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Hedging against Peak Oil Shocks

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Abstract

Many policymakers and pundits have made the case that the United States should become "energy independent." One economic interpretation of energy independence is that increased domestic energy production leads to greater risk sharing in the presence of imperfect capital markets. The wealth effects of energy production increase during peak oil shocks that help energy-producing states hedge against peak oil shocks. I test this hypothesis using consumption and gross state product data for US states for the period 1963-2007. I find that risk sharing is approximately 50 percent higher in energy producing states than non-energy states. The results suggest that oil shocks have different effects on energy and non-energy producing states. I offer two explanations for the finding. First, residents of non-energy producing states do not place enough of the assets in their wealth portfolio in energy stocks that allow them to hedge against peak oil shocks. Second, the wealth effects of energy production increase during peak oil shocks which helps residents (in energy producing states) smooth consumption and income. The analysis has two policy implications: 1) non-energy states should increase the share of energy stocks in their wealth portfolios; and 2) an increase in domestic energy production should increase risk sharing in the United States.

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The increase in the price of gasoline to more than $5.00 per gallon and a rise in the price of a barrel of oil to more than $147 in the summer of 2008 has raised serious concerns among policymakers and the general public about the future cost of energy. Many pundits and politicians have argued that the United States should make "energy independence" a public policy goal for economic and political reasons. Energy independence will reduce the United States' reliance on foreign oil from many governments that support terrorism and do not recognize basic human rights. Some believe that the United States should develop alternative sources of energy that compete with fossil fuels so that the United States becomes less reliant on fossil fuels that damage the environment by putting carbon dioxide into the atmosphere (Pickens, 2008). To this point, Congress is considering a cap and trade bill that is supposed to create incentives for firms and families to use cleaner sources of energy. The bill raises fuel economy standards and imposes large taxes on firms that emit pollutants into the atmosphere by using fuels such as dirty coal and diesel oil. Other scholars and experts argue that the United States should focus on developing domestic fossil fuel reserves given that alternative energy sources are generally not efficient or competitive with traditional sources of energy (Gingrich and Haley, 2008).

Although scholars may disagree over the best means for increasing domestic energy production in the United States, one issue that is often not well defined is the economic meaning of the word "energy independence." One economic interpretation of this term is that increased domestic energy production within the United States allows for greater risk sharing. This means that greater energy production, especially during negative oil/energy shocks, allows residents in energy producing states to better smooth

consumption and income given that energy-producing states tend to fair much better (because of the wealth effects of energy production) during an oil shock. To test this hypothesis, I employ models developed Asdrubali, Sorensen, and Yosha (1996) to the measure the importance of different sources of interstate smoothing (income and consumption) in the United States from 1963-2007. The empirical analysis suggests that energy-producing states have nearly 50 percent more smoothing than non-energy-producing states. Most of the risk sharing in energy-producing states is achieved through capital markets.

I then investigate some of the reasons that energy producing states might have more smoothing than non-energy states. One possible explanation is that residents of energy-producing states (as opposed to farmers and agricultural output) are more likely to hold claims on energy-producing assets that can easily be bought and sold on capital markets to smooth consumption. Residents of non-energy-producing states are probably also less likely to hold energy stocks in their wealth portfolios. This is consistent with the existence of home bias in wealth portfolios: the empirical finding that residents of a particular state are more likely to hold assets of local companies. Another possible explanation is the wealth effects of energy production during a peak oil shock in an energy producing state.[1] For example, suppose a large oil shock hits the US economy. In large energy producing states like Texas and Alaska, the negative economic impact of a peak oil shock is much smaller (or even positive) than in a non-energy producing state. The oil shock increases production and employment in the energy sector that has a

[1] Hess and Shin (1996) find that energy-producing states have output growth rates that are less correlated with non-energy producing states. They also find that energy producing states have greater consumption sharing with non-energy producing states over the period 1978-1990 by looking at the ratio of the growth rate of consumption relative to the growth rate of output.

multiplier effect for the rest of the economy in the state (and possibly neighboring states through interstate trade that helps smooth consumption over time). The "wealth effect" of energy production is shown by the fact that an increase in the price of oil raises the unemployment rate in non-energy states, but does not have a statistically significant effect on the unemployment rate in energy-producing states. An oil shock has a similar effect on non-farm employment in energy and non-energy producing states. An oil shock generally increases non-farm employment in energy producing states while reducing employment in non-energy producing states. The empirical results suggest the presence of aggregation bias: oil shocks have different effects on US states once they are separated into energy and non-energy producing regions. Overall, the analysis illuminates the potential benefits of increased fossil fuel production and the effects of home bias in non-energy-producing states on risk sharing in the United States.

I begin the analysis with a discussion of income and consumption smoothing. This is followed by a discussion of the data and empirical analysis. I then investigate the impact of oil shocks on US states, energy and non-energy producing states. The paper concludes with a discussion of the results for US energy policy.

I. Risk Sharing

Risk sharing among states or a group of countries like the European Union (EU) or the North American Free Trade (NAFTA) agreement is supposed to reduce the volatility of income and consumption. The basic idea of risk sharing is to pool economic production generated by all states and then equally distribute that pool to each state (on a

per capita basis). If there is a flood on the Mississippi River that destroys several towns, for example, then the residents of the town will be able to maintain a relatively constant stream of consumption (possibly through insurance markets) because of interstate risk sharing. Within the United States, the pooling of risks across state lines means that income and consumption of a state depends on the output of the entire country. Since the GDP of the United States is generally less volatile than the output of an individual state, risk sharing allows a state to reduce its income and consumption volatility.

Asdrubali, Sorensen and Yosha (1996) argue that there are three important channels through which states pool risks over the business cycle.[2] Capital market smoothing is one important mechanism that arises from interstate ownership of productive assets. For example, suppose that there is an oil shock that impacts all states in America, especially non-oil producing states. Residents in non-energy producing states can hedge against peak oil shocks by holding assets in oil producing states such as oil wells or shares of Chevron or Shell. Interstate ownership of energy stocks will help residents smooth consumption and income against oil shocks.

The second mechanism of risk sharing is called disposable income smoothing which follows from the federal system of taxes and transfers. To understand how this mechanism works, consider the impact of an oil shock in Alaska and a non-energy producing state such as Connecticut, all else equal. Disposable income in Alaska will increase while disposable income in Connecticut will decline (this example assumes that an oil shock raises income in Alaska). Since the tax system is progressive, disposable income in Alaska will not rise as much as income. The increase in Alaskan tax revenue from the oil shock will help fund federal transfers to non-oil producing states such as

[2] For an analysis of regional risk sharing in the United States, see Sorensen and Yosha (2000).

Connecticut. As a result, taxes and transfer payments help insulate Connecticut's disposable income over time from negative shocks such as oil. As a result, transfers and taxes from oil to non-oil producing states (or vice-versa in the event of a decline in oil prices) will help reduce the volatility of state-level consumption.

The third mechanism is credit markets that help residents make adjustments to their saving rate and wealth portfolios to smooth consumption over time. For example, when oil prices fall, residents in oil producing states can save less of their disposable income or sell some of their assets such as real estate to residents in other states. Alternatively, residents can borrow from financial markets to smooth consumption over time. This means that a state's consumption will be less volatile than its disposable income.

To measure the amount of interstate risk sharing in the United States, I implement the methodology developed by Asdrubali, Sorensen, and Yosha (1996). They decompose the period-by-period, cross sectional variance in gross state product. Consider the following identity:

$$gsp^i = \frac{gsp^i}{si^i}\frac{si^i}{dsi^i}\frac{dsi^i}{c^i}c^i, \qquad (1)$$

where *gsp*, *si*, *dsi*, and *c* denote per capita state product, state income, disposable state income, and state consumption, respectively. The superscript *i* is an index of states. State income includes dividend, interest, and rental income payments across borders. Disposable state income includes federal taxes and transfers.[3] As noted by Asdrubali et. al, (1996) smoothing takes place through capital markets, the federal tax-transfer system,

[3] See the Data Appendix and Asdrubali et. al (1996) for a more complete discussion of the definition of the variables employed in the empirical analysis.

and credit markets if the three terms on the right hand side of equation (1) --

$\frac{gsp^i}{si^i}\frac{si^i}{dsi^i}\frac{dsi^i}{c^i}$ --vary with gross state product.

I take the logs and differences of equation (1) and then multiply both sides by the change in the natural log of gross state product and take expectations. This yields the following equation that decomposes the cross-sectional variance of *gsp*.

$$\begin{aligned}\text{var}(\Delta\log\ gsp) = \text{cov}\big(&\Delta\log\ gsp,\ \Delta\log\ gsp - \Delta\log\ si\big) + \text{cov}\big(\Delta\log\ gsp,\ \Delta\log\ si - \Delta\log\ dsi\big) \\ &+ \text{cov}\big(\Delta\log\ gsp,\ \Delta\log\ dsi - \Delta\log\ c\big) + \text{cov}\big(\Delta\log\ gsp,\ \Delta\log\ c\big) \qquad (2)\end{aligned}$$

Dividing equation (2) by the variance of $\Delta\log\ gsp$ yields

$$1 = \beta_K + \beta_F + \beta_C + \beta_U, \qquad (3)$$

β_K is an ordinary least squares (OLS) estimate of the slope in the regression of $\Delta\log\ gsp^i - \Delta\log\ si^i$ on $\Delta\log\ gsp^i$. The economic interpretation of β_K is the incremental amount of risk sharing that takes place through capital markets. A larger positive value of β_K implies greater income smoothing through capital markets.

β_F captures the amount of risk sharing through the federal tax-transfer system. The coefficient estimate of risk sharing via the federal tax-transfer system is obtained by a regression of $\Delta\log\ si^i - \Delta\log\ dsi^i$ on $\Delta\log\ gsp^i$. For credit markets, the slope coefficient in the regression $\Delta\log\ dsi^i - \Delta\log\ c^i$ on $\Delta\log\ gsp^i$ measures the extent to which consumption fluctuates less than disposable income in response to changes in gross state product. β_U is the slope of the regression of $\Delta\log\ c^i$ on Δgsp^i. This measures the amount of risk that is not smoothed by US states. The smoothing coefficient

essentially measures the sensitivity of changes in consumption to changes in gross state product. In the presence of full risk sharing, β_U is equal to 0 and the sum of $\beta_K + \beta_F + \beta_C$ is equal to one. The beta coefficients are not constrained to be positive or less than one. A beta coefficient of less than 0 indicates dis-smoothing (negative smoothing).

To identify the importance of capital markets, the federal tax-transfer system, and credit markets for income and consumption smoothing in the United States, I estimate the following panel regressions:

$$\Delta \log gsp_t^i - \Delta \log si_t^i = v_{K,t} + \beta_K \Delta \log gsp_t^i + u_{K,t}^i \quad (4)$$

$$\Delta \log si_t^i - \Delta \log dsi_t^i = v_{F,t} + \beta_F \Delta \log gsp_t^i + u_{F,t}^i \quad (5)$$

$$\Delta \log dsi_t^i - \Delta \log c_t^i = v_{C,t} + \beta_C \Delta \log gsp_t^i + u_{C,t}^i \quad (6)$$

$$\Delta \log c_t^i = v_{U,t} + \beta_U \Delta \log gsp_t^i + u_{U,t}^i \quad (7)$$

The v's represent time fixed effects. The beta coefficients are weighted averages of the cross-sectional regressions that break risk sharing down into each of its four components. The beta coefficients capture the extent to which changes in gross state product impact state consumption in the same year.

For the empirical analysis, I employ annual estimates of personal income and gross state product provided by the Bureau of Economic Analysis from 1963 to 2007.[4] I use non-durable retail sales to proxy for state-level consumption even though these data are subject to some bias given that retail consumption data is not reported by place of residence (includes purchases by commuters and non-residents of a state). The state-level estimates of non-durable retail sales are provided by Moody's.com. Since data on actual

[4] I use the same definition of state income and disposable income as Asdrubali et. al (1996). See the Data Appendix for a more complete description as well as Asdrubali et. al (1996).

private consumption is not available, I follow Asdrubali et. al (1996) and rescale retail sales by the ratio of total private consumption to total US retail sales. This means that the measure of state consumption is the sum of state government consumption and rescaled retail sales (Asdrubali et. al, 1996). The data employed in the analysis are in nominal terms given that each variable is constructed at the state level, which implies that dividing each covariate by the price level would yield identical results. The panel regressions are estimated using robust standard errors. The empirical results of risk sharing for all US states are reported in Table 1.

