THE IMPACT OF OIL PRICE FLUCTUATIONS ON THE ECONOMIES OF ENERGY PRODUCING STATES

Gary L. Hunt*

Introduction

Since the end of 1981, oil prices have been falling in both nominal and real terms. As measured by the refiners' acquisition cost of crude oil, nominal oil prices fell about $10 per barrel between 1981 and 1985. Another decline of nearly $14 per barrel occurred between the fourth quarter of 1985 and the second quarter of 1986. These declines reversed the general trend of rising oil prices experienced during the 1970s.

There are several channels through which these oil price fluctuations influence the economic performance of energy producing states. Direct effects are experienced in the oil and gas industry as production, drilling, and exploration activities change. These changes produce indirect and induced effects in other sectors, the magnitude of which depends on the extent to which the state's economy is integrated around oil and gas. Additional influences are transmitted through channels that are related to changes in the level and composition of macroeconomic activity. Factor intensities may also be affected.

The purpose of this paper is to identify several of the key channels through which oil price fluctuations affect the economies of energy producing states and to estimate the size of these effects for several selected states. These estimates are used to assess the role of fluctuating oil prices in the selected states' recent economic performance and to provide an indication of near-term future trends.

In the next section, the historical trends in oil prices are presented along with several measures of state economic performance for Colorado, Oklahoma, and Wyoming. The extent of both sectoral diversity and integration around oil and gas differs substantially across these states and therefore provides a rich set of experience on which to estimate the range of impacts that fluctuating oil prices can have at the state level.

In the section on model specification, the various channels of influence are identified and a small-scale model is specified to incorporate the key channels. In the section on empirical methodology, the data and econometric methodology are presented and discussed. In the section on estimated equations, the econometric estimates are presented and analyzed. The implications for state economic performance are discussed in the final section in the context of recent performance.

Overview of Historical Peformance

Oil Prices

In the first quarter of 1973, the refiners' acquisition cost of crude oil (composite of domestic and imported) stood at $4.88 per barrel. Within one year, the per barrel cost had increased to $8.24 and represented the first of two oil price shocks that would occur over the period 1974 through 1981. After another year had passed, the refiners' cost was at $9.83. The cost continued to rise steadily through 1978, and by the first quarter of 1979 was at $13.41 per barrel. During the course of 1979, the second oil price shock was initiated. By the first quarter of 1980, the refiners' cost had climbed to $25.93 per barrel. The cost per barrel peaked (on a quarterly average basis) in the first quarter of 1981 at $36.54. In eight years, the nominal dollar cost of crude oil had increased by almost 650 percent—representing a compound annual growth rate of over 28 percent in nominal terms. In real terms,[1] oil prices had advanced by almost 300 percent, or at a compound annual growth rate of over 18 percent.

Oil prices began to decline in the second quarter of 1981. By the second quarter of 1983, the refiners' cost was at $28.61 per barrel in nominal terms. On a quarterly average basis, the cost fluctuated in the $28-29 per barrel range until 1985, when it moved within the $26.50 to $27.00 range. By the second quarter of 1986, refiners' cost had fallen to about $13 per barrel. In real terms, the price of oil in the second quarter of 1986 was 28 percent of its value in the first quarter of 1981.

State Economic Performance

The economic performance of Colorado, Oklahoma, and Wyoming during the 1970s and 1980s was influenced significantly by behavior of oil prices. As shown in Tables 1, 2, and 3, the growth rate for mining employment[2] was typically very high in these three states in 1973 and 1974, the first oil price shock period, and also during 1979-81, the second oil price shock period. During the interim period, growth in mining employment was generally strong. Although the timing and magnitudes vary across states, the *direct* impact of sharply rising oil

---

*Director, State Economic Modeling Project, Center for Economic Analysis, University of Colorado at Boulder. The author would like to thank Wharton Econometric Forecasting Associates for making available data, software, and simulations of their quarterly U. S. macro model without which this study would not have been feasible.

prices is evident in every case. The decline in oil prices (both in nominal and real terms) that began in 1981 is reflected in negative employment growth in the mining sectors of each state beginning in late 1981 and early 1982. (On a quarterly basis, the decline begins in the first or second quarter of 1982.) This negative growth persists through 1985 and is accentuated in early 1986 when real oil prices declined sharply.

With the exception of national recessionary periods (1974-75 and 1980-82), total employment growth was relatively high in each state during the period of rising oil prices. As oil prices began to fall, however, weakness in total employment growth began to develop. Each of the three states experienced negative growth during 1982 with negative growth also occurring in 1983 in Wyoming. Given the negative impact of the severe 1982 recession on oil prices, the declines in total state employment in 1982 likely reflect the transmission of national business cycle conditions to the three states through the "oil price" channel. However, in the cases of Colorado and Oklahoma, impacts were also transmitted through a decline in the durable goods manufacturing industries present in each states' economic base.

The softness in Oklahoma and Wyoming since the 1982 recession year is probably largely attributable to declining real oil prices. Colorado has felt this pressure as well, as evidenced by declines in oil and gas employment, but the boom in investment and high tech goods in 1984 disguises the negative impacts of a declining oil and gas sector in the state. Since the precipitous decline in oil prices in early 1986, employment growth in all three states has been slow or negative with the exception of a curious growth spurt in Wyoming in the second quarter of 1986.[3]

Unemployment rates for the three states typically are low or declining in the nonrecession years during the period of oil price increases. Since 1982, the rates typically have increased along with declining oil prices. Increases have been particularly sizeable during 1986. The growth rates of real personal income in Colorado, Oklahoma, and Wyoming were correspondingly high during the period of increasing oil and gas activity and escalating

Table 1

Colorado Economic Performance, 1973:1-1986:3
Annualized Growth Rate from Previously Listed Quarter

