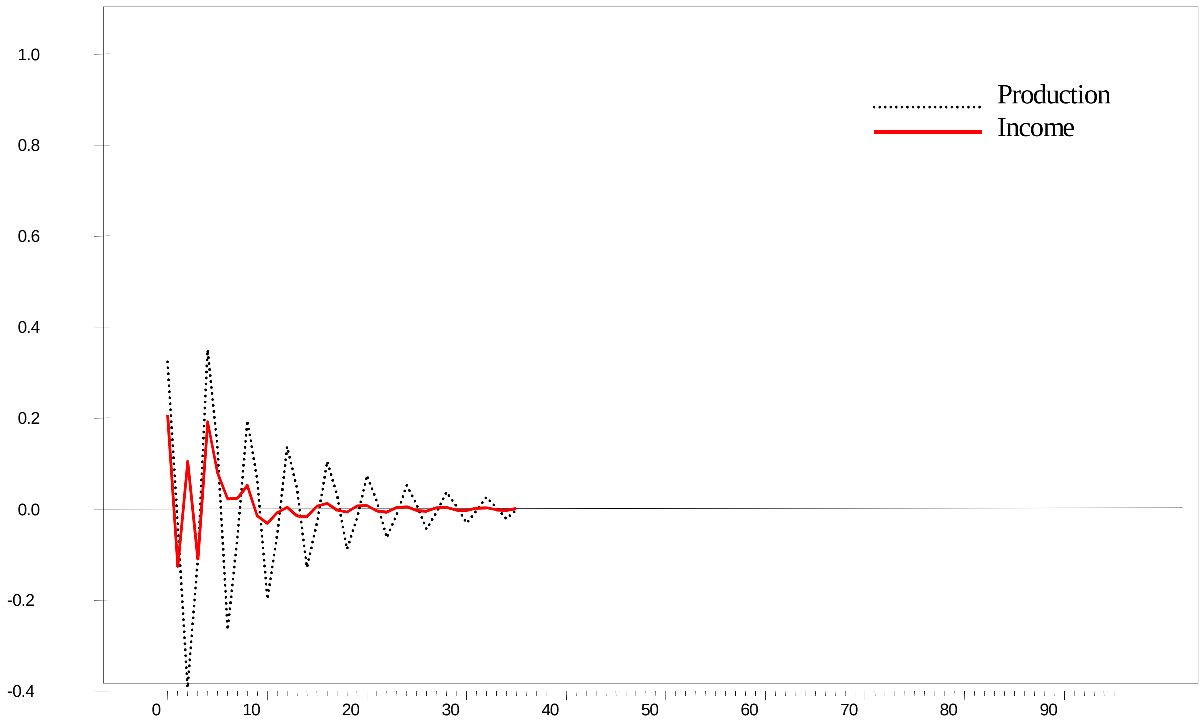

Figure 10: Responses of Gulf Production & AL Personal Income to Price.

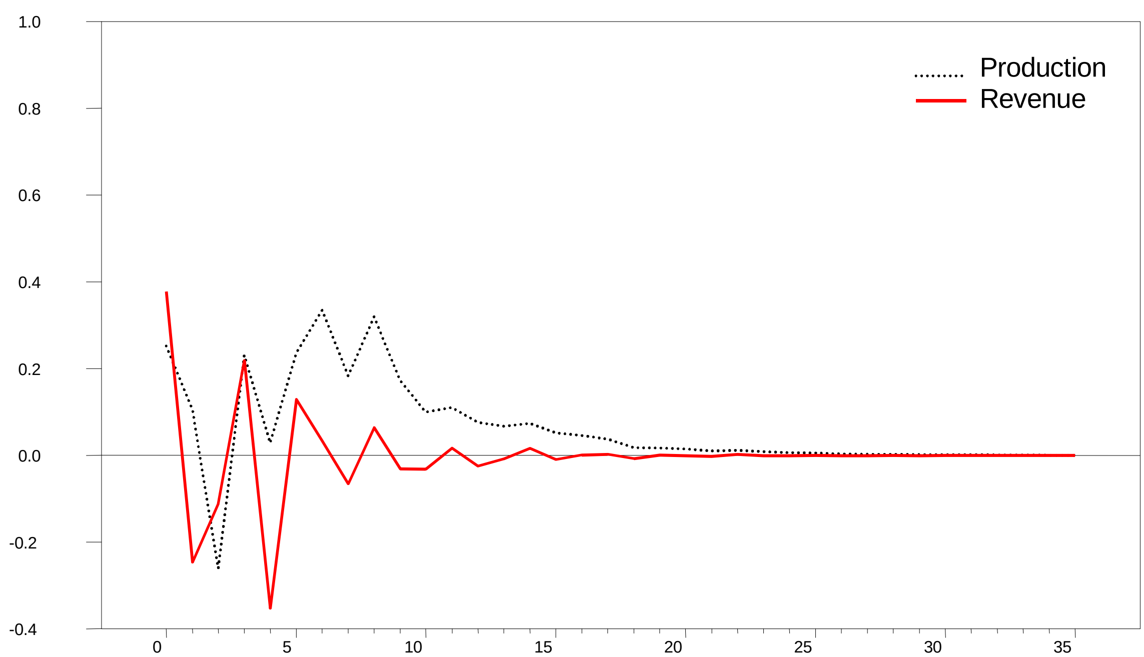

Figure 11: Responses of Gulf Production & AL Revenue to Price.

Petroleum production also rises to a maximum of 0.27 percent (in 1 quarter) and falls to a minimum of 0.24 percent (in 3 quarters) below its initial level. Alabama unemployment and OCS aggregate oil production returns to initial equilibrium level at about the 24th period. It is noted that while all variables return to their original equilibrium, the dynamic paths are not the same. Oil production fluctuates much more than unemployment rate.

The response of Alabama personal income to price in the context of all Gulf oil production is shown in Figure 10. A positive shock to price leads to positive response from both oil production and personal income. In this case the affected variables fluctuate around their base-levels, although this pattern is more pronounced for oil production. The dynamic paths for production and revenue are depicted in Figure 11. Alabama's state revenue responds positively to positive price shock. The response is within 0.38 percent of its initial levels before a shock. However, the movements in revenue and oil production are not in tandem.

5.1.3. Price Shock, Gulf OCS Production, and the Mississippi Economy: The response of Gulf oil production and Mississippi unemployment rate, MSQUR, to a one-time positive shock to crude oil price is shown in Figure 12. The immediate effect is a decrease in unemployment rate and an increase in oil production. Unemployment rate reaches its highest level of about 0.29 percent above its initial equilibrium in 6 quarters and its minimum level of 0.13 percent in the first quarter. Aggregate OCS production fluctuates around its equilibrium throughout, rises to a maximum of 0.25 percent in the first quarter and falls to a minimum of 0.24 percent below its initial level in 3 quarters. Production returns fairly quickly to its initial level after the price shock while unemployment takes longer to return to full equilibrium.