As shown in the last column of Table 1, capital markets smooth more than 48 percent of shocks to gross state product over the entire sample period 1963-2007. The government accounts for about eight percent of smoothing. Credit markets smooth more than 13 percent of shocks to gross state product. About 30 percent of shocks are not smoothed over the last 45 years. The analysis indicates that capital and credit markets are much more important for smoothing than the government.

The remaining columns in Table 1 decompose the amount of risk-sharing over various sub-sample periods. Table 1 shows that the importance of capital markets has risen over time, increasing from about 24 percent in the 1960s to more than 60 percent at the turn of the century. The tax-transfer system accounts for less than 10 percent for less of smoothing over each sub-sample period. Credit markets, on the other hand, have generally become less important over time. The percentage of shocks to gross state product that are smoothed from credit market has fallen from about 26 percent in the early 1960s to about 13 percent in the last ten years. Overall, the total amount of

smoothing in the US economy has risen over time as shown by the decline in β_U from 42 percent in the 1960s to 16 percent over the period 1995 to 2005.[5]

To investigate the importance of oil/natural gas/energy production for risk sharing, I divide US states into energy and non-energy producing states. I define an energy producing state as one where energy production accounts for at least five percent of a state's gross state product. Using this criteria, I have six energy states: Alaska, Oklahoma, Louisiana, New Mexico, Texas, and Wyoming. In each case, fossil fuel production is the most important component of energy production. Table 2 shows that energy production has averaged at least 10 percent for the six states over the entire sample period. Figure 1 and Table 2 show oil production as a share of gross state product over the period 1963-2007. Oil production as a percent of gross state product (for the large energy producing states) peaked in the early 1908s before declining in the 1990s. Recently, oil production as a fraction of gross state product has largely increased because of the rise in energy prices. Table 3 compares the economic characteristics of energy and non-energy producing states. Non-energy producing states tend to have larger economies as measured by real GDP from 1977-2007. The rate of economic growth is similar for energy and non-energy producing states. The empirical results dividing states into energy and non-energy producing regions are reported in Panels B and C of Table 1. For the energy states, I find that capital markets smooth more than 70 percent of shocks to gross state output over the entire sample period. Credit market and the federal tax-transfer

[5] The finding of less than full risk sharing is consistent with the results of Cochrane (1991), Crucini (1995), and Hess and Shin (1998). French and Poterba (1991), Canova and Ravn (1996), Obstfeld (1994), van Wincoop (1994), and Lewis (1996) examine international portfolio diversification and risk sharing.

system smooth less than six percent of shocks in energy producing states.[6] Less than 18 percent of shocks are unsmoothed in energy producing states. In contrast, capital markets smooth slightly less than 35 percent of shocks to gross state product for non-energy producing states. The total amount of smoothing from the federal government tax-transfer system and credit markets is less than 27 percent over the period 1963-2007. Overall, the total amount of income that is unsmoothed is much higher in non-energy producing states; more than 38 percent of shocks to gross state product are not smoothed in non-energy producing states.

A similar picture emerges if I examine the components of risk sharing over various sub-sample periods. For energy-producing states, capital markets account for a much higher level of smoothing than non-energy producing states for each sub-period. Credit markets are generally more important for smoothing consumption in non-energy-producing states. These differences are due, in part, to differences in the underlying economic structure of the different economies in these two states. As pointed out by Asdrubali et. al (1996), it might be much easier to sell shares in an oil company on capital markets as opposed to agricultural output. In addition, residents in a non-energy producing state are much less likely to hold assets such as stocks in oil producing industries given the large home bias effect observed in capital markets. Another possible explanation is that agricultural shocks tend to be much less persistent than manufacturing shocks. As a result, you might expect the amount of capital market smoothing to be much higher in energy producing states and the amount of credit market smoothing to be

[6] Atkeson and Bayoumi (1993), Goodhart and Smith (1993) and Bayoumi and Masson (1995) examine various aspects of the tax-transfer system.

significantly greater in agricultural states where farmers use credit cooperative and financial institutions to smooth consumption over time.

As a final check, I estimated the total amount of smoothing during peak oil shocks since the early 1970s. The empirical estimates appear in Table 4. The empirical results show that the total amount of smoothing is much larger in energy-producing states than in non-energy producing states during episodes of peak oil shocks. This is true even of the recent oil shock (2004-07) where capital markets smoothed more than 75 percent of shocks in energy producing states compared to 36 percent in non-energy producing states. Overall, the empirical evidence strongly suggests that there is a much higher amount of smoothing in energy producing states.

One potential shortcoming of the empirical analysis is that the baseline panel regressions estimate the relationship between shocks to gross state product and their impact on state consumption in the same year. It is possible that it takes time for residents of a state to make adjustments to their wealth portfolio by buying and selling stocks and borrowing from financial institutions to smooth consumption and income over time. To consider this possibility, I re-estimated the empirical results using a dynamic analysis (Asdrubali et. al, 1996). I alter the empirical specification where the data are differenced using intervals of k years (k=1, 2, 3, 5, 10). The empirical results are reported in Table 5. The tenor of the empirical results remains unchanged. There is a significantly higher amount of total smoothing in energy producing states than non-energy producing states regardless of the differencing intervals employed in the empirical analysis. Most of the difference occurs through the greater amount of risk sharing in capital markets.

II. Oil Shocks, Gross State Product, and Employment

The risk sharing regressions suggest that oil shocks may have different effects on energy and non-energy producing states in the short-run. A peak oil shock is likely to have a much larger negative impact on a state's output than a state that does not produce oil or natural gas. A state with a large energy sector, on the other hand, may benefit (or be less negatively affected) from a peak oil shock depending on the size of the wealth effect. Alaska, for example, experienced double digit real GDP growth and a decline in its unemployment rate in the early 1980s as a result of the large oil shock.

To examine the economic impact of oil shocks on energy and non-energy producing states, I first analyze the impact of oil shocks on gross state product using a bivariate panel vectorautoregression (PVAR) for the period 1969-2007. The two variable system includes the growth rate of gross state product for each state and the percent change in the real oil price I deflate the gross state product data using the GDP deflator for the period 1969-1976 and the gross state product deflator for each state for the period 1977-2007. Real international oil prices are measured as the West Texas Intermediate Crude divided by the US CPI. The bivariate panel VAR is estimated with a lag length of one. The empirical results for the whole sample period are reported in Figure 2. The impulse response functions show the impact of a one-standard deviation shock to the change in the natural logarithm of real oil prices on the change in the unemployment rate.

Figure 2 shows that oil shocks significantly reduce the growth rate for all states for the period 1969-2007. Panel B suggests that oil shocks have a similar impact on non-energy producing states. A one-standard deviation shock to the change in oil prices

significantly reduces the rate of economic growth. Panel C indicates that oil shocks have a different effect on energy-producing states. Oil shocks do not have a statistically significant effect on economic growth in energy-producing states for the entire sample period.[7]

To further investigate the impact of oil shocks on economic growth, I re-estimate the panel vectorautoregressions (PVAR) over various sub-sample periods (1969-1985, 1986-1999, and 1990-2007). The bivariate panel VAR is estimated with a lag length of one. The results appear in Panels A, B, and C of Figures 3, 4, and 5. The basic tenor of the results remains unchanged: 1) oil shocks reduce economic growth in non-energy producing states; and 2) oil shocks generally do not have a statistically significant effect on energy-producing states. The analysis shows that the effect of oil shocks on individual US states depends on whether or not the state has a sizable energy-producing sector.

I next analyze the economic impact of oil shocks on annual unemployment and non-farm employment data from 1963-2008 using a bivariate panel vectorautoregression (PVAR). The two-variable system consists of the annual change in the unemployment rate and the annual change in the real price of oil. The unemployment rate is taken from the website of the Bureau of Labor Statistics (BLS). Table 6 shows state-level data on employment, the size of the labor force, the number of workers unemployed, and the unemployment rate for all states, energy producing states, and non-energy producing states for the period 1976-2008. The descriptive statistics suggest that unemployment in energy states tends to be slightly more than one half of a percent higher than other states,

[7] The finding that oil shocks reduce economic growth are consistent with the findings of Hamilton (1983, 1985, 1986, and 2003). Hamilton, however, examines the impact of peak oil shocks on aggregate economic activity in the United States. He does not examine the effect of oil shocks on energy and non-energy producing states. Killian (2008a, 2008b, 2009) examines the effect of oil supply and oil demand shocks on economic activity using a structural vector autoregression.

although this result is not statistically significant. A lag length of one year with a six-year forecasting horizon (in the impulse response analysis) is employed for the empirical analysis. The impulse response functions for all 50 states along with 95 percent confidence intervals appear in Figure 2. The impulse response functions show the impact of a one-standard deviation shock to the change in the natural logarithm of real oil prices on the change in the unemployment rate.

Figure 6 shows that an innovation to oil prices increases the unemployment rate for all US states over the period 1976-2007. The hump-shaped impulse response functions show that the impact of a one-standard deviation in the change in real oil prices rises for about three years before it begins to decline. After six years, an oil shock no longer has a statistically significant impact on unemployment. I observe a similar pattern in the impulse response function for non-energy states that is repeated in Panel B of Figure 6. An oil shock initially increases unemployment for about three years before the shock starts to dissipate. The impact of an oil shock is very different for energy-producing states, however. Although the unemployment rate rises for energy states, Panel C of Figure 6 shows that the effect is not statistically significant at any forecasting horizons. The baseline unemployment analysis suggests that oil shocks have a different impact on energy and non-energy-producing states.

I then divided the sample into several sub-samples including 1976-1985, 1986-1999, and 2000-2007. The impulse response functions for the various sub-sample periods appear in Figures 7 through 9. In general, I find that oil shocks increased the unemployment rate for all states and non-energy-producing states. Oil shocks did not have a statistically significant effect on energy-producing states in all of the sub-sample

periods. The only empirical result that is not consistent in the analysis is the finding that oil shocks did not significantly increase the unemployment rate for all states and non-energy-producing states for the period 1999-2007. This result is likely due to the fact that the US economy expanded during the period between 2002 and 2007 even though oil prices significantly increased. However, it is likely that the recent rise in oil prices led to an increase in the unemployment once gross state product data for 2009 is available and can be included in the empirical analysis. Hamilton (2009) argues that the large rise in oil prices played an important role in the onset of the current recession that was exacerbated by the financial crisis.

I also investigate the impact of oil shocks on non-farm employment since unemployment understates the number of unemployed during a recession given that some workers exit the labor force. The empirical results for non-farm employment are presented in Figure 10. Again, I find that an oil shock reduces non-farm employment across all states. A different story emerges once I separate energy and non-energy-producing states, however. An oil shock increases non-farm employment in energy states (although this effect is not statistically significant at the 5 percent level) while reducing employment in non-farm states over the period 1970-2007. The result also holds for the different sub-sample periods (1970-1985, 1896-1999, and 1990-2007) as shown in the impulse responses reported in Figures 11 through 13. The analysis suggests that oil shocks have either increased non-farm employment in energy-producing states or have not had a statistically significant effect. For all states and non-energy-producing states, oil shocks significantly reduce non-farm employment.

The mining sector is another industry that is impacted by an oil shock. Again, I estimate another panel vector autoregression (PVAR) to estimate the effect of an oil shock on employment in the mining sector in all states, energy and non-energy producing states (states where energy production accounts for less than five percent of gross state product). As shown in Figure 14, I find that an oil shock increases employment in the mining sector for all states. The empirical result is robust to the various sub-sample periods (1970-1985, 1986-1999, and 1990-2007) that are reported in Panels B, C, and D in Figure 14. Overall, I interpret the empirical evidence consistent with the hypothesis that oil shocks, at least in the short-run, have different effects in energy and non-energy-producing states.