Quarter	Employment: Oil & Gas	Employment: Total	Real Personal Income	Unemployment Rate
1973:1	—	—	—	3.0
1974:1	12.3	3.3	2.1	3.4
1975:1	18.8	0.4	-2.9	5.1
1976:1	7.8	3.8	6.5	5.0
1977:1	7.8	3.8	3.2	4.9
1978:1	19.8	8.9	8.1	4.0
1979:1	7.3	7.0	5.5	3.2
1980:1	19.4	4.0	1.1	5.1
1981:1	37.3	2.7	1.8	5.6
1982:1	33.6	3.7	5.3	6.6
1983:1	-11.8	-1.0	2.1	7.5
1984:1	1.9	4.7	4.6	6.0
1985:1	- 3.0	3.7	3.8	5.8
1986:1	-10.9	1.9	1.7	6.5
1986:2	24.8	-0.1	2.1	6.9
1986:3	-26.5	-1.7	—	7.2

Sources: Colorado Department of Labor and Employment; U. S. Bureau of Economic Analysis.

Table 2

Oklahoma Economic Performance, 1973:1-1986:3
Annualized Growth Rate from Previously Listed Quarter

Quarter	Employment — Mining	Employment — Total	Real Personal Income	Unemployment Rate
1973:1	—	—	—	NA
1974:1	7.9	5.3	3.2	NA
1975:1	11.3	1.9	-0.2	6.3
1976:1	2.9	3.3	7.0	6.4
1977:1	5.9	3.6	4.3	5.6
1978:1	11.4	4.9	2.7	4.5
1979:1	12.5	6.4	8.5	3.8
1980:1	15.8	5.6	2.3	4.3
1981:1	31.0	4.6	4.2	4.0
1982:1	32.5	5.6	9.0	4.3
1983:1	-29.1	-5.6	-4.0	9.8
1984:1	-9.9	0.9	1.3	7.5
1985:1	-8.4	0.0	2.2	7.6
1986:1	-12.4	-1.2	-0.4	7.9
1986:2	-32.5	0.8	1.7	8.6
1986:3	-15.5	-6.2	NA	8.8

Sources: U.S. Bureau of Labor Statistics; U.S. Bureau of Economic Analysis; Wharton Econometric Forecasting Associates.

real oil prices. However, in the years of the oil price shocks, real income growth slowed due to the impact of sharply escalating oil prices on the general inflation rate. During the period of declining oil prices, the rates of real income growth slowed in Oklahoma and Wyoming relative to the rates experienced during the period of increasing oil prices. Colorado experienced a slowdown as well, except during the investment and high tech boom in 1984.

In summary, the economic performance of Colorado, Oklahoma, and Wyoming in the 1970s and 1980s was influenced significantly by the rise and fall of oil prices. This is most clearly seen in the growth patterns of employment in the oil and gas industry and the mining sector. The data in Tables 1, 2, and 3 also suggest that national business cycle conditions and local industry mix played a role as well. To estimate the extent to which fluctuating oil prices influence the economies of Colorado, Oklahoma, and Wyoming, a small-scale economic model is specified and estimated for each state. These models attempt to capture the main channels through which oil prices and other key factors contribute to state economic performance. Model specification is addressed in the following section. Estimation is treated in the section on empirical methodology.

Model Specification

Oil price fluctuations initially impact a state's economic performance through influencing the level of activity in the state's oil and gas industry and through changes in the overall growth and composition of macroeconomic activity. The magnitude of these direct affects are a function of how responsive oil and gas sector activity is to changes in real oil prices and how responsive the state's industry mix is to changes in the growth rate and composition of aggregate economic activity. In addition, the impact of changing oil prices on the overall level of prices influences the level of real personal income and, therefore, local comsumption.

The direct effects generate indirect effects throughout the locally-oriented business sector. The magnitude of these indirect effects depends on the extent to which the

Table 3

Wyoming Economic Performance, 1973:1 - 1986:3
Annualized Growth Rate from Previously Listed Quarter

Quarter	Employment: Mining	Employment: Total	Real Personal Income	Unemployment Rate
1973:1	—	—		
1974:1	20.3	10.0	7.2	—
1975:1	21.6	7.7	0.4	5.4
1976:1	3.3	6.3	8.9	5.0
1977:1	20.8	7.1	6.7	4.5
1978:1	20.1	13.5	12.1	3.8
1979:1	112.6	7.3	9.6	3.2
1980:1	8.2	6.0	4.8	4.1
1981:1	8.1	5.2	3.6	4.7
1982:1	5.4	2.7	-0.1	5.1
1983:1	-23.8	-7.6	-6.6	9.8
1984:1	-4.8	-2.3	-2.2	7.9
1985:1	-7.5	0.4	1.8	7.9
1986:1	-3.4	0.3	4.2	10.4
1986:2	-38.2	2.9	3.1	9.8
1986:3	-13.2	0.1	NA	8.3

Sources: U.S. Bureau of Labor Statistics; U.S. Bureau of Economic Analysis; Wharton Econometric Forecasting Associates.

state's economy is integrated around the oil and gas industry or other key export sectors that are strongly affected by changes in oil prices or macroeconomic activity.

The personal income earned in the production processes associated with the direct and indirect effects induces additional activity (induced effects) through household consumption and investment and through local government expenditure of additional tax revenues.