Figure 13 shows the time path of Mississippi personal income to price in association with aggregate petroleum production in the Gulf OCS. A positive response to price shock by production and personal income is evident in Figure 13. Both variables fluctuate, although the pattern is more persistent and pronounced for oil production. The dynamic paths of production and revenue in response to a positive price shock are depicted in Figure 14. The Figure shows that gross revenue in Mississippi responds negatively to a positive price shock. Revenue initially falls to 0.35 percent of its initial levels before the shock before rising towards its initial equilibrium level. But, as it is the case with Alabama, all variables fluctuate widely.

5.1.4. Price Shock, Gulf OCS Production, and the Texas Economy: According to Figure 15, the immediate effect of a price shock to the interaction among Texas economy and OCS aggregate petroleum production is a decrease in unemployment rate and an increase in oil production. The overall effect is quite small for both variables. Although production and unemployment return to their original equilibrium, the dynamic paths are not the same; unemployment rate path is slightly different—longer and less cyclical. Oil production fluctuates in a much more cyclical trend but around its equilibrium level.

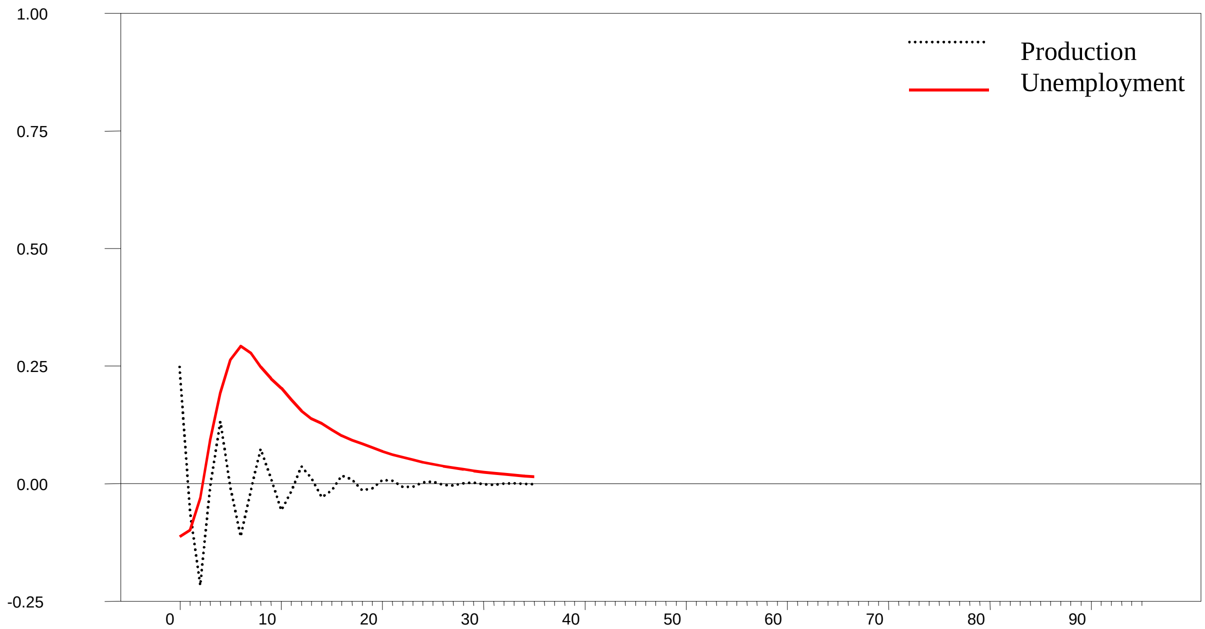

Figure 12: Responses of Gulf Production & MS Unemployment Rate to Price.

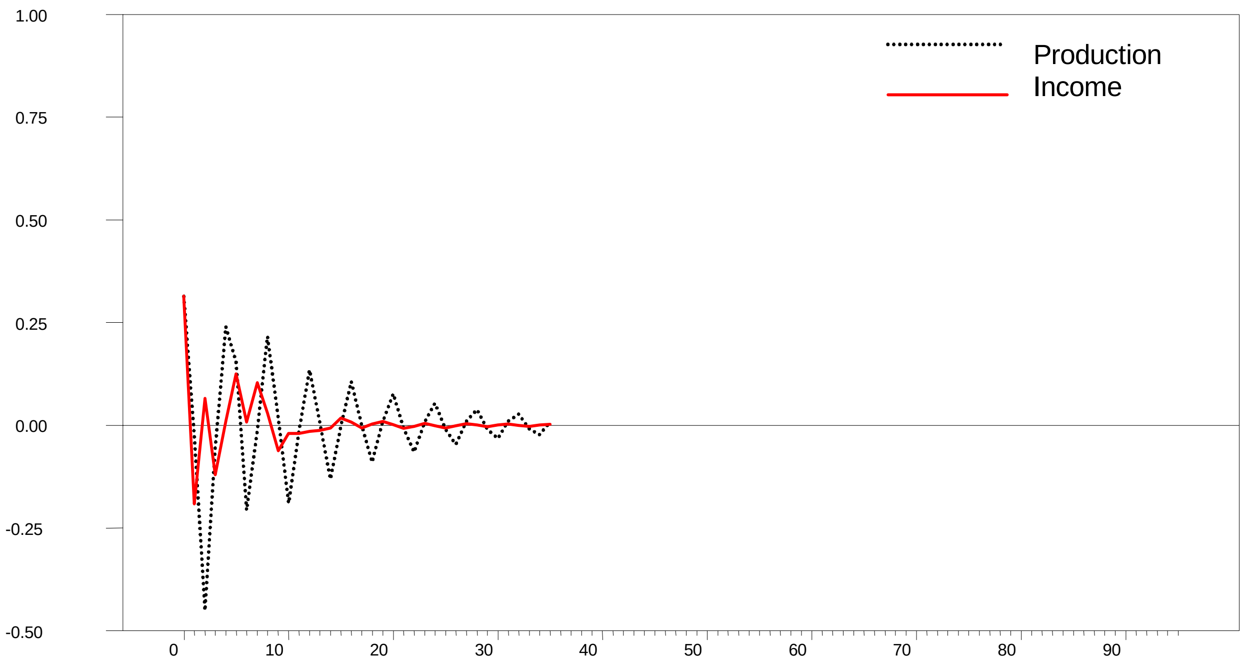

Figure 13: Responses of Gulf Production & MS Personal Income to Price.