Finally, I also examine whether migration is another mechanism residents use to smooth income during peak oil shocks. One might expect residents to migrate to energy producing states during a peak oil shock to smooth income and consumption. Barro and Salai-Martin (1991) found that American migrate at the rate of slightly less than three percent per year using periodic and irregular data published by the Bureau of the Census. To test the impact of oil shocks on state migration, I first compute the growth rate of gross state product without migration. I then regress the growth rate in gross state product per capita on the change in the gross state migration rate per capita for energy and non-energy producing states with time fixed effects using new annual data from the Bureau of Census for the period 2000-2007. The results, reported Table 7, suggest that migration does not appear to be a very important source of income and consumption smoothing during periods of a large rise in oil. The coefficient of .97 represents the fraction of shocks that were not smoothed in energy and non-energy producing states by migration

over the period 2000-2007. The results are approximately equal to the one-year elasticity of the one-year net migration rate Barro and Sala-i-Martin (1991) found for the United States. My results suggest that migration is not very different between energy and non-energy producing states over the recent oil shocks. The results are not very conclusive, however, given that the analysis is based on one oil shock that does not include the peak oil shock of 2008 and subsequent economic downturn. This is an item of future research as additional migration data become available and oil shocks occur.

III. Conclusion

What is the meaning of energy independence? One interpretation of this widely used word by politicians, pundits, and members of the press is that it is an increased ability to share risks across an economy by increasing domestic energy production. Although oil shocks reduce economic activity in an economy as consumers and firms are forced to allocate a greater share of their budget for transportation and the production of goods, they also increase economic activity in areas that produce energy. This leads to an increased amount of income and consumption smoothing in an economy. Alaska, for example, often experiences a boom when there is an oil shock. The existence of Alaska and other energy states helps to insulate the US economy from the negative effects of oil shocks through capital markets and to a lesser extent through the federal tax-transfer system.

This study has several implications for policymakers. First, it shows than an analysis of oil shocks on the entire US economy suffers from aggregation bias. Oil shocks have a different effect on energy and non-energy producing states. Second, the

study shows the potential benefits of increasing domestic energy production in the presence of imperfect capital market/home bias. The wealth effects of increased energy production would help residents of a state smooth consumption and income over time. Increased domestic energy production could take the form of off-shore oil exploration, increased drilling on public lands, or tapping the large US natural gas reserves. Indeed, several states are considering whether or not they should increase drilling on public lands and Congress is discussing the impact of expanding oil exploration and drilling in the Gulf of Mexico and Atlantic Ocean. Third, the analysis provides little insight into the possible benefits of increasing alternative energy production in the United States. This is simply too difficult to do on a macroeconomic level given that alternative energy accounts for a very small fraction of total energy consumption in the United States. But alternative sources of energy are unlikely to be an important source of energy and interstate risk sharing in the United States given that they are generally inefficient and costly.

A simpler and potentially much more cost effective method for hedging against peak oil shocks is financial markets. The empirical analysis suggests that energy producing states have a much larger amount of total smoothing (income and consumption) than non-energy states. This might suggest that residents in non-energy states should increase the size of the energy sector in their wealth portfolios to hedge against oil shocks. Although data on individual stock portfolios is not widely available, future research could simulate the potential impact of increase the weight of the energy sector in a theoretical wealth portfolio. The downside of this policy is that there may be

political reasons (terrorism and reliance on failed states for oil imports) that the United States may want to increase domestic energy production.

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Table 1. Results of Panel Regression

Estimates of Income and Consumption Smoothing (Percent): Subperiods

Panel A. All States

	1963-1969	1970-1979	1980-1989	1990-1999	2000-2007	1995-2005	1963-2007
(Capital Markets) β_K	24.28	31.85	59.64	62.89	51.46	65.14	48.29
	(4.88)	(4.18)	(11.87)	(6.88)	(8.40)	(7.44)	(6.30)
(Federal Govt.) β_F	7.24	9.81	9.08	3.00	9.97	6.17	8.01
	(1.75)	(1.59)	(1.31)	(1.73)	(1.87)	(1.41)	(0.65)
(Credit Markets) β_C	26.33	27.15	4.34	4.02	28.03	12.84	13.52
	(10.76)	(8.06)	(6.66)	(6.40)	(8.08)	(5.20)	(5.15)
(Not Smoothed) β_U	42.15	31.20	26.94	30.10	10.53	15.85	30.19
	(8.17)	(5.61)	(5.99)	(7.91)	(9.83)	(5.06)	(4.32)

Panel B. Oil States

	1963-1969	1970-1979	1980-1989	1990-1999	2000-2007	1995-2005	1963-2007
(Capital Markets) β_K	39.27	37.71	102.96	83.61	91.00	86.53	72.53
	(6.27)	(2.22)	(14.12)	(5.35)	(19.47)	(14.92)	(3.30)
(Federal Govt.) β_F	4.84	15.44	5.29	-1.29	3.89	-0.12	5.90
	(4.52)	(0.82)	(1.76)	(2.03)	(5.60)	(2.14)	(0.70)
(Credit Markets) β_C	15.35	28.38	-21.75	-1.28	2.81	4.32	4.05
	(22.09)	(8.88)	(8.48)	(17.22)	(19.44)	(12.50)	(6.05)
(Not Smoothed) β_U	40.55	18.47	13.50	18.96	2.30	9.28	17.52
	(19.06)	(8.00)	(5.77)	(13.15)	(11.45)	(4.86)	(5.90)

Panel C. Non Oil States

	1963-1969	1970-1979	1980-1989	1990-1999	2000-2007	1995-2005	1963-2007
(Capital Markets) β_K	21.77	28.81	37.11	46.60	43.10	52.11	34.47
	(5.21)	(5.79)	(1.62)	(7.32)	(6.62)	(7.60)	(3.70)
(Federal Govt.) β_F	7.79	6.82	9.79	5.59	12.18	8.91	8.38
	(1.94)	(0.98)	(0.78)	(1.37)	(1.20)	(1.25)	(0.62)
(Credit Markets) β_C	27.35	33.47	11.17	5.20	28.31	17.91	18.70
	(11.82)	(11.25)	(8.37)	(6.90)	(10.53)	(6.37)	(7.71)
(Not Smoothed) β_U	43.09	30.90	41.94	42.62	16.40	21.07	38.45
	(9.27)	(7.88)	(7.44)	(8.20)	(13.55)	(6.78)	(5.41)

Note: Standard Errors are in parenthesis.

Table 2. Oil Production as a Percent of Gross State Product

	1963-1969	1970-1979	1980-1989	1990-1999	2000-2006	1963-2006
Alaska	9.12	11.45	37.37	21.72	18.86	20.48
Louisiana	21.51	22.22	26.93	13.45	9.42	19.15
New Mexico	12.16	12.72	15.58	5.56	8.13	10.93
Oklahoma	9.68	9.31	14.60	5.25	6.52	9.20
Texas	10.08	10.36	13.01	6.76	5.91	9.39
Wyoming	21.56	20.10	27.36	16.49	12.54	19.96
Average	14.02	14.36	22.48	11.54	10.23	14.85

Table 3. Analysis of Real GDP and growth rate of Real GDP

Sample: Real GDP data (in millions) by state (1977-2007)

1. All States: GDP, growth rate of GDP

	Min.	Max	Mean	Standard Deviation
GDP	4,644,115	11,465,764	7,583,483	2,138,542
Growth rate of GDP	-1.24%	7.38%	3.01%	1.82%

2. Energy Rich States: GDP, growth rate of GDP

	Min.	Max	Mean	Standard Deviation
GDP	513,352	1,273,721	824,471	226,717
Growth rate of GDP	-4.08%	5.84%	3.03%	2.30%

3. No Energy States: GDP, growth rate of GDP

	Min.	Max	Mean	Standard Deviation
GDP	4,186,428	10,298,644	6,836,271	1,926,645
Growth rate of GDP	-1.33%	7.55%	3.00%	1.90%

Table 4. Results of Panel Regression
Estimates of Income and Consumption Smoothing for Different Frequencies of the Data (Percent)

Panel A. All States

	k=1	k=2	k=3	k=5	k=10
(Capital Markets) β_K	48.29	40.10	42.50	32.20	28.90
	(6.30)	(3.50)	(3.60)	(4.10)	(5.80)
(Federal Govt.) β_F	8.01	9.30	9.40	8.50	5.10
	(0.65)	(0.70)	(0.70)	(1.10)	(1.10)
(Credit Markets) β_C	13.52	12.10	6.80	8.00	3.10
	(5.15)	(3.90)	(3.10)	(5.00)	(3.60)
(Not Smoothed) β_U	30.19	38.50	41.40	51.30	63.00
	(4.32)	(4.90)	(5.00)	(5.10)	(6.70)

Panel B. Oil States

	k=1	k=2	k=3	k=5	k=10
(Capital Markets) β_K	72.53	52.70	51.60	45.20	43.40
	(3.30)	(2.90)	(5.00)	(4.10)	(3.30)
(Federal Govt.) β_F	5.90	6.90	6.10	1.40	0.40
	(0.70)	(0.80)	(0.90)	(1.20)	(2.00)
(Credit Markets) β_C	4.05	16.90	14.40	8.00	-3.80
	(6.05)	(8.00)	(10.00)	(8.10)	(4.30)
(Not Smoothed) β_U	17.52	23.50	27.90	45.40	60.00
	(5.90)	(7.00)	(5.40)	(4.70)	(6.50)

Panel C. NonOil States

	k=1	k=2	k=3	k=5	k=10
(Capital Markets) β_K	34.47	30.40	31.60	22.70	13.60
	(3.70)	(2.60)	(4.10)	(2.30)	(4.10)
(Federal Govt.) β_F	8.38	10.00	10.50	9.60	4.50
	(0.62)	(0.70)	(0.50)	(0.80)	(1.00)
(Credit Markets) β_C	18.70	11.50	3.40	10.70	2.40
	(7.71)	(6.10)	(3.60)	(7.40)	(6.60)
(Not Smoothed) β_U	38.45	48.20	54.50	57.00	79.50
	(5.41)	(6.00)	(5.40)	(8.30)	(8.60)

Note: Standard Errors are in parenthesis.

Table 5. Results of Panel Regression during Peak Oil Shocks
Estimates of Income and Consumption Smoothing (Percent): Subperiods

Panel A. All States

	1971-1974	1978-1981	2004-2007	1970-1985
(Capital Markets) β_K	30.10	49.21	38.95	39.65
	(5.71)	(7.32)	(9.59)	(4.20)
(Federal Govt.) β_F	8.43	6.86	13.36	9.43
	(1.96)	(1.99)	(2.96)	(0.50)
(Credit Markets) β_C	29.58	9.47	32.42	20.52
	(10.91)	(9.73)	(9.29)	(6.35)
(Not Smoothed) β_U	31.89	34.45	15.27	30.40
	(7.52)	(8.64)	(12.08)	(4.55)

Panel B. Oil States

	1971-1974	1978-1981	2004-2007	1970-1985
(Capital Markets) β_K	45.10	66.79	75.92	44.57
	(3.80)	(4.46)	(52.42)	(2.27)
(Federal Govt.) β_F	19.39	-1.12	21.37	11.17
	(5.89)	(1.79)	(14.90)	(0.89)
(Credit Markets) β_C	29.24	7.68	23.88	28.32
	(12.31)	(21.99)	(23.51)	(7.06)
(Not Smoothed) β_U	6.27	26.66	-21.18	15.94
	(17.21)	(21.50)	(30.83)	(6.32)

Panel C. Non-Oil States

	1971-1974	1978-1981	2004-2007	1970-1985
(Capital Markets) β_K	23.89	18.36	36.20	30.43
	(5.31)	(6.88)	(7.63)	(4.54)
(Federal Govt.) β_F	5.17	11.78	13.23	8.67
	(1.45)	(1.24)	(1.89)	(0.75)
(Credit Markets) β_C	36.63	27.53	24.13	25.09
	(12.77)	(16.16)	(11.68)	(9.64)
(Not Smoothed) β_U	34.31	42.33	26.43	35.81
	(9.98)	(13.01)	(14.50)	(6.37)

Note: Standard Errors are in parenthesis.