To capture these various effects, the following general model framework is specified:

(1) $DEMG_t = f_1[A_{11}(L)\, DRPO_t]$

(2) $DEMF_t = f_2[A_{21}(L)DRPO_t, A_{2j}(L)DX_{jt}, B_{11}(L)DEMG_t, B_{12}(L)DEO_t, B_{13}(L)DRPY_t]$

(3) $DEFC_t = f_3[A_{31}(L)DEFCU_t]$

(4) $DEO_t = f_4[A_{4k}(L)DX_{kt}, B_{41}(L)DEMG_t, B_{42}(L)DEMF_t, B_{43}(L)DEFC_t, B_{44}(L)DRPY_t]$

(5) $DRPY_t = f_5[A_{51}(L)DX_{1t}, B_{51}(L)DEE_t, B_{52}(L)DUR_t]$

(6) $DUR_t = f_6[A_{6i}(L)DX_{it}, B_{61}(L)DEE_t]$

(7) $DEE_t = DEMG_t + DEMF_t + DEFC_t + DEO_t$

where

DEMG = change in mining employment

DEMF = change in manufacturing employment

DEFC = change in federal government civilian employment

DEO = DEE - DEMG - DEMF - DEFC

DRPY = change in real personal income

DUR = change in unemployment rate

DEE = change in total civilian non-agricultural employment

DRPO = change in real oil prices

DEFCU = change in federal government civilian employment, United States

DX = change in various exogenous, macro-economic variables related to state's industry mix

L = the lag operator

$A_{ij}(L), B_{ij}(L)$ = polynominals in the lag operator

Equation (1) links oil and gas industry (or mining sector) employment changes to changes in real oil prices. The direct effects of real oil prices and the growth and composition of aggregate activity on the state's manufacturing and non-manufacturing employment are captured in Equations (2) and (4). The DXs in these equations are chosen to reflect each state's basic industry mix. The DXs chosen for each state will be presented below. To capture the extent of economic integration in a state's economy around oil and gas and other export-oriented sectors, DEMG and DEO are specified on the right-hand side (RHS) of Equation (2), and DEMG, DEMF, and DEFC are specified on the RHS of Equation (4). To reflect the presence of rather large amounts of federal civilian employment in each state, changes in local federal civilian employment are made a function of the corresponding national changes in Equation (3).

Changes in real personal income are specified as a function of local total employment changes and changes in unemployment (a proxy for the effect of labor market conditions on wage rate growth). In addition to these local influences, local personal income is also assumed to be related to both government transfer payments to persons and farm proprietor's income, nationally. The latter is important since all three states have significant agricultural sectors. The former picks up trends in government income transfer programs.

Equation (6) specifies the change in the unemployment rate as a function of local employment change, the spread between local and United States unemployment rates and a constant term. The "spread variable" is a proxy for the impact of unemployment rate differentials on migration, and through this channel, future labor force growth and, therefore, future unemployment. The constant term proxies trends in labor force growth related to population growth and increasing labor force participation rates. Without the "spread variable," relatively high and sustained employment growth would imply continued decreases in the unemployment rate. The high employment growth experienced in Colorado, Oklahoma, and Wyoming during the period of oil price increases induced sizeable migration flows (at least in the case of Colorado), thereby dampening the impact of employment growth on the unemployment rate.

In summary, the direct effects of real oil price changes and related (and unrelated) changes in the level and composition of aggregate activity are captured by the DRPO, DX, and DEFCU variables on the RHS of Equations (1)-(6). The indirect effects are captured by the presence of DEMG, DEMF, DEFC, and DEO on the RHS of Equations (2) and (4). Induced effects are captured through the specification of DRPY on the RHS of Equations (2) and (4) and by the feedbacks through the unemployment rate and income equations. Note that the use of *real* personal income provides an additional channel through which oil price changes can influence economic performance. As oil prices rise (fall), an induced rise (fall) in the general price level occurs. Correspondingly, real income falls (rises). Empirically, this real income channel of influence has been found to be very important in transmitting the effects of changing oil prices. The impact of changing real (or relative) oil prices on factor intensities is not explicitly treated in this model specification. Although there is empirical support for substitution among energy, labor, capital, and materials, data constraints precluded incorporating this channel. In the short run, the impacts of factor intensity changes are probably small in comparison to the other effects identified above. Given the quarterly nature of this analysis presented in this paper, it is assumed that any factor intensity effects present would be rather small and have negligible consequences for the conclusions reached in this paper.

Based on a brief review of historical data on each state's employment by industry, a set of key sectors and related macro variables were identified for each state.

These are presented by state in Table 4. The decision to include or exclude these various macro variables was empircally based.

Empirical Methodology

Econometric Estimation

Equations (1)-(6) are stochastic relations. Equation (7) is an indentity. The first step in estimating Equations (1)-(6) involved determining the differencing order(s) required to achieve covariance stationarity. Either first or first and fourth order differences were sufficient to induce stationarity. The second step was to estimate univariate transfer functions for each stochastic equation. The autocorrelation and partial autocorrelation functions for the residuals from these fits along with the Q-statistics were evaluated to determine the initial stochastic specification needed to obtain white noise residuals. Each transfer function was then reestimated with the initially identified stochastic structure. This process of estimating and diagnostic checking of residuals was iterated until an adequate model was achieved. During this iterative process, the lag lengths for each RHS variable was determined by slightly overfitting what was initially believed to be the correct lag length. The sets of RHS variables initially tried are those listed in Table 4.

The final univariate transfer function models were selected based on the sign-correctness and significance of the parameter estimates, the reasonableness of the estimated parameter values and of the lag lengths, and the "whiteness" of the residuals. Because of the simultaneous nature of the model, the next step was to take the estimated univariate transfer function models along with the identity [(Equation (7)] and estimate them simultaneously using full information maximum likelihood (FIML). Final estimated systems for each state were selected on the basis of the reasonableness of the parameter estimates (sign-correctness, significance, and magnitude), the "whiteness" of the residuals (equation-by-equation), the appropriateness of the lag length, and the reasonableness of the multipliers.

Data

All data used to estimate the state models are seasonally adjusted quarterly figures. The personal income data are expressed at annual rates. State employment data are from the BLS 790 files and related state sources and are for civilian, nonagricultural workers. The unemployment rate data are from the monthly household survey. Personal income data are from the Bureau of Economic Analysis, Regional Economic Information System data files. National variables are from various sources including the National Income and Product Accounts, the Department of Energy, and the Federal Reserve Board and are seasonally adjusted. Wharton Econometric Forecasting Associates kindly provided all of the macro data and the state data for Oklahoma and Wyoming.