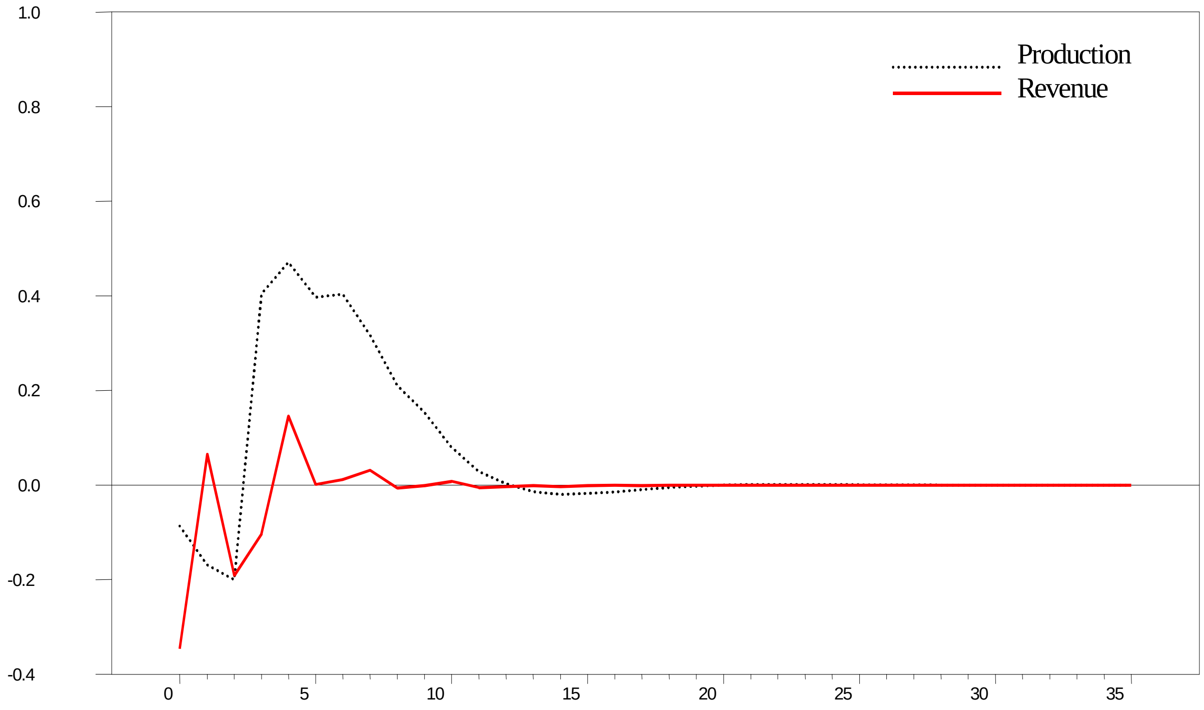

Figure 14: Responses of Gulf Production & MS Revenue to Price.

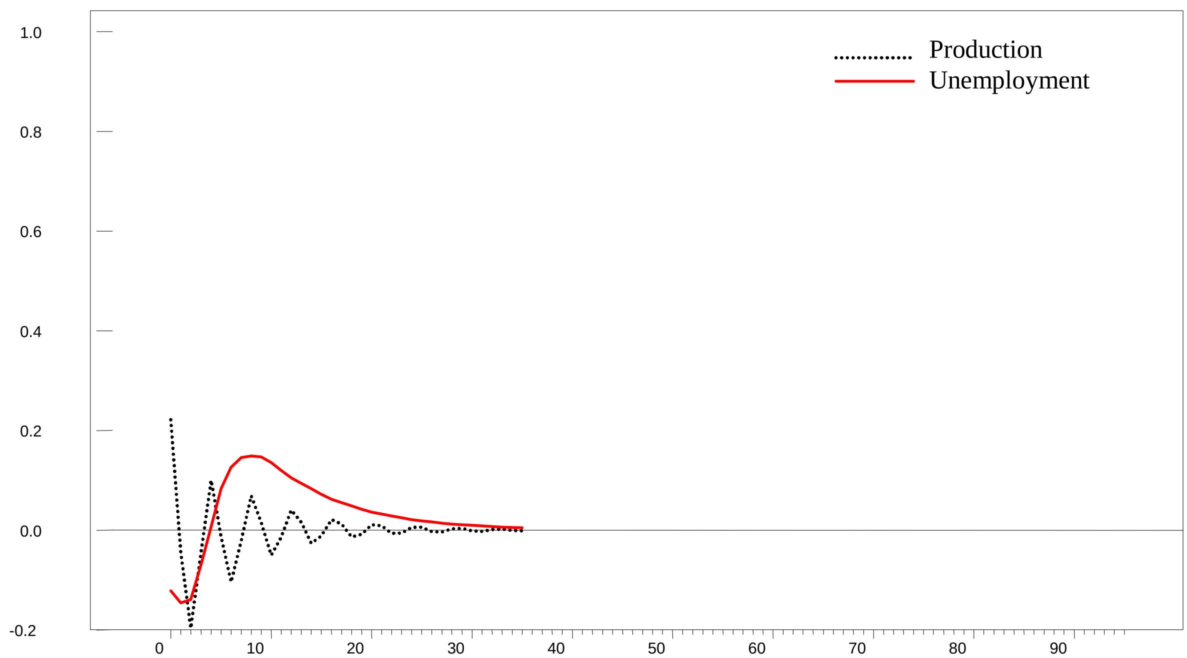

Figure 15: Responses of Gulf Production & TX Unemployment Rate to Price.

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 production and Louisiana quarterly personal income to a positive shock to crude petroleum prices are depicted in Figure 19. The figure shows that the impact of price on personal income is positive and it reaches a maximum of 0.33 percent within a year (3 quarters). The restoration to its original equilibrium is also in less than 12 quarters.

5.2.2. Price Shock, OCS Deepwater Production, and the Alabama Economy: In Figure 20 response of unemployment to a price shock is negative initially and deepwater production response is also unexpectedly negative. The response path for unemployment is striking. The unemployment response at its maximum is much larger (1.24 percent) than the initial shock to price. The subsequent hike in unemployment rate follows the ensuing sharp decline in price after the initial shock. The restoration to initial equilibrium takes much longer for unemployment and production in comparison to other scenarios. The response to positive price shock by Alabama personal income and OCS deepwater production are presented in Figure 21. The Figure shows that personal income fluctuates within 0.13 percent of its original equilibrium, whereas the variation in deepwater production nearly doubled the fluctuations in personal income following a price shock.

5.2.3. Price Shock, OCS Deepwater Production, and the Mississippi Economy: As evident in Figure 22, the response of deepwater production or Mississippi unemployment rate to price shock is negative. The negative responsiveness is unexpected with respect to deepwater production. The response, however, shows minimal effects over time as deviations from equilibrium levels appear insignificant. The response to positive price shock by deepwater production and Mississippi personal income is presented in Figure 23. The figure shows that changes in personal income are never above or below 0.2 percent and similarly production deviations are less than 0.25 percent. Hence, impacts of oil price shock on Mississippi economy are very small in magnitude.