Table 6. Summary Statistics for State Employment Data, 1976-2008

All States: Unemployment and labor force, rate of unemployment, rate of change of unemployment

	Min.	Max	Mean	Standard Deviation
Unemployed	5,826,145	10,952,409	7,873,067	1,264,859
Labor Force	96,968,657	155,365,644	128,847,089	17,135,198
Unemployment Rate	4.05%	9.79%	6.23%	1.39%

Energy Rich States: Unemployment and labor force, rate of unemployment, rate of change of unemployment

	Min.	Max	Mean	Standard Deviation
Unemployed	498,374	1,222,321	842,704	180,785
Labor Force	9,252,957	17,138,136	13,715,992	2,196,938
Unemployment Rate	4.24%	9.48%	6.21%	1.35%

No Energy States: Unemployment and labor force, rate of unemployment, rate of change of unemployment

	Min.	Max	Mean	Standard Deviation
Unemployed	4,420,755	8,955,718	6,164,803	1,057,675
Labor Force	79,685,095	122,836,144	102,974,846	12,806,552
Unemployment Rate	3.86%	9.99%	6.11%	1.48%

Table 7. Effects of Interstate Migration: Results of Panel Regression

	2001-2008
All States	96.53
	(0.78)
Oil or Coal States	95.61
	(0.82)
NonOil or Coal States	93.11
	(4.76)

Note: Standard Errors are in parenthesis.

Figure 1. Oil Product as Share of GSP

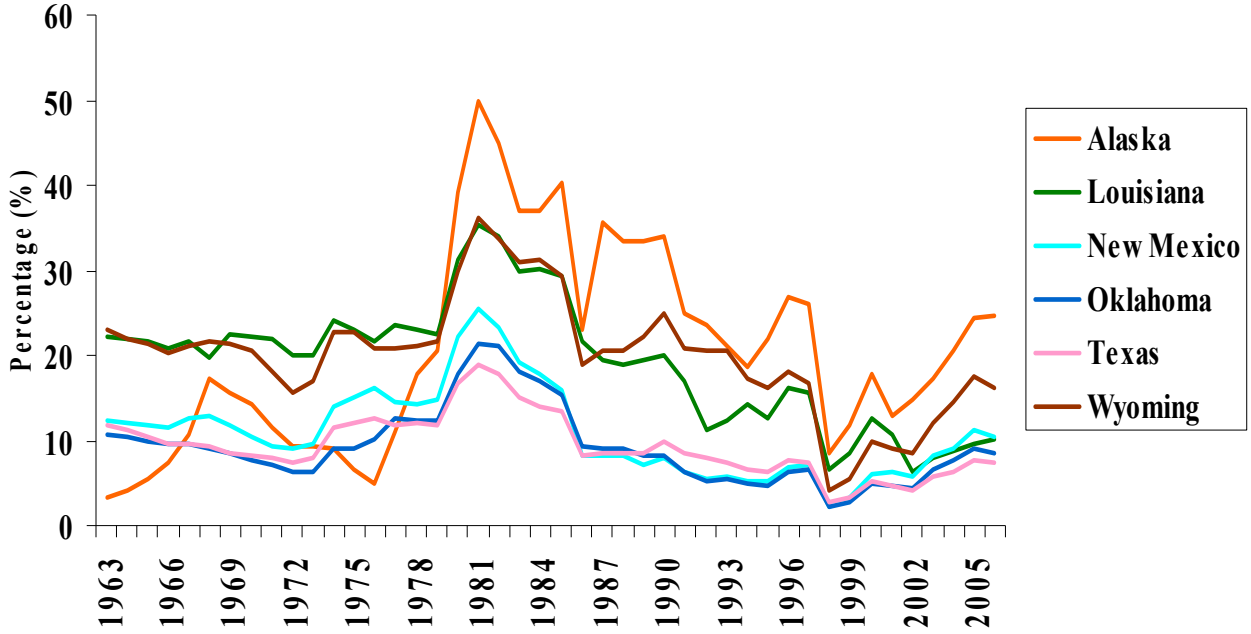
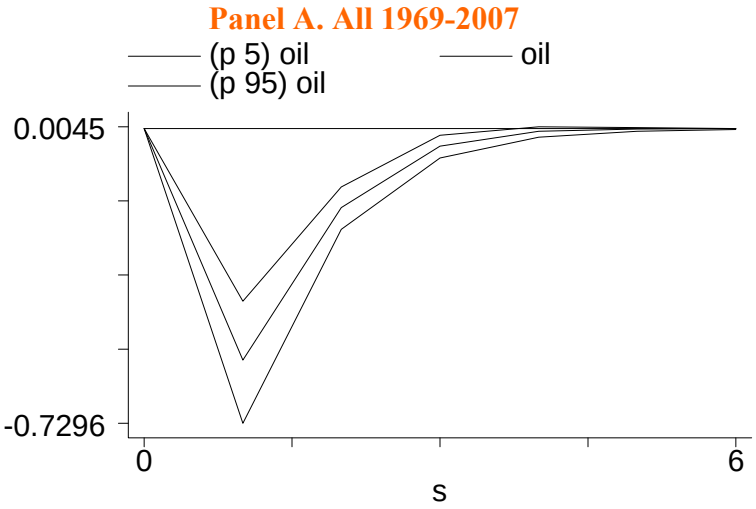
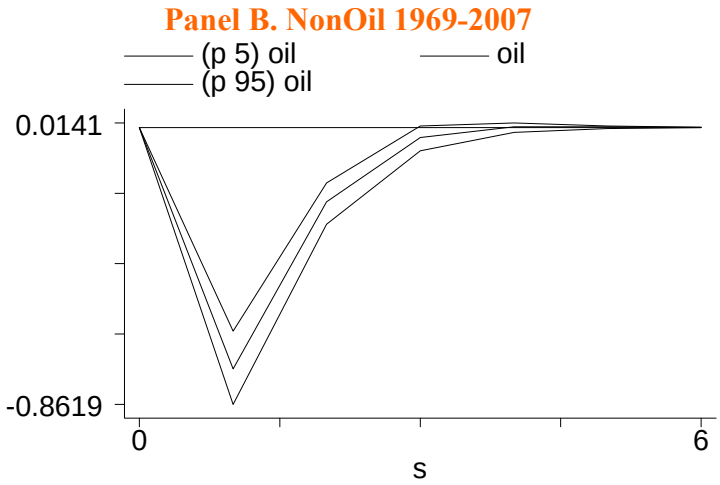


Figure 2. GSP Growth Rate (1969-2007)





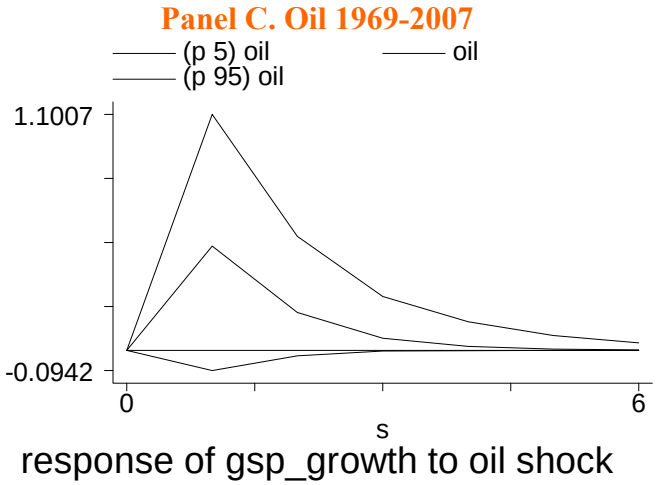
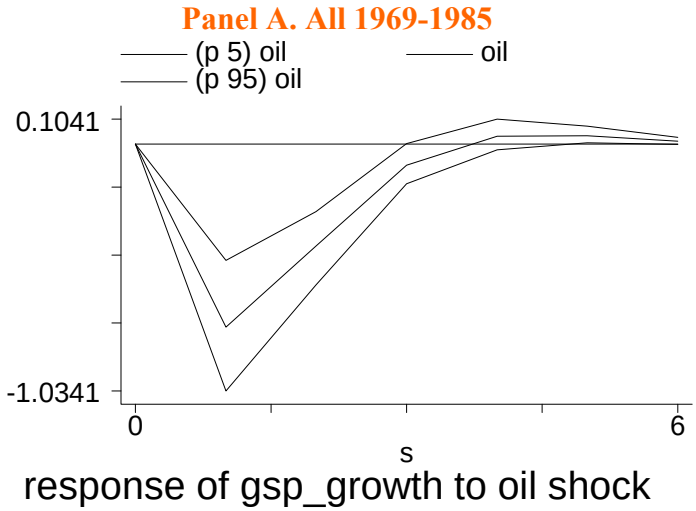
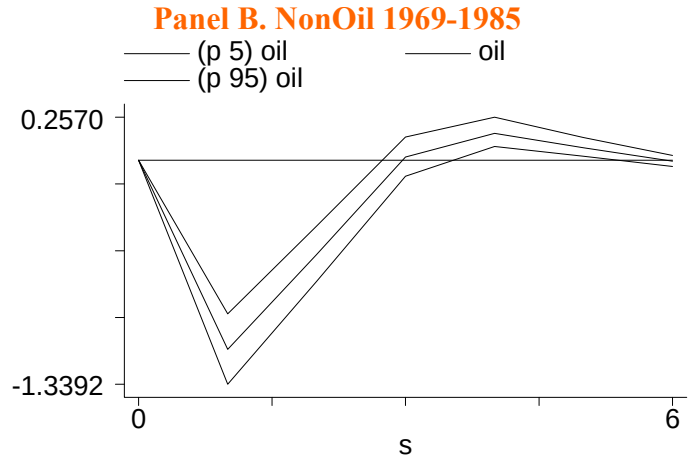


Figure 3. GSP Growth Rate (1969-1985)





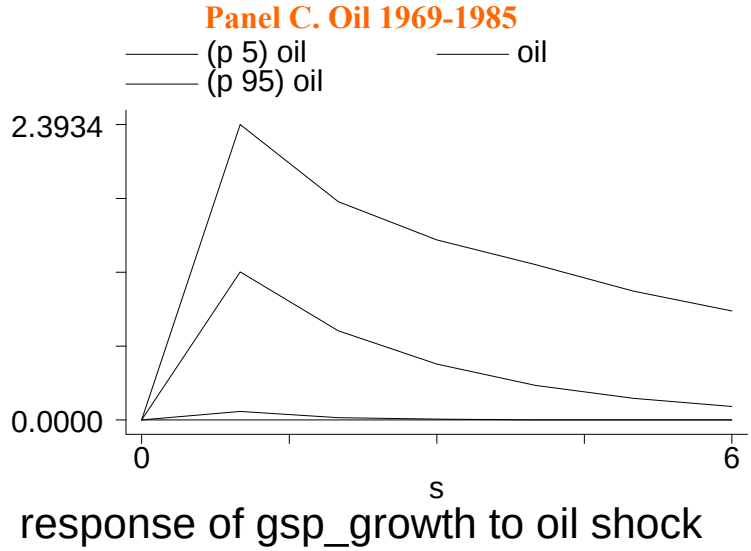
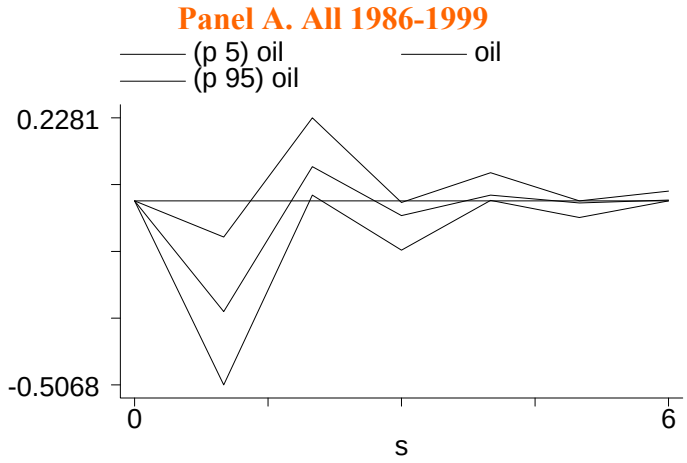
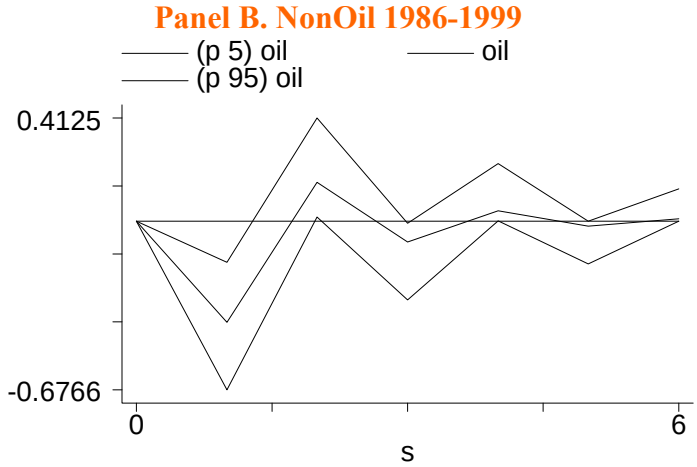