The sample used for Colorado runs from 1970:1 through 1985:4. All macro and Colorado series are complete for this period with the exception of the nominal dollar refiners' acquisition of crude oil which begins in 1974:1 . This series was extrapolated back to 1970:1 using the producer price index for crude petroleum.

The sample for Oklahoma also runs from 1970:1 through 1985:4 with the exception of the unemployment rate which begins in 1975:1 For Wyoming, the sample runs from 1972:1 through 1985:4 with the exception of the unemployment rate which begins in 1975.1. The unavailability of unemployment rate data in these two states prior to 1975 creates a problem in the use of FIML estimation. To conserve observations, FIML is applied to Equations (1)-(5) and (7) for Oklahoma and Wyoming. The unemployment rate equation is estimated separately. As a result of this procedure, certain parameters may be inconsistently estimated. To drop the pre-1975 observations seemed to create more potential problems, however, since one of the two major oil price run -ups occurred in this period.

Estimated Equations

The FIML estimates for the Oklahoma, Wyoming, and Colorado equations are presented in Tables 5, 6, and 7, respectively. These estimates are based on a convariance matrix restricted to be diagonal in form. This restriction was found to be helpful in obtaining consistently reasonable results across models. The use of this restriction results in estimates that are not precisely full information estimates. However, the approach chosen does deal with the important issues of simultaneity and ARMA error structures. The Oklahoma and Wyoming equations follow the specification set forth in the section on model specification. The Colorado model has several additional sectors of detail that enables a more refined analysis of the channels through which oil price fluctuations influence state economic performance. This additional detail was feasible to obtain for Colorado due to the ready availability to the author of the additional data required. The exogenous macro variables used in the three sets of equations that were not previously defined appear in Table 8.

The equations for Oklahoma are all reasonable in terms of signs and all coefficients are significant at or above the ten percent level. Many coefficients have t-ratios exceeding 2.0. The equation fits based on R^2s are

Table 4

Key Sectors and Related Macro Variables by State

Industry	Macro Variable(s)
COLORADO	
Oil and Gas	Real price of oil
Meat Products	Real output SIC 201
Beverages	Real output (SIC 208)
Rubber and Plastics	Real output SIC 30 (less 301)
Computers/Office Machines	Real output SIC 357
Electronic Components	Real output SIC 367
Communications Equipment	Real output SIC 366
Aerospace Systems	Real output SICs 372, 376
Business and Professional Services	Real output SICs 73, 81, 89
Tourism and Recreation	Exchange rate, real per capita income, population aged 25 to 34 years
Agriculture	Farm proprietors' income
Federal Government	Federal civilian employment
OKLAHOMA	
Oil and Gas	Real price of oil
Meat Products	Real output (SIC 201)
Apparel	Industrial production SIC 22
Petroleum Refining	Real price of oil
Oil Field Machinery	Real price of oil
Motor Vehicles and Equipment	Industrial production SIC 371
Aircraft and Parts	Industrial production SIC 372
Agriculture	Farm proprietors' income
Federal Government	Federal civilian employment
WYOMING	
Oil and Gas	Real price of oil
Agriculture	Farm proprietors' income
Federal Government	Federal civilian employment

good, given that the dependent variable is in change form. Based on the Q-statistics provided, the null hypothesis that each error is white noise (i.e., not autocorrelated) cannot be rejected. The rather large value of Q(24) for Equation (OK.5) reflects a large, insignificant, autocorrelation at a lag of 24. The Q(23) statistic is 22.2.

Although the model's estimated equations appear to be reasonable, the long-run employment multiplier for employment changes in the mining sector is 2.4.[4] This seems somewhat low for a state such as Oklahoma that is rather concentrated in oil and gas. A recent study of the energy industry in Texas reported an employment multiplier of about 4.1 [Hill]. If a multiplier of 2.4 is too low for Oklahoma, then the indirect and induced effects of changing oil prices will be understated. This caveat should be kept in mind when interpreting the simulation results

Table 5

Estimated Equations: Oklahoma

(OK.1)

$$DEMGOS_t = [0.5357 + 0.3274L^2]\ DRPO_t + [1/(1-0.8411L + 0.2665L^3)]\ a_{1t}$$
(0.1826) (0.1825) (0.1028) (0.1025)

R^2 (changes) = 0.61
Q(12) = 9.0 Q(16) = 9.2 Q(24) = 11.4

(OK.2)

$$DEMFOS_t = [0.1885](DRPO_{t-1} + DRPO_{t-2}) + [0.1726]\ DIP22US_t + [0.0924]\ DIP371US_t +$$
(0.1301) (0.0792) (0.420)

$$[0.1779]\ DIP372US_t + [0.4278]\ DEMGOS_t + [1/(1-0.4908L - 0.3725L^2 +$$
(0.0715) (0.1145) (0.1288) (0.1283)

$$0.3386L^3)]\ a_{2t}$$
(0.1218)

R^2 (changes) = 0.70
Q(12) = 6.5 Q(16) = 11.1 Q(24) = 18.0

(OK.3)

$$DEFCOS_t = [11.3034]\ DEFCUS_t + [1/(1-0.4755L^4)\ a_{3t}$$
(1.6335) (0.1083)

R^2 (changes) = 0.52
Q(12) = 6.9 Q(16) = 11.4 Q(24) = 16.3

(OK.4)

$$DEOOS_t = DEOOS_{t-4} + [0.2952](DQLPSVUS_t - DQLPSVUS_{t-4})$$
(0.1979)

$$- [2.9095](DRIM_t - DRIM_{t-4}) + [0.8704](DEMGOS_t - DEMOS_{t-4}) +$$
(1.4409) (0.1885)

$$+ [0.0067L^2](DRPYOS_t - DRPYOS_{t-4}) + [1/(1+0.4059L + 0.4108L^4)]\ a_{4t}$$
(0.0041) (0.1357) (0.1412)