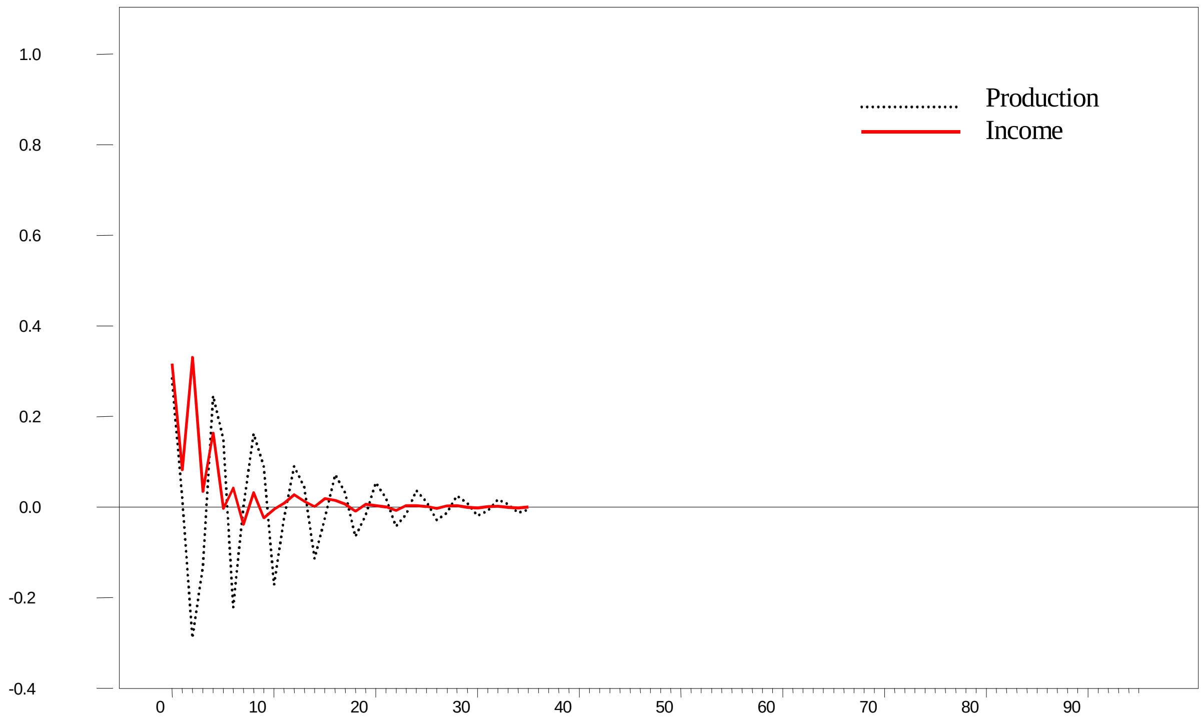

Figure 16: Responses of Gulf Production & TX Personal Income to Price.

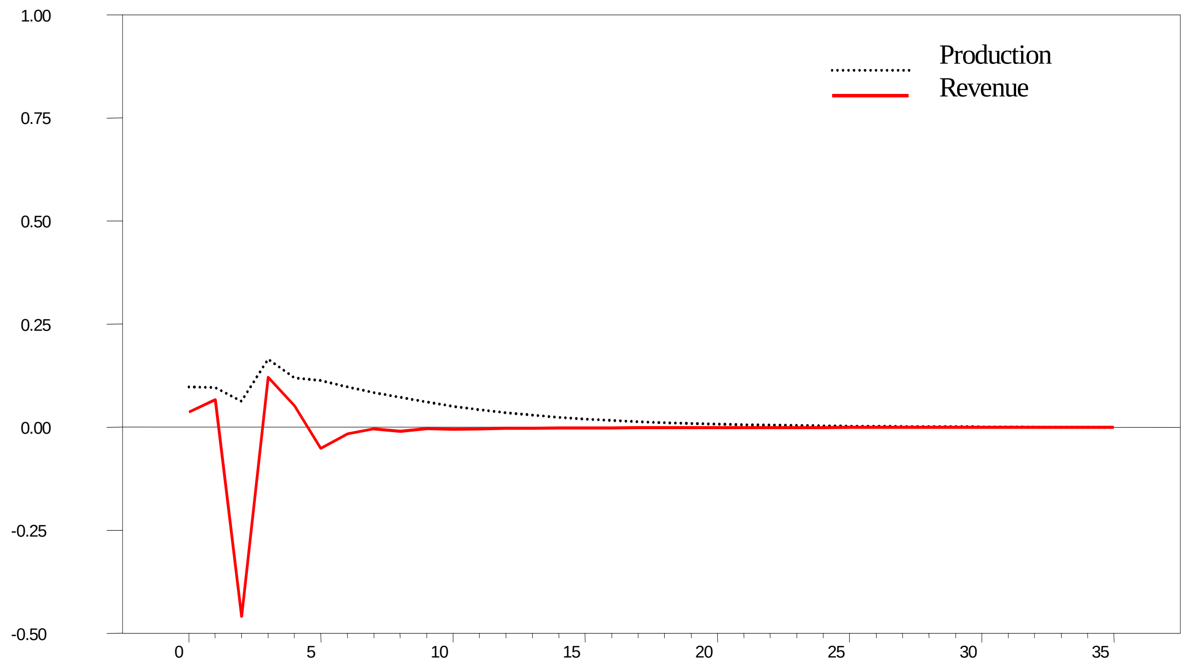

Figure 17: Responses of Gulf Production & TX Revenue to Price.