Figure 4. GSP Growth Rate (1986-1999)





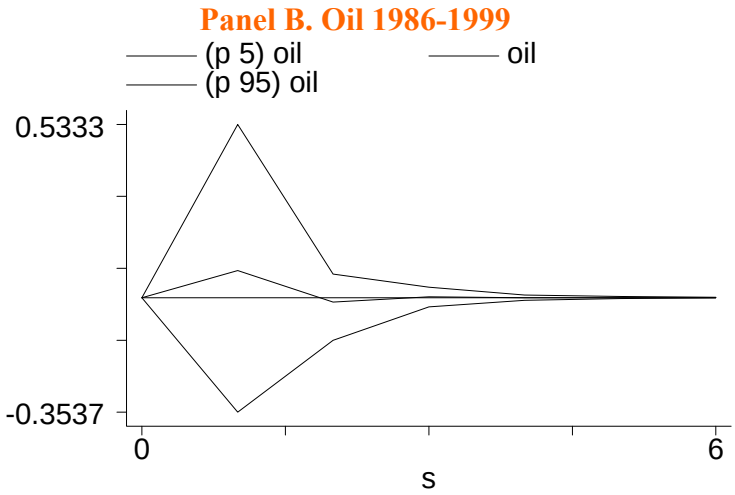
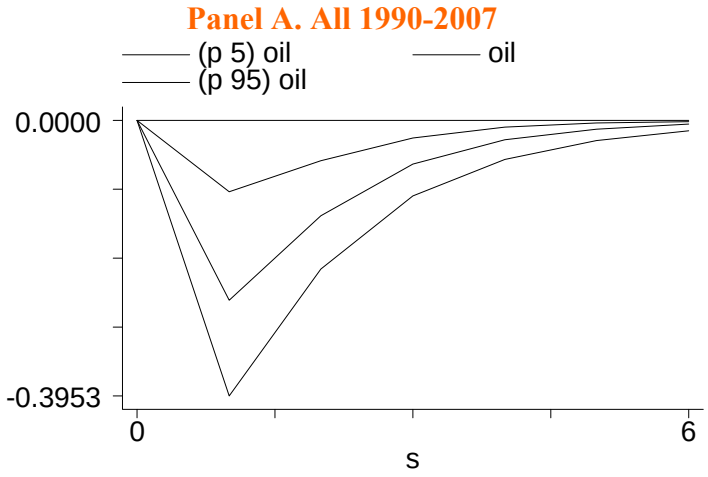
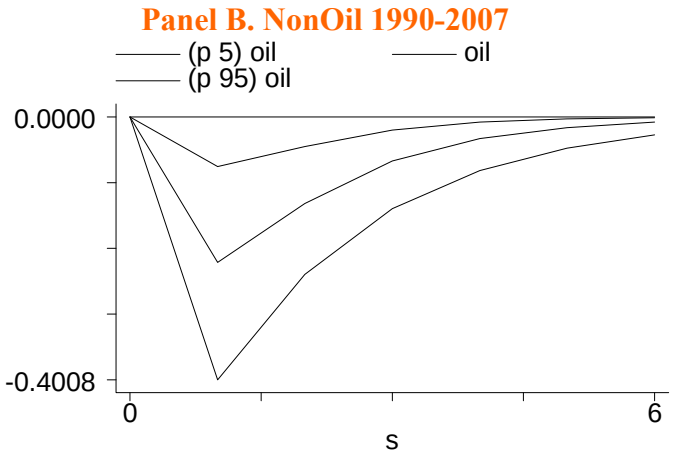


Figure 5. GSP Growth Rate (1990-2007)





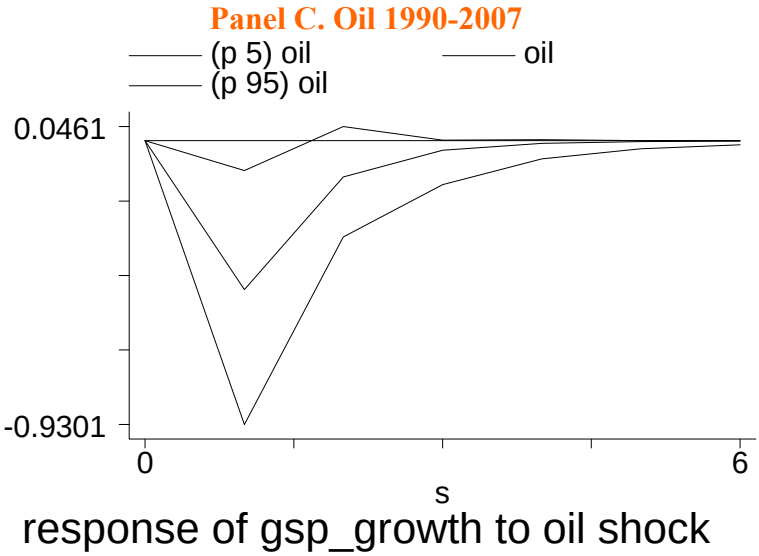
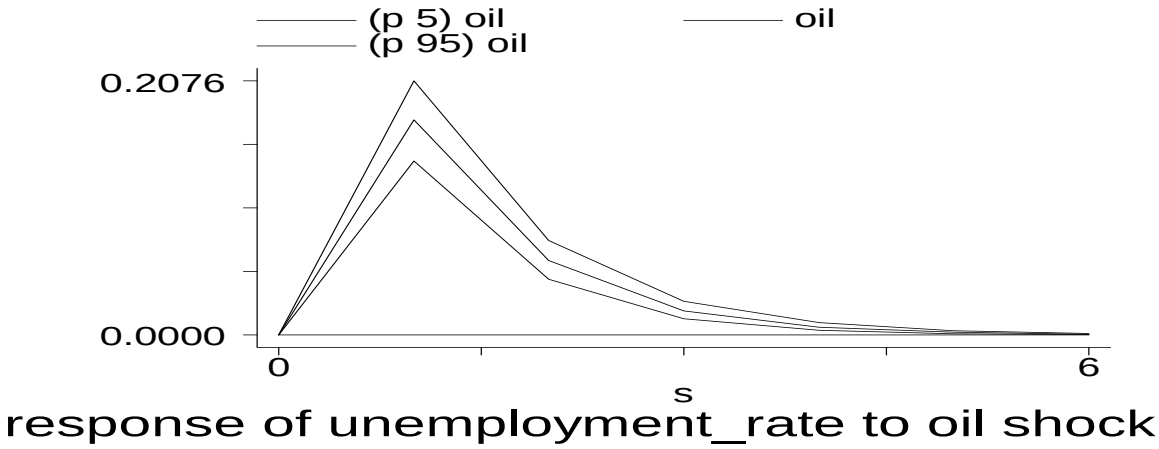
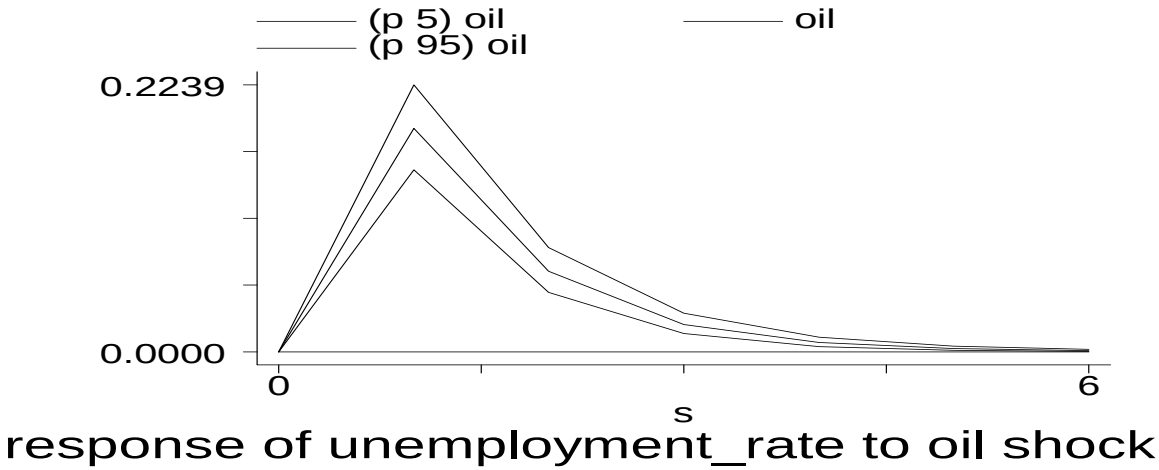


Figure 6. Unemployment Rate (1976-2008)