R^2 (changes) = 0.71
Q(12) = 7.6 Q(16) = 9.1 Q(24) = 15.1

(OK.5)

$$DRPYOS_t = [10.9572]\ DFYU_t + [16.7843]\ DFGTPS_t +$$
$$\quad (5.5582) \qquad\qquad (7.0787)$$

$$[7.4003]\ DEEOS_t + [1/(1+0.3390L)]\ a_{5t}$$
$$(1.0853) \qquad\qquad (0.1367)$$

R^2 (changes) = 0.37
Q(12) = 11.3 Q(16) = 16.2 Q(24) = 28.0

(OK.6)

$$DUROS_t = 0.2149 - [0.0245]\ DEEOS_t - [0.4151L^2](DUROS_t - DURUS_t) +$$
$$(0.1021)\ (0.0035) \qquad (0.1180)$$

$$[1/(1-0.6115L + 0.2669L^3)]\ a_{6t}$$
$$(0.1250) \quad (0.1220)$$

R^2 (changes) = 0.69
Q(12) = 6.6 Q(16) = 8.3 Q(24) = 15.7

The last two letters of each endogenous variable (OS), indicates "Oklahoma, seasonally adjusted."

presented in the next section. Additional research is required to determine if the Oklahoma multiplier is too low, and if it is, what features of the specification are causing the downward bias.

The Wyoming model's estimated equations are all reasonable in terms of signs and significance levels for estimated parameters. The fits are very good in most cases with R^2s at 0.8 and 0.9 for several equations. Recall that the R^2s are for first-differenced dependent variables.

With the exceptions of the real income and federal employment equations, the equations' Q-statistics indicate that the null hypothesis of white noise for the residuals cannot be rejected. In the federal employment equation, the rather high Q-statistics result from high autocorrelations (ACs) at long lags (19 and 24). Omitting these, the Q(24) equals about 22.0. The problem in the real income equation also occurs due to high ACs at rather long lags (9, 10, and 11). The Q(8) is 2.8. Given the rather low R^2 for this equation and the absence of significance for United States farm proprietor's income, federal transfer payments, and a trend factor in the equation leads one to suspect that some influence on real income in Wyoming has been omitted or that the data is relatively noisy. The simulations done in the next section should not be affected too much, however, given that the estimated value for the parameter on the change in employment variable is of about the right size (5,140 constant 1967 dollars per job, or about 16,500 current dollars per job on average).

The employment multiplier implied by the model for a change in mining sector employment in Wyoming is 2.4. Given the relatively small size of the Wyoming economy and the sizeable leakages that certainly must occur, this multiplier does not seem unreasonable. If anything, it may be somewhat high. In comparison to Oklahoma, if 2.4 is about right for Wyoming, then Oklahoma's multiplier, in all probability, is higher than this.

The estimated Colorado model presented in Table 7 contains equations for manufacturing employment, federal civilian government employment, real personal income, and the unemployment rate as in the cases of Oklahoma and Wyoming. In addition, equations for changes in oil and gas industry employment (DE13CS), changes in construction employment (DECCCS), and changes in amusement-recreation sector employment (DEARCS) are specified and estimated. The residual employment change category is denoted DEOCS.

The objective of the additional disaggregation is to attempt to capture additional channels through which oil price changes influence Colorado. Focusing on oil and gas employment versus mining employment overall (which includes, *inter alia*, metals and sand and gravel

Table 6

Estimated Equations: Wyoming

(WY.1)

$$DEMGWS_t = DEMGMS_{t-4} + \underset{(0.0702)}{[0.2684L]} (DRPO_t - DRPO_{t-4}) +$$

$$[(1+\underset{(0.1808)}{0.4837L})/(1-\underset{(0.1811)}{0.3182L} + \underset{(0.1361)}{0.3820L^4})]\, a_{1t}$$

R^2 (changes) = 0.61
Q(12) = 6.4 Q(16) = 9.8 Q(24) = 18.5

(WY.2)

$$DEMFWS_t = DEMFWS_{t-4} + \underset{(0.0011)}{[0.0026]} (DRPYWS_t - DRPYWS_{t-4}) +$$

$$\underset{(0.0281)}{[0.0524]} (DEMGWS_t - DEMGWS_{t-4}) +$$

$$[(1-\underset{(0.0929)}{0.7941L^4})/(1+\underset{(0.1581)}{0.2659L^2})]\, a_{2t}$$

R^2 (changes) = 0.86
Q(12) = 6.9 Q(16) = 10.8 Q(24) = 15.6

(WY.3)

$$DEOWS_t = DEOWS_{t-4} + \underset{(0.2376)}{[0.9244]} (DEMGWS_t - DEMGWS_{t-4}) +$$

$$[(1-\underset{(0.1754)}{0.3711L})/(1+\underset{(0.1382)}{0.3803L^2} + \underset{(0.1367)}{0.5951L^4})]\, a_{3t}$$

R^2 (changes) = 0.90
Q(12) = 7.2 Q(16) = 8.5 Q(24) = 12.0

(WY.4)

$$DRPYWS_t = \underset{(0.8951)}{[5.1398]} DEEWS_t + [1/(1-\underset{(0.0807)}{0.8897L^4})]\, a_{4t}$$

R^2 (changes) = 0.45
Q(12) = 19.0 Q(16) = 21.9 Q(24) = 32.4

(WY.5)

$$DEFCWS_t = DEFCWS_{t-4} + \underset{(0.7386)}{[2.9994]}(DEFCUS_t - DEFCUS_{t-4}) +$$

$$[1/(1+\underset{(0.1348)}{0.3463}L + \underset{(0.1413)}{0.3422}L^2 + \underset{(0.1509)}{0.4201}L^3 + \underset{(0.1492)}{0.6224}L^4)]\, a_{5t}$$