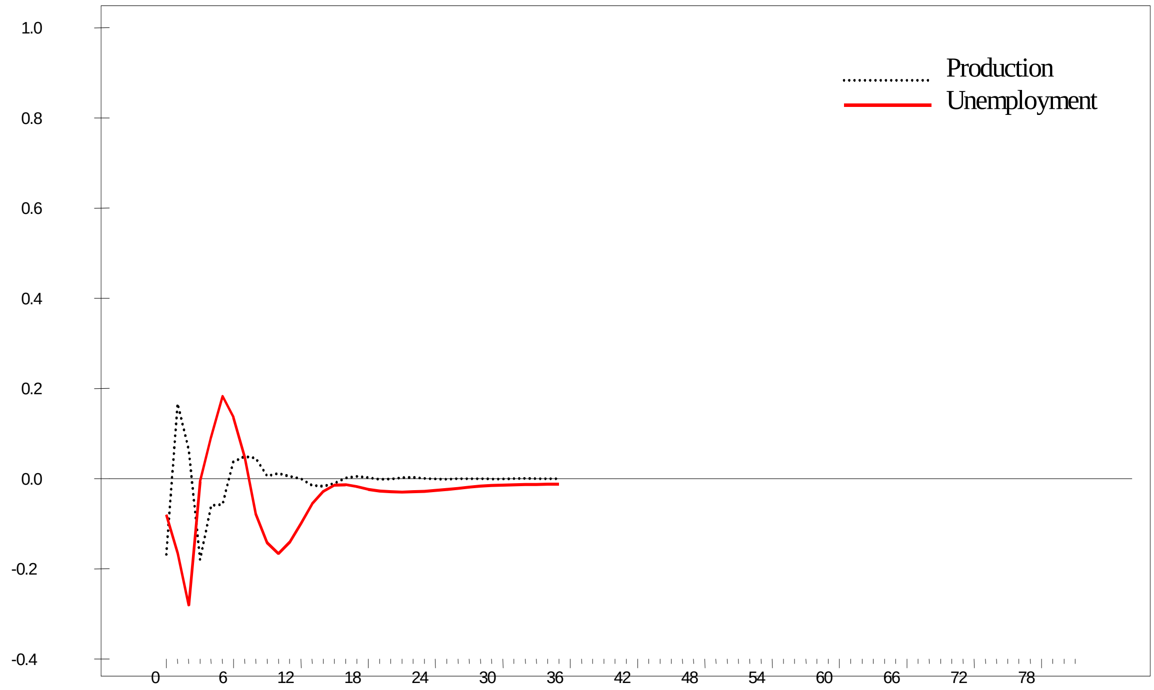

Figure 18: Responses of Deepwater Production & LA Unemployment to Price.

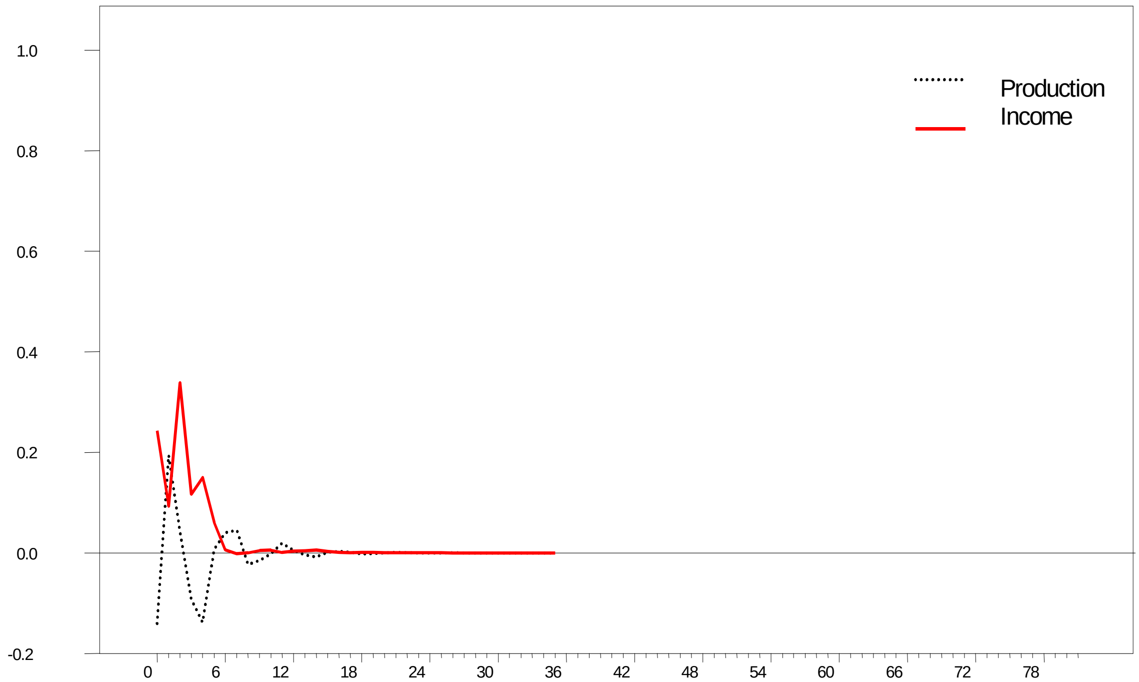

Figure 19: Responses of Deepwater Production & LA Personal Income to Price.

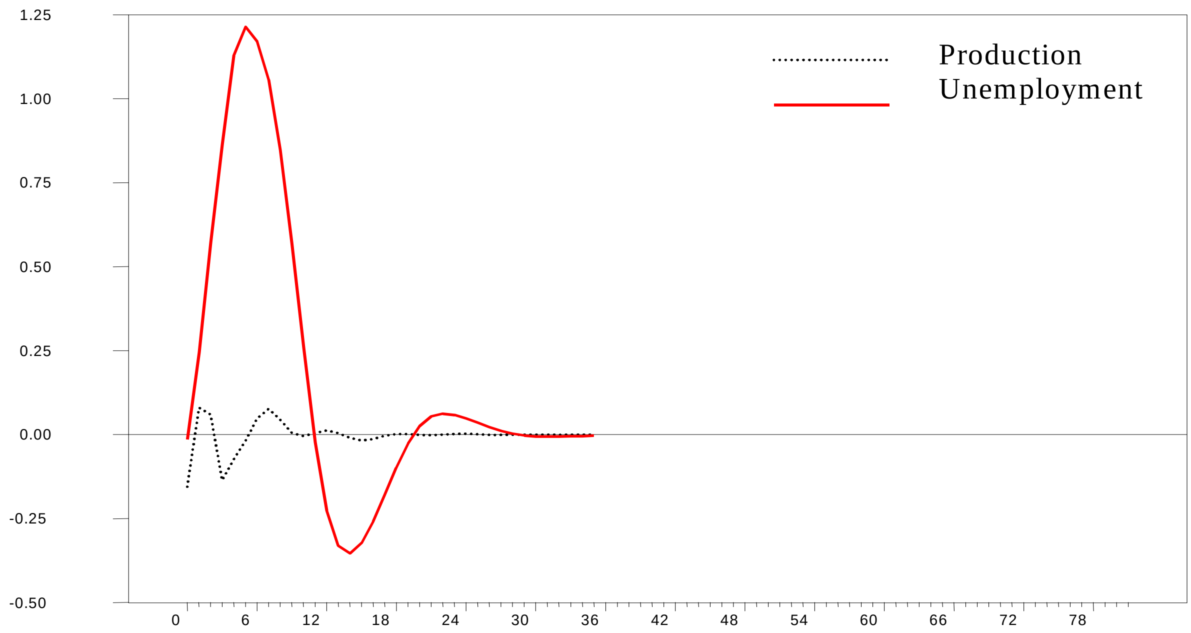

Figure 20: Responses of Deepwater Production & AL Unemployment Rate to Price.