Panel A. All 1976-2008



Panel B. NonOil 1976-2008



Panel C. Oil 1976-2008

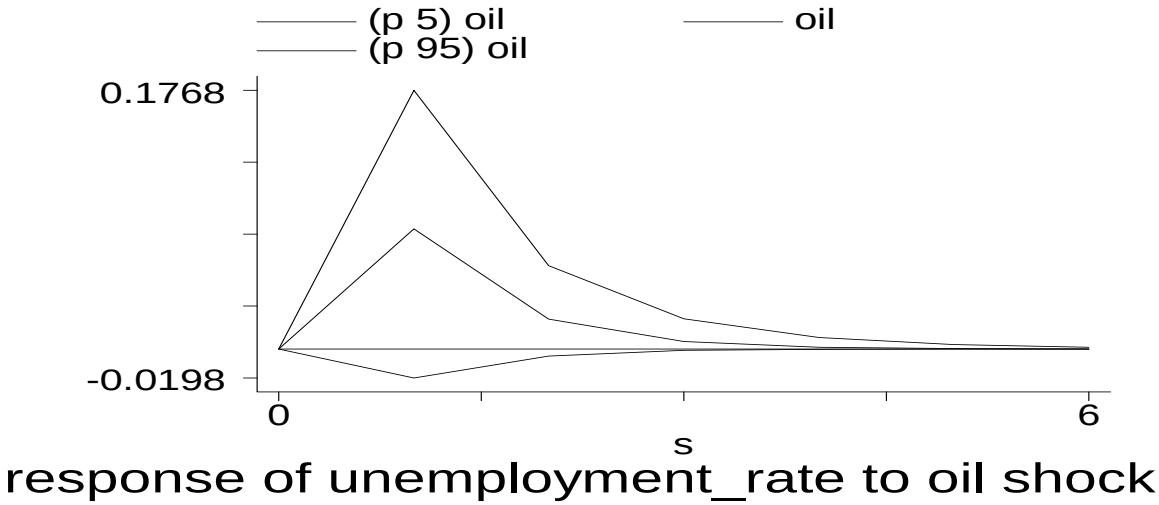
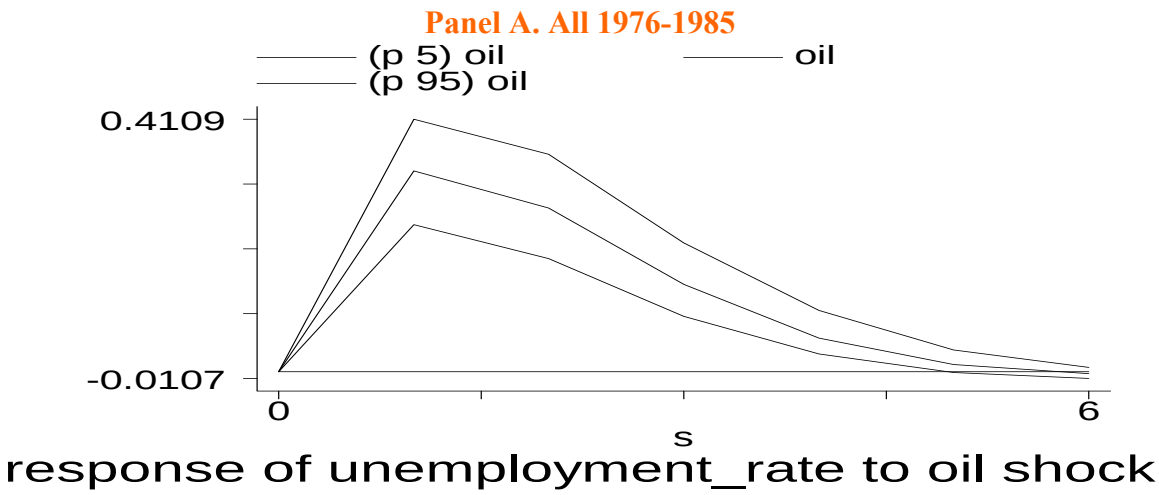
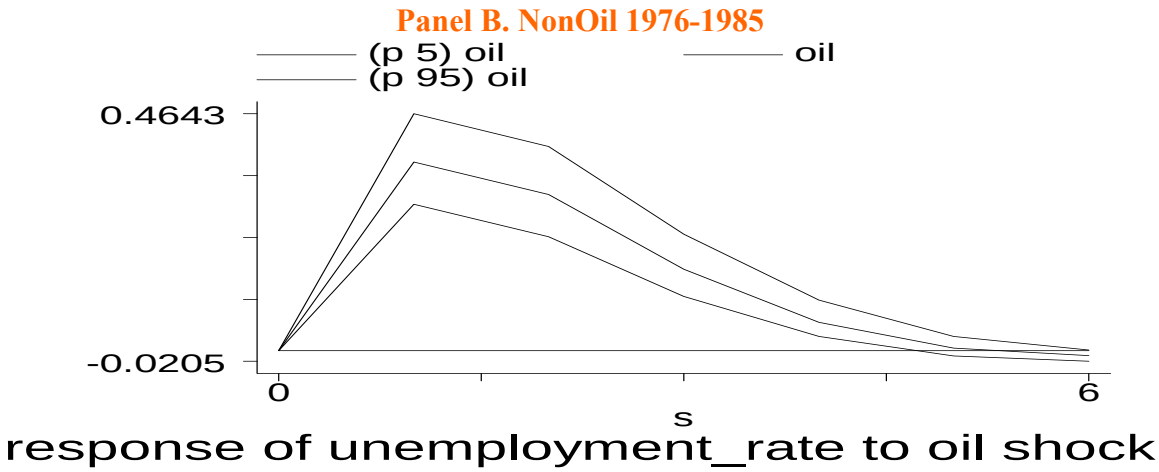


Figure 7. Unemployment Rate (1976-1985)





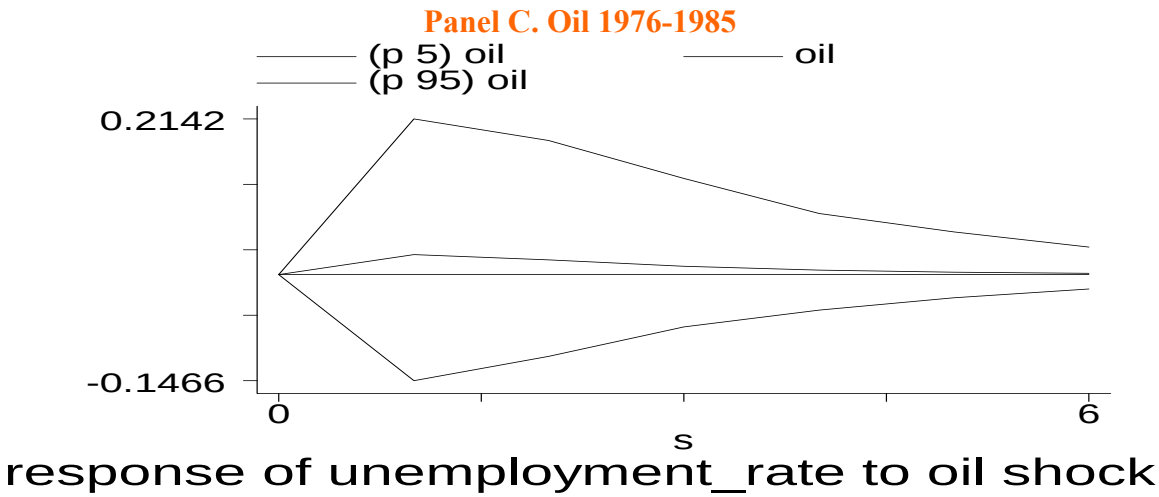


Figure 8. Unemployment Rate (1986-1999)

Panel A. All 1986-1999

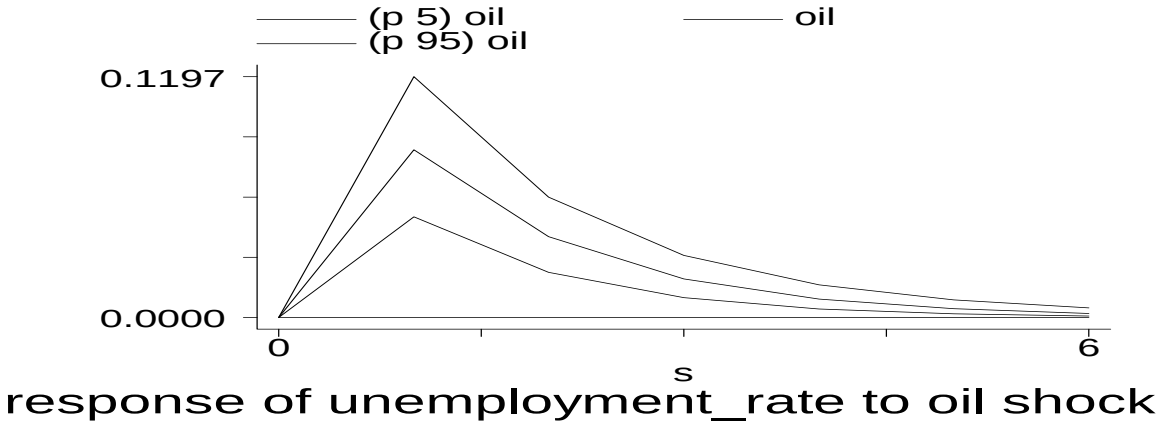
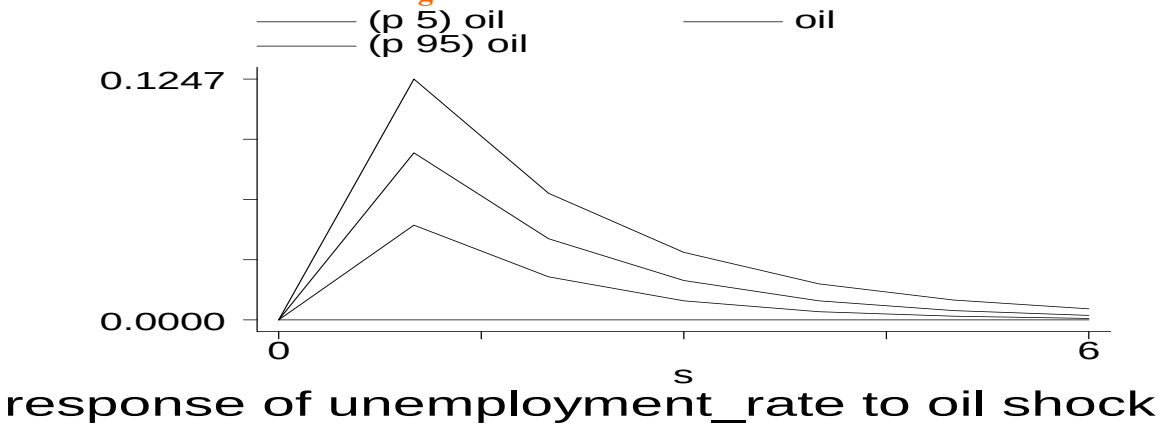


Figure B. NonOil 1986-1999



Panel C. Oil 1986-1999

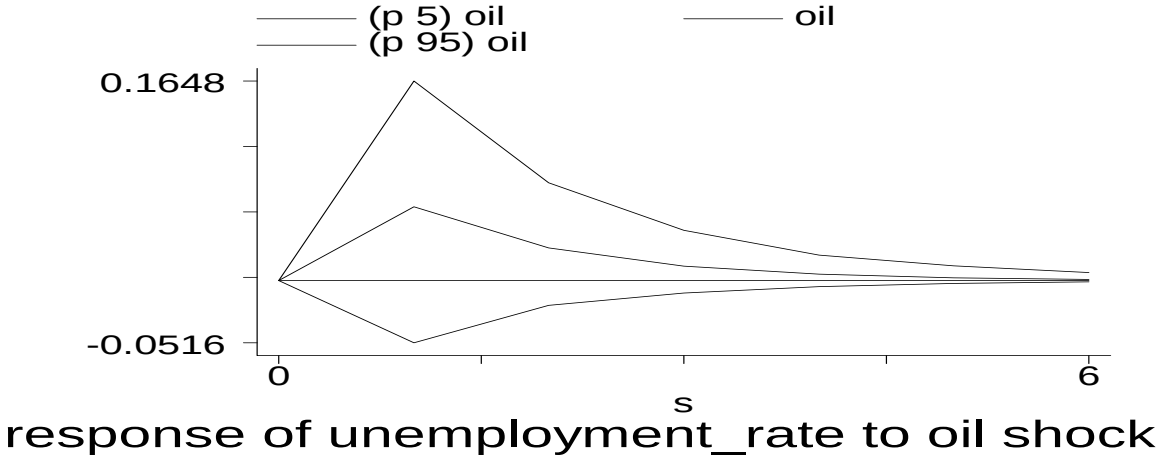
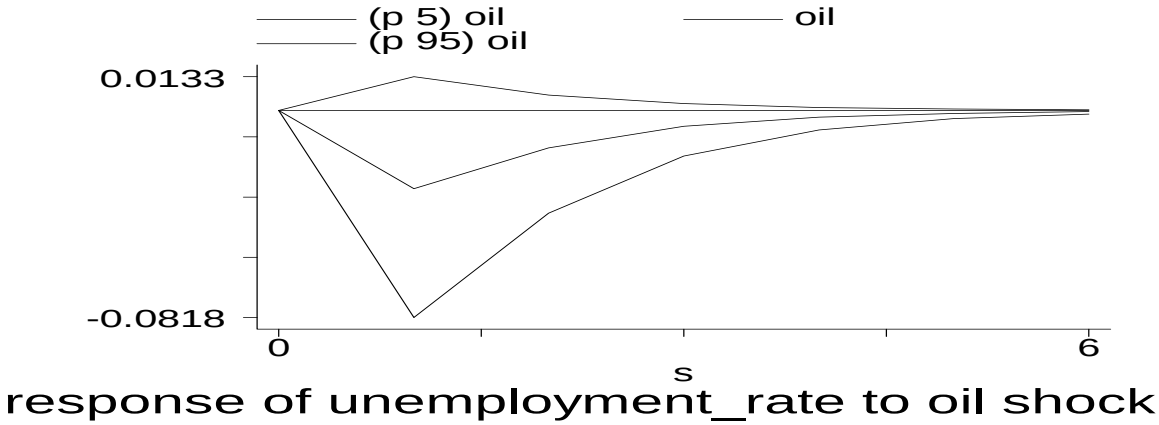
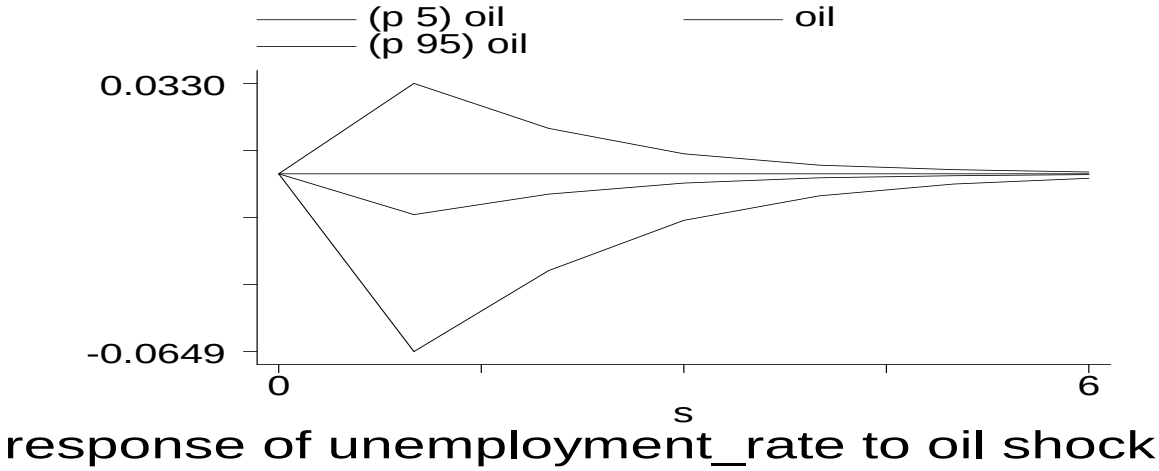