R^2 (changes) = 0.91
Q(12) = 11.3 Q(16) = 18.1 (Q(24) = 31.7

(WY.6)

$$DURWS_t = \underset{(0.0604)}{0.2025} - \underset{(0.0116)}{[0.0513]}\, DEEWS_t -$$

$$\underset{(0.1051)}{[0.4847}L^2](DURWS_t - DURUS_t) +$$

$$[1/(1-\underset{(0.1373)}{0.3171}L + \underset{(0.1306)}{0.4273}L^5)]\, a_{6t}$$

R^2 (changes) = 0.84
Q(12) = 4.7 Q(16) = 9.1 Q(24) = 17.3

The last two letters of each endogenous variable (WS), indicates "Wyoming, seasonally adjusted."

mining) should increase the accuracy of the estimates of one of the most direct channels by which price fluctuations are transmitted to the Colorado economy. Tourism and recreation are very important to Colorado. United States real personal income and relative transportation costs are two key determinants of travel and recreation. Real oil price changes influence both of these in the same direction in terms of travel and recreation demand. Having an equation related to employment in the tourism and recreation sector enables these macro effects to be estimated.

Oil price changes have impacted construction in Colorado through the demand for office space for energy company headquarters and regional offices. The effect of increases in oil prices on office building in Colorado have been dramatic, as Denver has been chosen as a center for energy management activities for the Rocky Mountain West. The specification and estimation of a construction employment equation enables an assessment of impact through this channel. Moreover, the construction sector typically has relatively high multipliers due to its degree of local integration. The lack of a construction employment equation for Oklahoma may be leading to a downward bias in the mining sector multiplier for Oklahoma.

The estimated parameters for the Colorado model's equations appear to be reasonable in terms of sign-correctness and statistical significance. All are significant at the ten percent level or better with many having t-ratios exceeding 2.0 or 3.0. The fits are all good with R^2s typically between 0.65 and 0.70. As before, these apply to dependent variables measured as first differences. The Q-statistics all support the "whiteness" of the residuals. The rather high value of Q(24) in the DEARCS equation occurs due to a couple of high AC's between lags 16 and 24. The Q(16) value of 6.7 is ample support for white noise residuals in this equation.

The employment multiplier for oil and gas industry employment changes is 2.2. As in the case of Oklahoma, this seems somewhat low, given Colorado's role as a regional energy center for the Rocky Mountain West. Using another state modeling methodology (Treyz, et al.) the multiplier for Colorado is estimated to be between 2.5 and 2.9 [Hunt and Oldham]. To the extent that the estimated model's multiplier is somewhat low, the indirect and induced effects will be understated. This should be remembered when interpreting the results presented in the following section.

Given that the focus of this paper is on the impacts of oil price fluctuations, our focus must turn to the analysis

Table 7

Estimated Equations: Colorado

(CO.1)

$DE13SC_t = [0.0472 + 0.1730L]\ DRPO_t + [1 + 0.6022L + 0.8226L^2]\ a_{1t}$
(0.0207) (0.0206) (0.0879) (0.0868)

R^2 (changes) = 0.67
Q(12) = 8.6 Q(16) = 12.7 Q(24) = 15.8

(CO.2)

$DEMFCS_t = [0.2052]\ DQHTUS_t + [0.0608]\ DQADUS_t + [0.1169]\ (DE13CS_t + DECCCS_t) +$
(0.0592) (0.0481) (0.0567)

$[0.0031L]\ DRPYCS_t + [1/(1 - 0.7007L + 0.2301L4)]\ a_{2t}$
(0.0015) (0.1069) (0.0987)

R2 (changes) = 0.72
Q(12) = 7.4 Q(16) = 10.8 Q(24) = 17.7

(CO.3)

$DEARCS_t = [1.5386L^5]\ DYPDU82PC_t - [0.0838]\ DRPO_t +$
(0.4145) (0.0321)

$[2.4078L]\ DPOP2534U_t - [0.0369]\ DEXRFRB_t +$
(0.7395) (0.0093)

$[0.0005]\ DRPYCS_t - [0.5008 + 0.3182L]\ DROUT1_t -$
(0.0003) (0.2046) (0.2027)

$[0.2525]\ DROUT2_t + [1 - 0.6396L]\ a_{3t}$
(0.1829) (0.1428)

R2 (changes) = 0.64
Q(12) = 5.6 Q(16) = 6.7 Q(24) = 24.9

(CO.4)

$DECCCS_t = -0.6272 - [0.8357]\ DRIM_t + [0.7639L]\ DE13CS_t + [0.5219]\ DEMFCS_t +$
(0.3339) (0.5388) (0.4496) (0.1085)

$[0.8038L]\ DEARCS_t + a_{4t}$
(0.5210)

R2 (changes) = 0.67
Q(12) = 11.6 Q(16) = 16.1 Q(24) = 19.5

(CO.5)

$$DEFCCS_t = \underset{(0.0192)}{0.0722} + [\underset{(1.2551)}{11.6137} + \underset{(1.2533)}{2.8363}L]\, DEFCUS_t + [1-\underset{(0.1097)}{0.5829}L]\, a_{5t}$$

R2 (changes) = 0.67
Q(12) = 9.4 Q(16) = 16.2 Q(24) = 22.7

(CO.6)

$$DEOCS_t = [\underset{(0.1752)}{0.7524}]\, DQBPSVUS_t + [\underset{(0.2393)}{1.2235}](DE13CS_{t-1} + DEMFCS_t) +$$

$$[\underset{(0.5976)}{1.8749}L]\, DEARCS_t + [\underset{(0.0037)}{0.0108}L^2]\, DRPYCS_t + [1+\underset{(0.1013)}{0.6912}L]\, a_{6t}$$