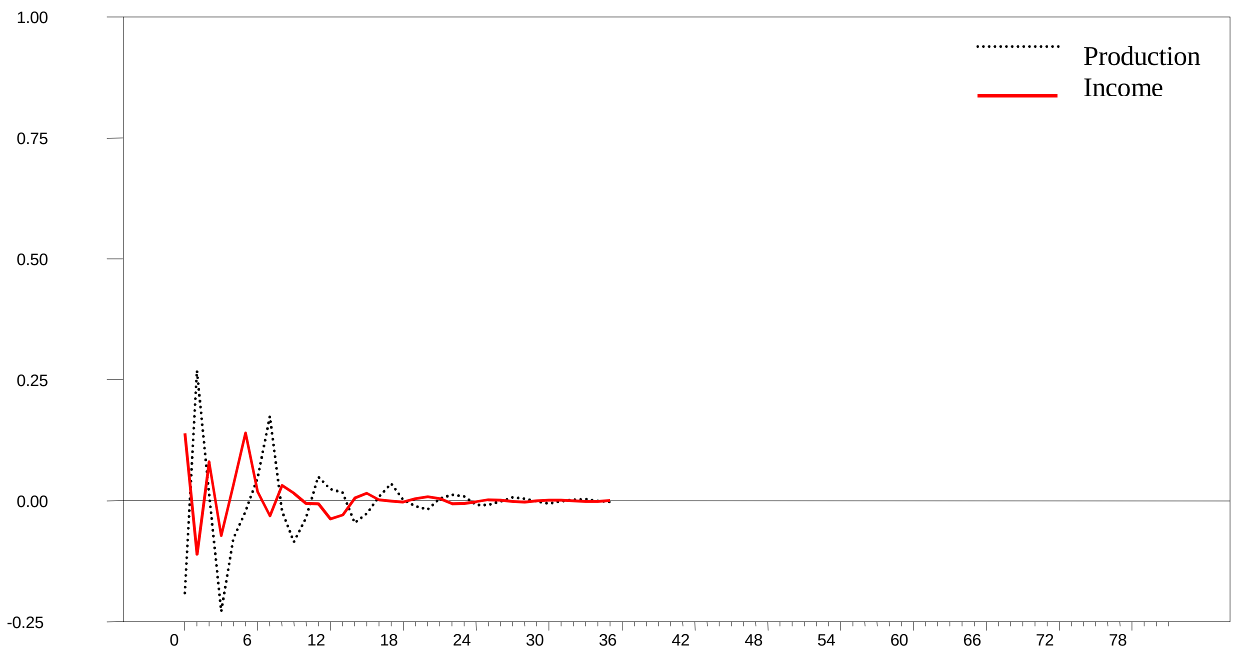

Figure 21: Responses of Deepwater Production & AL Personal Income to Price.

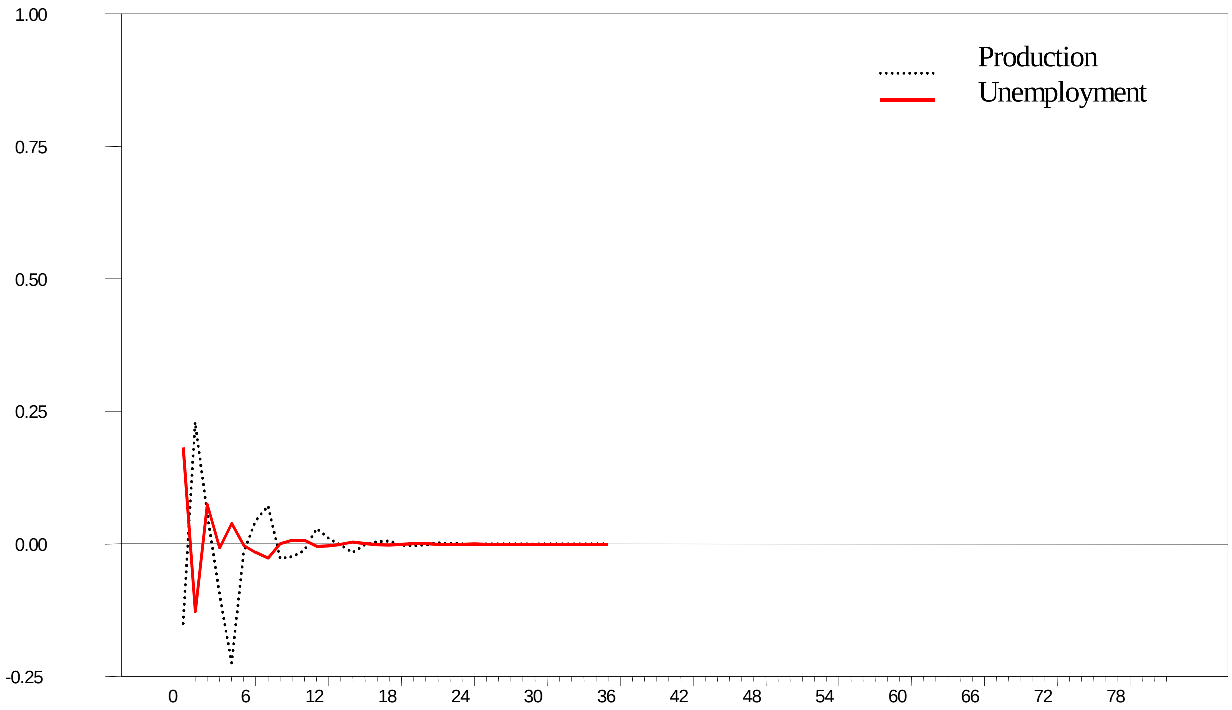

Figure 22: Responses of Deepwater Production & MS Unemployment Rate to Price.