Figure 9. Unemployment Rate (1990-2008)

Panel A. All 1990-2008



Panel B. NonOil 1990-2008



Panel C. Oil 1990-2008

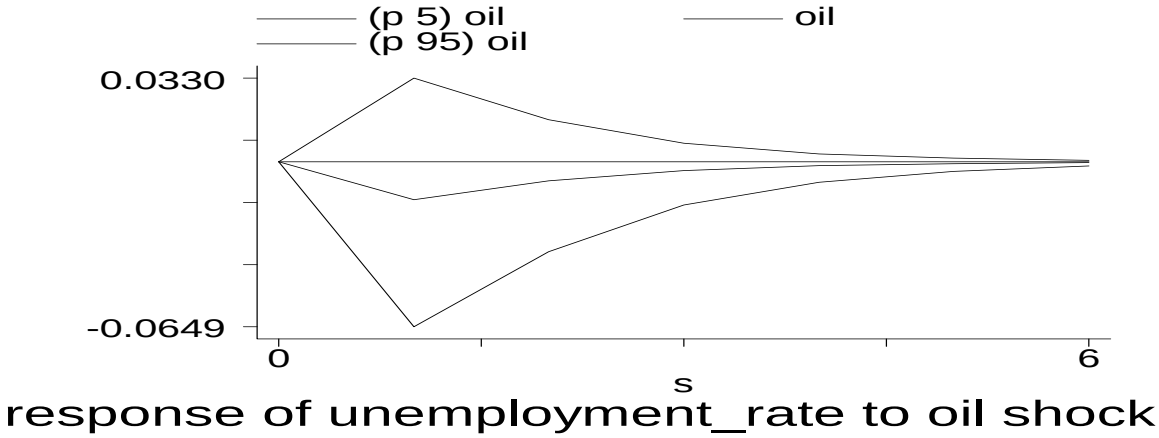
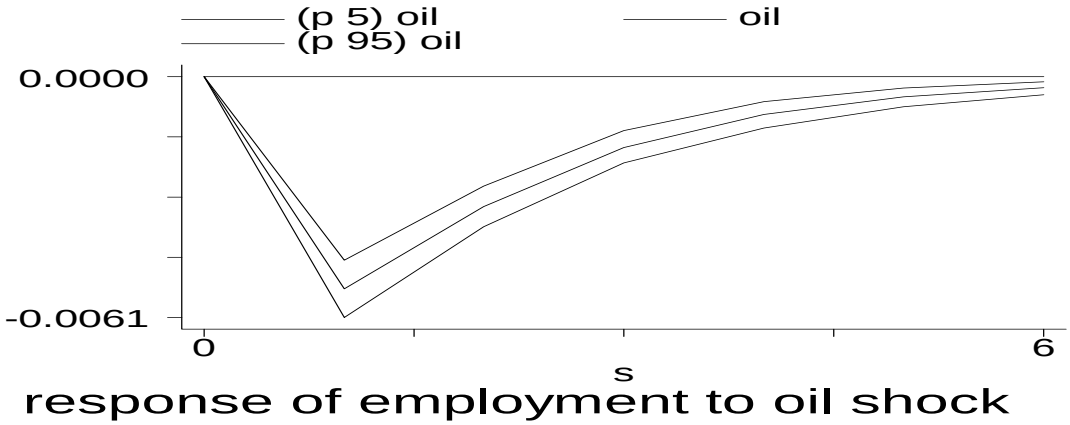


Figure 10. Nonfarm Employment (1970-2007)

Panel A. All 1970-2007



Panel B. NonOil 1970-2007

Panel C. Oil 1970-2007

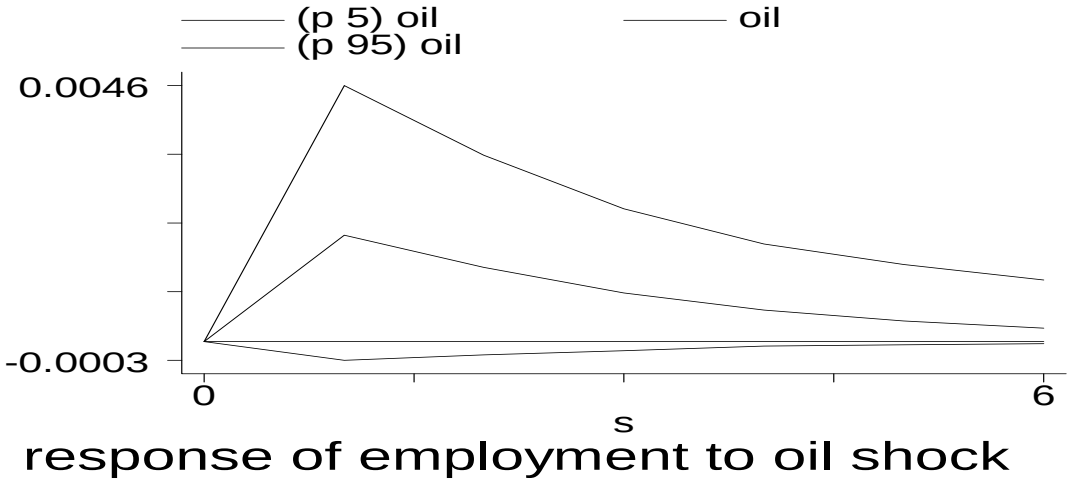
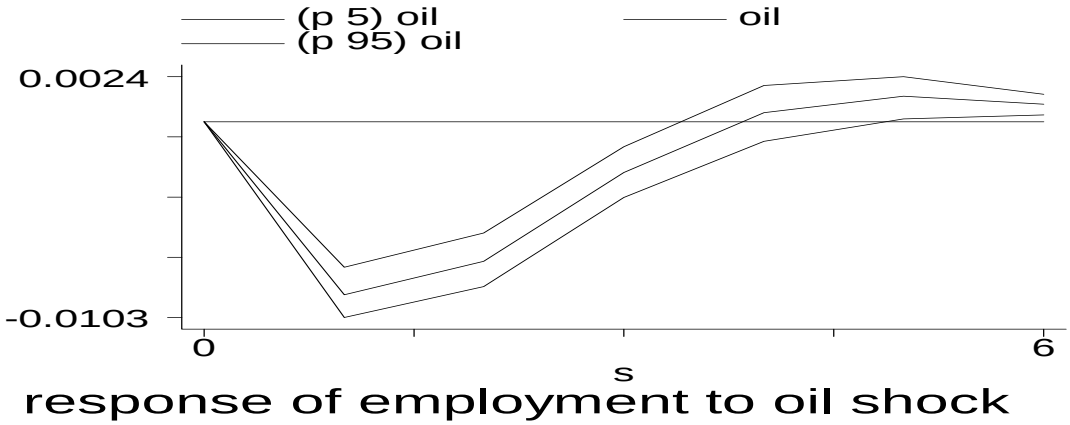


Figure 11. Nonfarm Employment (1970-1985)

Panel A. All 1970-1985



Panel B. NonOil 1970-1985

Panel C. Oil 1970-1985

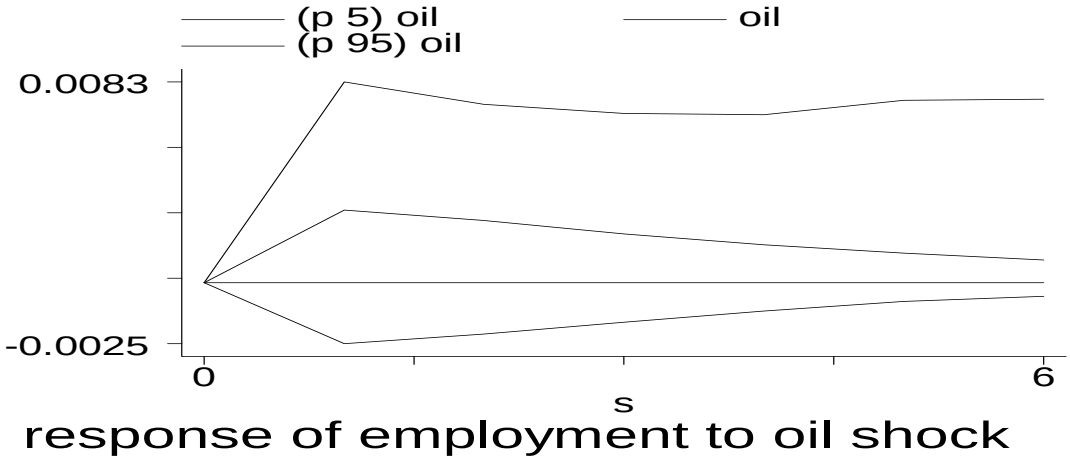
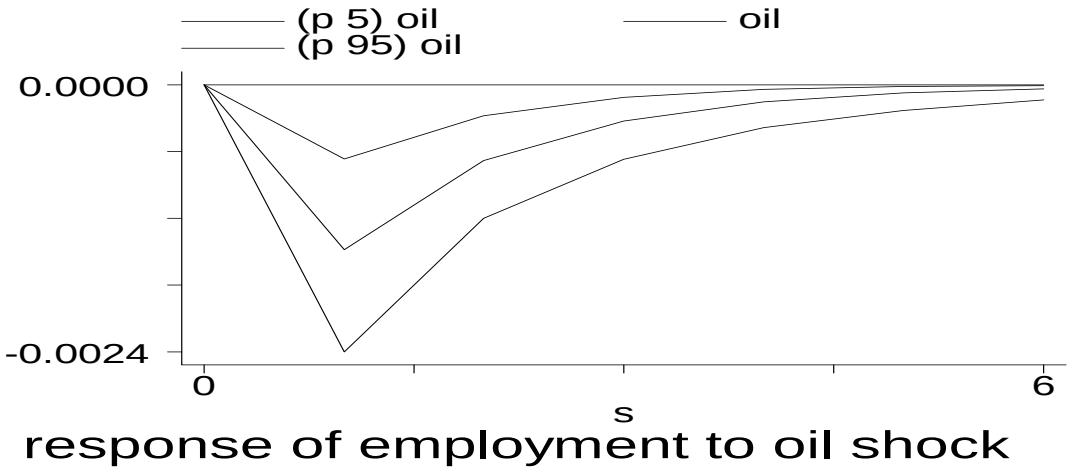