R2 (changes) = 0.52
Q(12) = 9.4 Q(16) = 10.5 Q(24) = 16.1

(CO.7)

$$DRPYCS_t = [\underset{(2.5262)}{10.2004}]\, DFYU_t + [\underset{(4.0857)}{17.3418}]\, DFGTPS_t +$$

$$[\underset{(0.8287)}{8.9063}]\, DEECS_t - [\underset{(15.5392)}{65.8817}]\, DURCS_t + [1+\underset{(0.1214)}{0.4536}L^4]\, a_{7t}$$

R^2 (changes) = 0.68
Q(12) = 14.3 Q(16) = 14.6 Q(24) = 22.9

(CO.8)

$$DURCS_t = \underset{(0.0800)}{0.3503} - [\underset{(0.0060)}{0.0273}]\, DEECS_t - [\underset{(0.1199)}{0.1824}L^2](DURCS_t - DURUS_t) +$$

$$[1/(1-\underset{(0.1129)}{0.3978}L + \underset{(0.1110)}{0.3917}L^4)]\, a_{8t}$$

R^2 (changes) = 0.53
Q(12) = 10.8 Q(16) = 14.0 Q(24) = 21.9

The last two letters of each endogenous variable (CS), indicates "Colorado, seasonally adjusted."

Table 8
Additional Exogenous Variables Used

Colorado

DQHTUS	=	change in real output of computers, office equipment, and electronic components, United States.
DQADUS	=	change in real output of communications equipment and complete aircraft, United States.
DYPDU82PC	=	change in per capita real personal disposable income, United States.
DPOP2534U	=	change in United States population aged 25 to 34.
DEXRFRB	=	change in the United States dollar exchange rate, Federal Reserve Board index.
DROUT1	=	dummy variable for Colorado drought in 1976-77.
DROUT2	=	dummy variable for Colorado drought in 1980-81.
DRIM	=	change in the *ex post* real mortgage rate.
DQBPSVUS	=	change in real output of business and professional services, United States.
DFYU	=	change in real farm proprietor's income, United States.
DFGTP	=	change in real federal government transfer payments to persons, United States.

Oklahoma (other than listed for Colorado)

DIP22US	=	change in industrial production index (IPI), apparel, United States.
DIP371US	=	change in IPI, motor vehicles and equipment, United States.
DIP372US	=	change in IPI, aircraft and parts, United States.

Wyoming

(no additional exogenous variables)

of such fluctuations using these equations for each state. In summation, the equations for each state have estimated parameters that are reasonably signed and that are typically highly significant. No autocorrelative problems are apparent and the fits are usually very good. The potential for simultaneity bias has been dealt with by using FIML estimation for each state's equations with a diagonal covariance matrix specification. The only concern at this point is that the indirect and induced employment effects may be understated, especially for Oklahoma.

Implications of Oil Price Fluctuations

The estimated equations for each state were simulated to determine the impacts of oil price fluctuations on state economic performance. There are three broad channels that can be identified for purposes of simulating oil price impacts. First of all, real oil price changes directly impact employment in the mining and oil and gas industries in Colorado, Oklahoma, and Wyoming. Additional direct effects occur as oil price changes induce corresponding changes in the level and composition of macroeconomic activity. These aggregate changes produce direct impacts on employment in manufacturing and other export-oriented sectors in each state. The extent to which these impacts are transmitted to any given state depends on the nature of the state's industry mix. The third broad channel of influence is through changes in real personal income brought about by energy price links to the general price index. Once these three broad sets of influences are obtained, the estimated state models compute the related direct effects on the respective state's economy. Given these direct effects, the models then can compute the indirect and induced effects.

The first step in performing the simulation is to obtain a baseline United States macro forecast and an alternative forecast under different oil price assumptions. Such simulations were generously provided by Wharton Econometric Forecasting Associates. Wharton's model of the United States economy was simulated quarterly for 1986 and 1987 under the current expectations for oil prices and levels of macroeconomic activity and under an assumed oil price path that was maintained at the 1985:4 value for the refiner's acquisition cost of crude. In real terms, these two paths diverge by up to $12.50 per barrel in 1986 and then begin to slowly converge through time. Using the outputs of these simulations along with data published by Wharton in an article on the macroeconomic impacts of an oil price collapse [Handler, *et al.*], the necessary alternative macroeconomy paths were obtained and fed into the state models.

Table 9 presents the simulation results for total employment for each of the three states for the higher and lower oil price paths. Lower oil prices produce a slight net increase in Colorado's employment. After four quarters Colorado's total employment has increased by 0.1 percent. After eight quarters the increase is 0.6 percent. In the case of Oklahoma, the net effect of lower oil prices is negative. After four quarters, total employment is two percent lower than under the alternative of higher oil prices. This is the maximum difference between two scenarios. After eight quarters, total employment is 1.3 percent lower. The net effect of lower oil prices in Wyoming is also negative. After four quarters, total employment is three percent lower. This is the maximum difference between the two scenarios. After eight quarters, total employment is 2.1 percent below the level associated with the higher oil price.

One of the factors leading to the qualitative difference in results for Colorado versus Oklahoma and Wyoming is that the net impact of lower oil prices on Colorado's manufacturing sector is positive. In the case of Oklahoma and Wyoming, the net effect is negative. Colorado's manufacturing sector receives more positive

Table 9

Percentage Difference in Total Employment
Lower Oil Prices Versus Higher Oil Prices

Quarter	Colorado	Oklahoma	Wyoming
1986:1	0.2%	-0.7%	0.0%
1986:2	0.2	-1.6	-1.5
1986:3	0.2	-1.8	-2.9
1986:4	0.1	-2.0	-3.0
1987:1	0.3	-1.8	-2.8
1987:2	0.4	-1.6	-2.3
1987:3	0.5	-1.4	-2.1
1987:4	0.6	-1.3	-2.1

Source: Center for Economic Analysis, University of Colorado at Boulder.