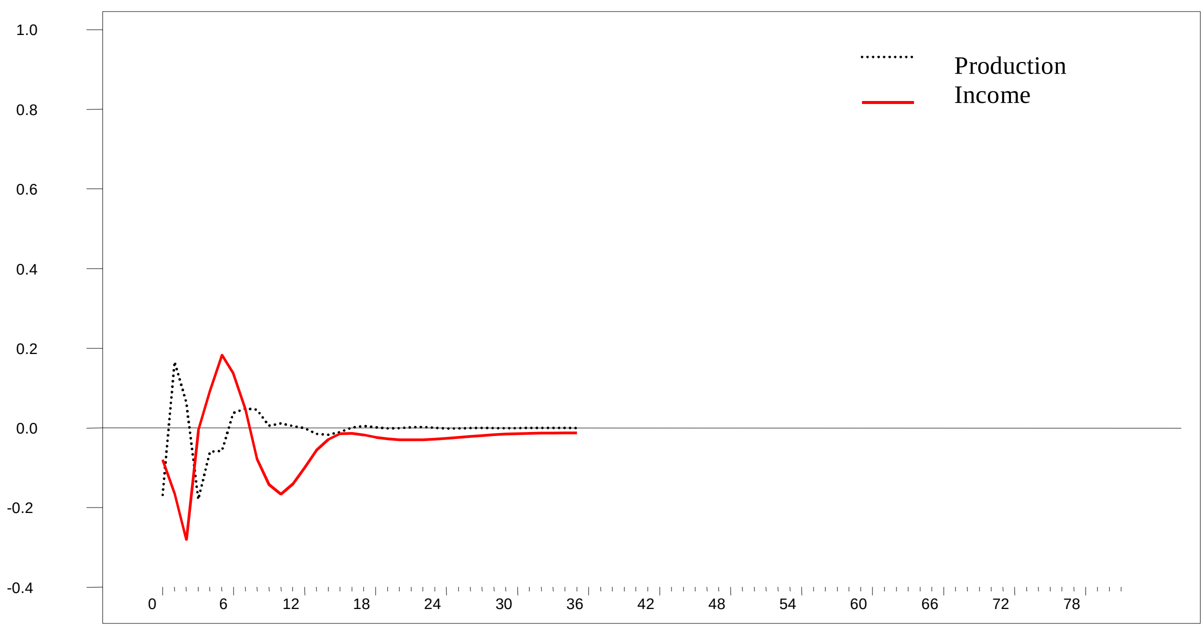

Figure 23: Responses of Deepwater Production & MS Personal Income to Price.

5.2.4. Price Shock, OCS Deepwater Production, and the Texas Economy: 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.

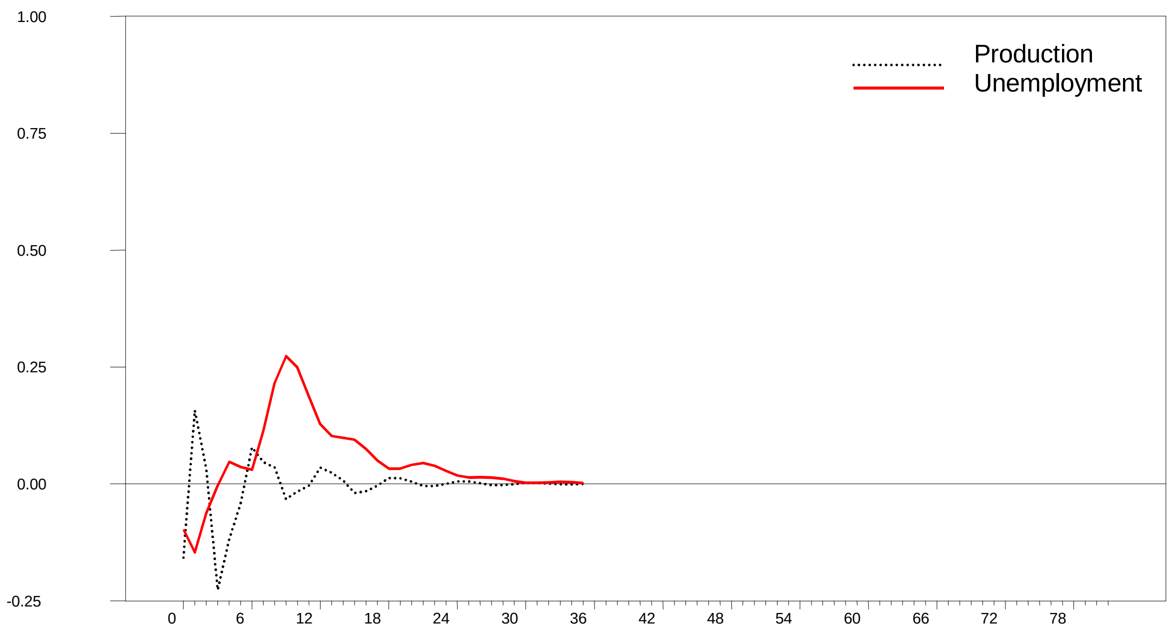

Figure 24: Responses of Deepwater Production & TX Unemployment Rate to Price.

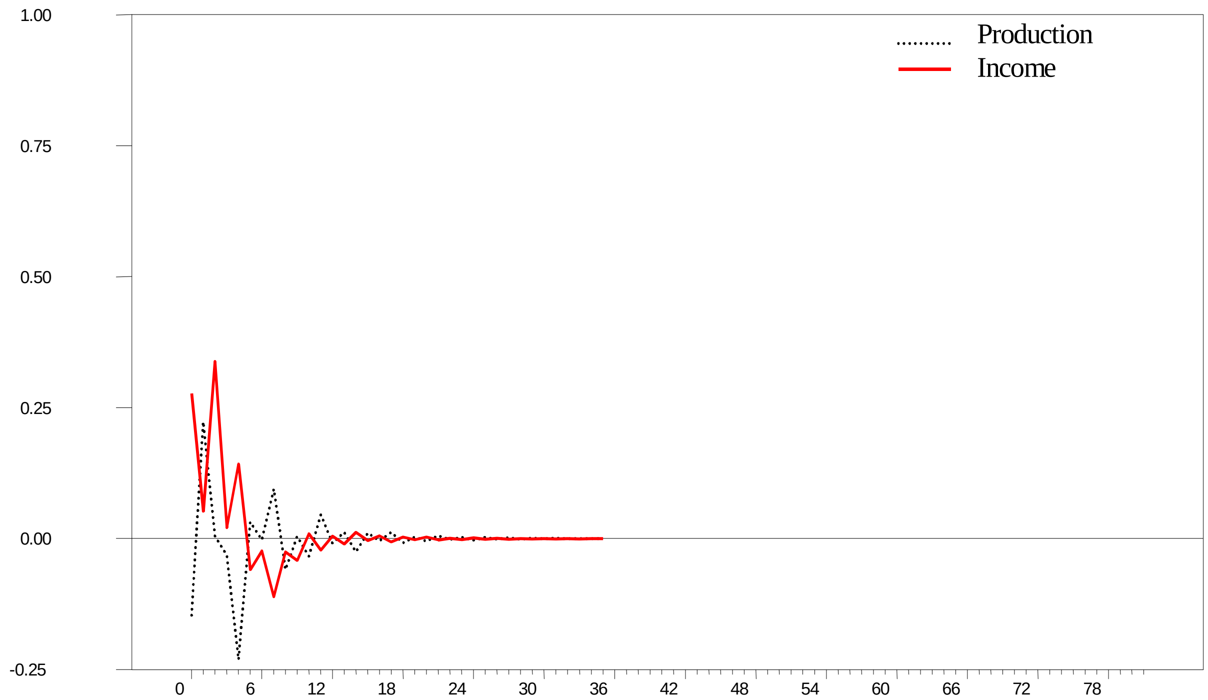

Figure 25: Responses of Deepwater Production & TX Personal Income to Price.