Figure 12. Nonfarm Employment (1986-1999)

Panel A. All 1986-1999

Panel B. NonOil 1986-1999



Panel C. Oil 1986-1999

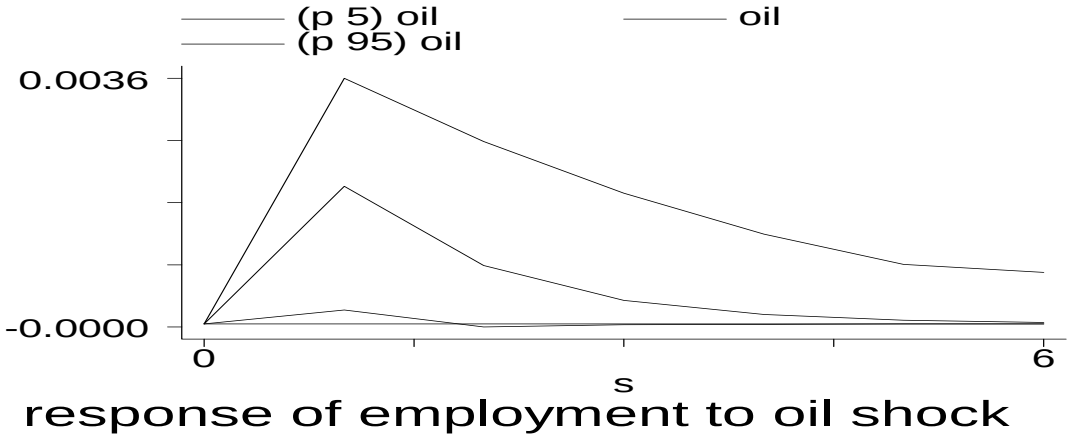


Figure 13. Nonfarm Employment (1990-2007)

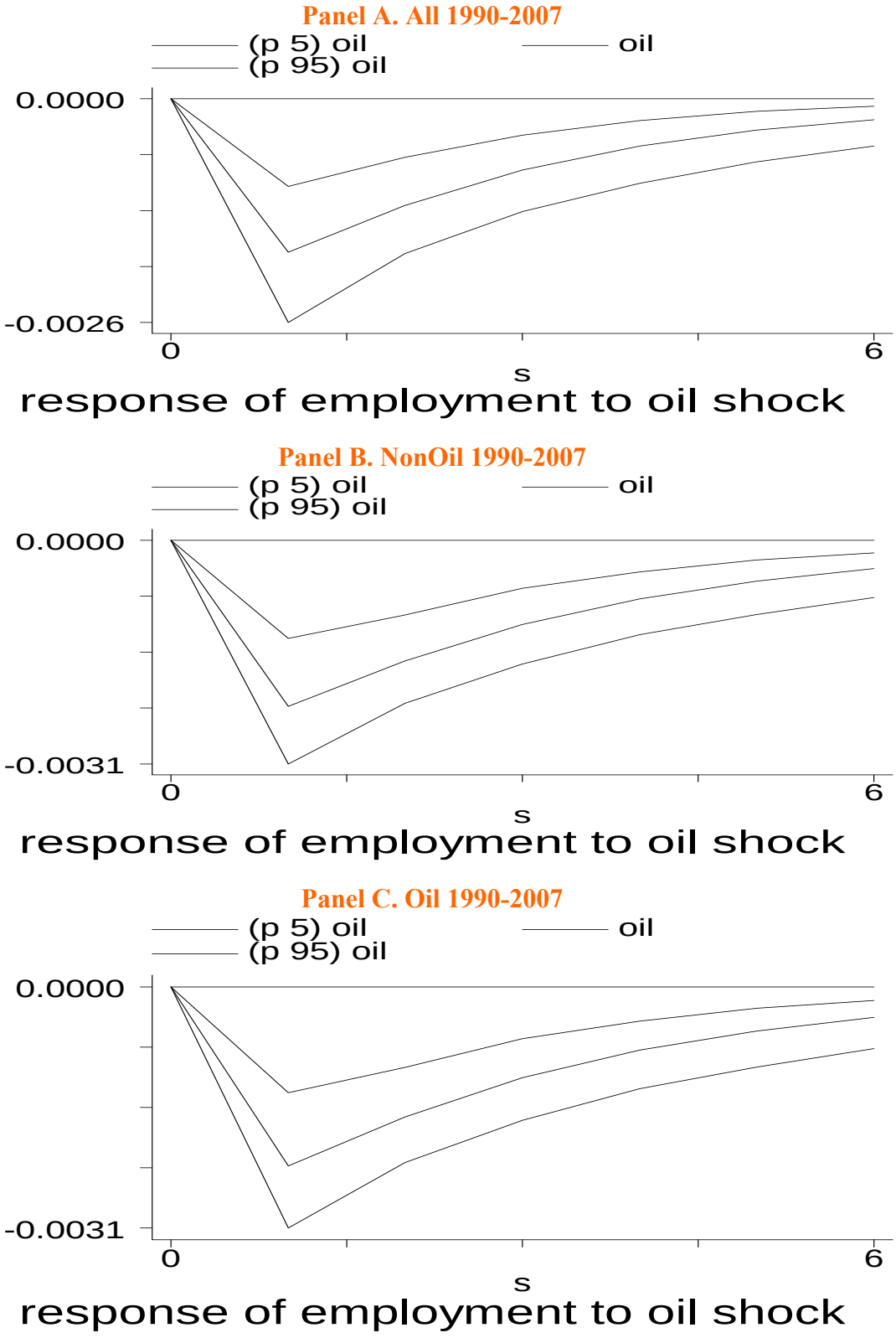
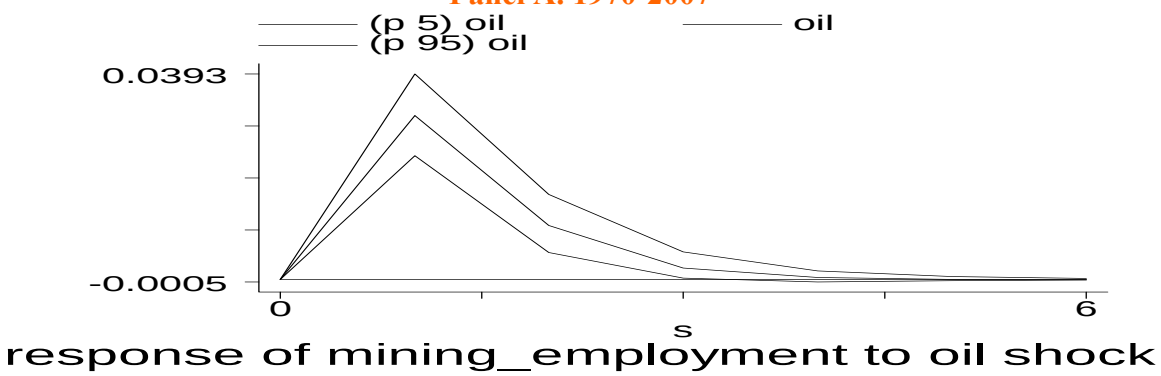
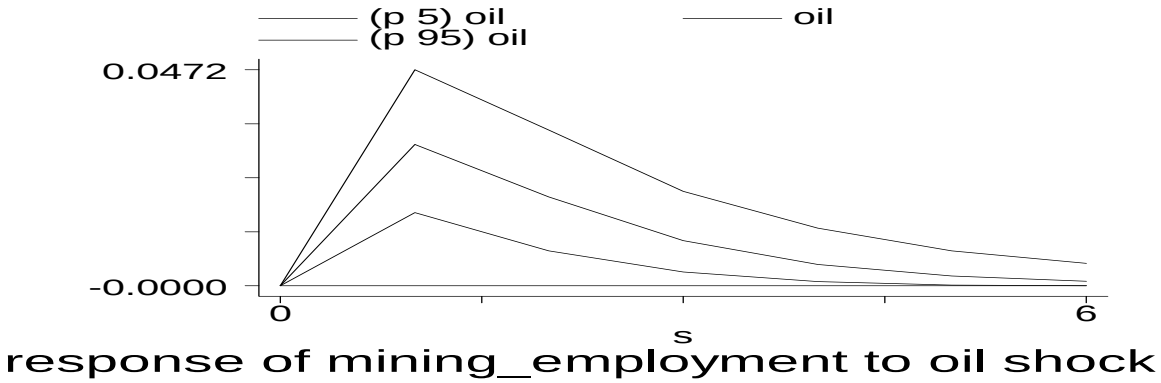


Figure 14. Mining Employment in Oil or Coal States

Panel A. 1970-2007



Panel B. 1970-1985



Panel C. 1986-1999

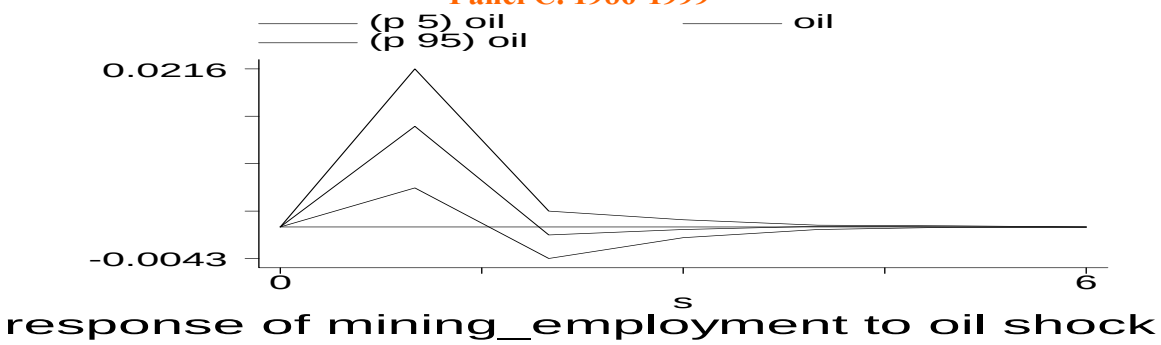
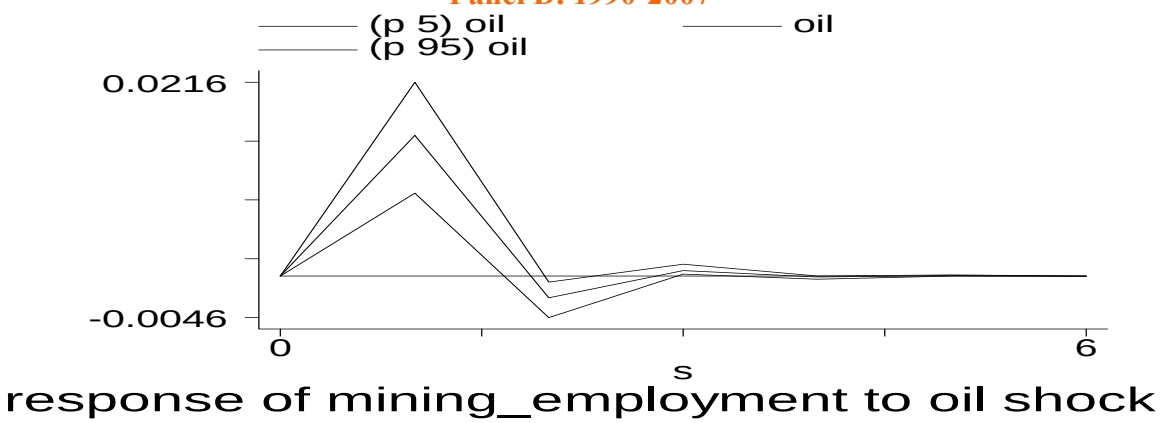


Figure 14. Mining Employment in Oil or Coal States

Panel D. 1990-2007