NOTE: Table entries are [total employment (lower oil prices) - total employment (higher oil prices)] expressed as a percentage of total employment (higher oil prices).

effects from changes in the macroeconomy than negative effects from local linkages to the oil and gas sector. Moreover, the overall positive impacts of lower oil prices on the Colorado economy produce additional induced demands for local-oriented manufacturing sectors such as printing and publishing, beverages, and paper products.

In Oklahoma, the positive effects resulting from changes in the macroeconomy are insufficient to offset the negative effects from local linkages to the oil and gas sector. In addition, the overall negative impacts of lower oil prices on the Oklahoma economy adversely affected induced demands for local-oriented manufacturing sectors resulting in further negative effects on manufacturing. This latter channel of influence is also a large factor in the manufacturing sector declines simulated for Wyoming under lower oil prices. Furthermore, Wyoming does not receive any significant positive impacts through its manufacturing sector from improved macroeconomic conditions.

The negative impacts in Oklahoma and Wyoming occurring through lower levels of induced demands show up in losses in the "other employment category" which includes retail trade, services, and other locally-oriented sectors. After four quarters, Wyoming's other employment sector is 1.7 percent lower in the lower price case than in the higher one. After eight quarters, the difference is -1.2 percent. In Oklahoma, the difference is -0.7 percent after four quarters and -0.4 percent after eight quarters. In Colorado the impact of lower oil prices on "other employment" is positive.

One of the important channels through which lower oil prices benefit Colorado is tourism and recreation. Low oil prices produce a strong macroeconomy, higher real personal incomes, and a drop in relative travel costs. These are positive changes for tourism and recreation. The results from the equation for this sector in the Colorado model (Equation CO.3) indicate that after four quarters, the lower oil price path generates 3.4 percent more employment in the industry than would have occurred under higher oil prices.

Another factor leading to qualitatively different results in Colorado than in Oklahoma and Wyoming is the direct effects of lower oil prices on the state's mining sector. In Colorado, oil and gas employment is about 11 percent lower after four quarters under the lower oil price scenario. This compares to 15 percent for Oklahoma and 12 percent for Wyoming. These are essentially the "peak" impacts for each state. After eight quarters, the impacts for each state's mining employment are -7.7 percent (Colorado), -11.2 percent (Oklahoma), and -8.6 percent (Wyoming).

These mining sector impacts appear to be less than recent data suggest actually occurred. To check the mining sector equations for systematic underreaction to real oil price changes, dynamic simulations were run for each state's equation. In every case, the response of mining employment was greater than was predicted by the equation. This was especially true in and around the period of the second OPEC oil price shock (1979-81). A revision of the models with more responsive mining sector equations would result in lower mining employment levels under the lower oil price regime than those reported here. These lower values would in turn generate lower levels of total employment than reported in Table 9. Additional work could be done to obtain more responsive mining employment equations, and thereby, produce results that are closer to what has actually unfolded in the three states in 1986 and 1987.

The construction sector in Colorado is impacted negatively by the decline in oil prices during 1986. However, it too, appears to be responding less to the oil price change than actual data indicate was the case for 1986. Part of the problem here is probably due to the lack of a stock adjustment specification for the construction sector. After the oil price decline in early 1986, vacancy rates increased substantially. The implied excess supply of space was a key negative factor for the performance of the Colorado construction sector in 1986 that was not accounted for by the specification. As in the case of the oil and gas sector specification, an improved equation for construction would have led to larger simulated declines in Colorado construction as a result of lower oil prices. Integrating the stock adjustment principle into the construction sector is an important additional area of research for improving the accuracy of state model's predictions of oil price fluctuations.

Nevertheless, the findings of this paper on the impacts of declining oil prices on the economies of energy producing states has shown that the relative effects importantly depend on the structure of the local economy. The more integrated the local economy is around energy mining activities, the larger the effects of fluctuating oil prices. Moreover, the more diversified the local economic base is, the more channels there are for the macroeconomy impacts of fluctuating oil prices to be transmitted to the local economy. The results of this empirical study indicate that among the three states studied, Colorado, Oklahoma, and Wyoming, Colorado's economy is structured to capture enough beneficial impacts of oil price declines to offset the negative impacts. The economic structure of Oklahoma leads to a net negative impact from declining oil prices; however, there are some channels available through which partially offsetting positive effects can be transmitted. In contrast, Wyoming's economy is structured in a way that leaves very little room for the positive effects of lower oil prices to be realized. Therefore, Wyoming suffers larger relative declines in the face of falling oil prices than does Oklahoma or Colorado.

NOTES

[1]Refiners' acquisition cost deflated by the GNP deflator.

[2]Oil and gas production, exploration, and drilling are classified as mining industries in the Standard Industrial Classification scheme by which many economic series are reported. Although "mining" includes metal and nonmetallic mining, including coal mining, oil and gas mining account for a very large share of the total in these three states. Coal is also very significant in Wyoming but its behavior should be consistent with that of oil and gas with respect to oil prices.

[3]Given the preliminary nature of the 1986 data and the potential for significant revisions, this second quarter figure could decline somewhat.

The multiplier was obtained by simulating a $5 change in the per barrel real price of oil and computing the change in mining and total employment after the changes died out (usually four quarters).

REFERENCES

Handler, D. P., P. Luce, and M. W. French. "An Oil Price Collapse." *Quarterly Model Outlook.* Wharton Econometric Forecasting Associates, November, 1985.

Hill, John K. "Energy's Contribution to the Growth of Employment in Texas, 1972-1982." *Economic Review.* Federal Reserve Bank of Dallas, May, 1986.

Hunt, G. L. and J. Oldham. "The Oil and Gas Sector of the Colorado Economy." *Economic Review.* Center for Economic Analysis, University of Colorado at Boulder, May, 1986.

Treyz, G. I. and B. H. Stevens. "The TFS Regional Modelling Methodology." *Regional Studies.* (1986). 547-62.