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 reported in Table 7 is estimated by normalizing the variable response to oil price shock at the corresponding maximum. Hence, the implicit assumption of a constant-elasticity has been invoked (Brown and Yucel, 1995).

With regard to state macroeconomic variables—unemployment, revenue, and personal income—the differences among states do not appear to be large. The respective means of each variable is included to give a sense of what each elasticity may mean in quantifiable terms. In general, all three macroeconomic variables are more elastic to price changes than oil and gas production. The highest oil price elasticity of unemployment is in Alabama (2.575) while Texas shows the least response (1.917). These represent a change of 0.2 and 0.119 in unemployment rates for Alabama and Texas, respectively. In the case of personal income response, each elasticity is similar in magnitude. In quantitative terms, and unlike in the case of unemployment rates, Texas is more responsive while Alabama is the least responsive. The responsiveness of revenue to price in all Gulf States is elastic, except for Mississippi (0.738).

Two major inferences can be made from the empirical analysis as reported in Tables 6 and 7. First, the effects of production on macroeconomic variables in the Gulf Coast States are generally less than those of changes in prices. In other words, unemployment rates, personal income, and annual revenue are more directly affected following changes in petroleum prices than they are affected consequential to the changes in petroleum production, which ensue from changes in prices. This pattern indicates that the direct effects of price shocks on the economy in general should be of greater interest to policy makers in the Gulf Coast States than the direct effects of prices on oil and gas production. The only exception to this pattern is the price effects on the annual state revenue in Mississippi.

The second inference is the lack of symmetry in the effects of a price shock and changes in petroleum production on economic performance indicators across the Gulf States. The empirical results show significant differences in the responsiveness of economic performance indicators to changes in prices across the states in the Gulf Coast. These differences are even more noticeable when the effects are translated into quantifiable terms (quantity equivalence of unemployment, state revenue and personal income with respect to the mean of the variable) than what the elasticity measures tend to portray (see Table 8).

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	Quarterly Personal Income	Annual Revenue
Louisiana			
Mean	8.09%	$59,650 Million	$4,963 Million
Elasticity	2.499	1.131	1.504
Quantity Equivalent*	0.20%	$675 Million	$74.666 Million
Alabama			
Mean	7.78%	$56,560 Million	$4,132 Million
Elasticity	2.575	1.066	1.554
Quantity Equivalent*	0.20%	$603 Million	$64.202 Million
Mississippi			
Mean	7.89%	$31,510 Million	$2,644 Million
Elasticity	2.358	1.172	0.738
Quantity Equivalent*	0.19%	$369 Million	$19.510 Million
Texas			
Mean	6.22%	$273,960 Million	$14,273 Million
Elasticity	1.917	1.211	1.135
Quantity Equivalent*	0.12%	$3,318 Million	$161.991 Million

* The corresponding average change in macroeconomic variables due to a percent change in price.

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*, more workers are needed to meet the new desired levels of output. Thus, employment levels in the states will rise (means unemployment rates decline) to meet industry needs. It is noted that this is a net effect, because an increase in price of crude oil should also increase production cost in industries where oil and gas are the primary production input, e.g. chemical and allied products. This final result may therefore imply that price-elasticity of employment in the oil and gas producing industry is greater than price-elasticity of income for oil and gas consuming industry in these states.

- Unemployment rates in the Gulf States appear to be relatively less sensitive to oil and gas production activities. That is, Gulf production role in states unemployment variation is relatively diminutive over time. In many instances, the impact of production shocks on unemployment is insignificant.

- Personal income increases following a crude oil price positive shock. This result is also consistent with the fact that all the states considered are oil producers although in varying magnitude. In general, the oil and gas industry pays relatively higher wages than most other industries in these states. It follows, therefore, that personal income in these states rises following an oil price increase. Of course, the degree of this increase in income is asymmetrical across states. In general, Louisiana and Texas have higher responsiveness to price change than Mississippi and Alabama.

- Revenue increases in each of the Gulf States following an unexpected increase in the price of crude oil and gas, except for Mississippi. However, as with employment, this must be regarded as a net-result. This is because other oil and gas using industries may decrease their production capacity and output leading to a decline in income tax base, another significant source of state revenue. It is also noted that because the impact of a price increase is not necessarily uniform across all states with positive response, the revenue effects are not uniform either. In fact, as noted, Mississippi's revenue decline may be an indication that the positive effect of production in the Gulf is not enough to override the negative effect of income tax base erosion.

Further, the response lags in the impulse response analysis give an indication of the length of the effects of a price shock on a state economy. At one extreme, a persistent effect will indicate a long-lasting impact that may in fact change the structure of the state economy. Thus our study suggests that:

- The impact of a price change takes about 45 quarters to return to equilibrium with respect to employment in Louisiana. Similar measures for Alabama, Mississippi, and Texas are 25, 35, and 38 quarters, respectively. In other words, such a price change may have more destabilizing effects on Louisiana, Texas, Mississippi, and Alabama, in that order. This change may be destabilizing because the change is a "shock" i.e. unexpected, which means firms and policy makers may find it difficult to respond adequately. This pattern among states may be explained by the fact that oil and gas production and oil and gas dependent industries are more prevalent in Texas and Louisiana than in the other states. However, Texas has a larger and more diversified economy than Louisiana and is more able to dampen the destabilizing effect of its exposure to the price shocks than Louisiana.

- Personal income can take about 18 quarters in Texas, 12 quarters in Louisiana and 8 quarters in Mississippi and Alabama to restore initial equilibrium after a price shock. In this case, Texas economic size seems to prolong the income effect of the change in price more than any other state in the Gulf States. However, the net oil exporting states are still far more exposed to such a shock than their net oil importing counterparts.

In an overall sense, two major observations are evident in this study. Contrary to our initial hypothesis, the effects of oil and gas price shock on coastal Gulf States are more direct than indirect (through oil and gas production). In other words, employment, personal income, and revenue are impacted more directly following a price change rather than through changes in oil and gas production following a price shock. Further, according to our empirical results, there is a strong statistical evidence to suggest an asymmetric response of each of the three macroeconomic variables to price in the four coastal Gulf States.

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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,

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

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 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:

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

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 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 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_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 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 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 equal to the number of restrictions. *T* is the number of observations and c is 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 equations 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 equations 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 produces a non-symmetric system such that either the right-hand variables are not the same across equations, or the lag-lengths differ 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 a 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 variables 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:

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

Where y_0 equals initial value of yt.

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

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

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

Where

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

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

$$u_t u`_t = \Omega = Ge_{t.} (Ge_{t.})` = Ge_{t.}\, e`_{t.} G` = GDG`$$

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.

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 form 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).

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

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

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.