AN INPUT-OUTPUT APPROACH FOR ANALYSIS OF ENERGY AND ECONOMIC POLICIES IN OKLAHOMA

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Energy policy is currently one of the most important national issues because of possible limitations on economic growth resulting from uncertainty over energy prices and potential energy supply disruption. State policy makers are faced with alternative energy choices but lack sufficient information for analysis of these choices. This study develops a comprehensive regional energy information system and integrates this information into a dynamic simulation and input-output model for evaluating alternative energy choices. The model is applied to the economy of Oklahoma, which is an energy-producing state. A strong dependence on the conventional energy sources, natural gas and petroleum products, may reduce substantially the energy Oklahoma will have for interregional trade by the year 2000. Baseline energy projections and impact analysis for Oklahoma lend importance to future policy decisions on alternative energy choices.

The economic and social development of the United States has been directly related to abundant energy supplies at relatively low prices. For the nation, the economy has shifted, in a relatively short period of time, from a position of abundant, low-cost energy to one of potential supply disruptions and uncertainty over energy prices. Oklahoma's economy, like the economies of all states, depends on the use of large amounts of energy and its position as a major net producer of oil and gas requires additional current and future energy policy choices revolving around incentives for energy production, for location of energy-consuming industries, and for conservation of certain sources of energy. Future revenues to producers and to the state and future costs to energy consumers will be affected by these choices. But policy makers lack sufficient information for analysis of these alternative energy choices.

The objective of this study is to develop a comprehensive energy information system and to integrate this information into a dynamic simulation model for purposes of evaluating alternative energy choices. Such research and development studies need to be accorded much higher priorities in an effort to provide the level of information required for effective policymaking in energy related matters. Research information is vital for decision-making by planners involved in agriculture, industry, and government activities.

AN ENERGY-BASED STATE SIMULATION MODEL

An input-output model of interrelationships of social accounts has the advantage of providing an organizational framework and a set of consistency checks that are difficult to achieve with other models. The model used here is patterned after the Iowa model by Maki, Suttor and Barnard (1) which was later applied to Oklahoma (2). The present model differs from previous ones by the addition of a comprehensive energy account to allow evaluation of alternative energy choices for the state of Oklahoma. The model simulates the Oklahoma economy from 1972 to 2000. The major contribution of the information system is its estimated distribution of energy utilization by input-output sector and basic energy source, thus recasting energy statistics into a form consistent with economic models composed of processing and final demand sectors.

The Oklahoma input-output model is composed of five major social accounts: (a) transactions account, (b) capital account, (c) human resource account, (d) government account, and (e) energy account. Energy sources used in this study are classified as natural gas, petroleum products, coal, and electricity. Methods of estimation and sources of data for these accounts are available in Ghebremedhin (3).

The structure of the simulation model is recursive, involving 119 major equations for a given year. There are four main parts in the model: (a) estimating final demand, (b) determining sector output, (c) projecting state economic variables, and (d) projecting state energy requirements and trade. Specification of the model starts with projection of components of final demand including personal consumption expenditures, private capital formation, change in business inventories, net exports, federal government purchases for national defense and nondefense, and state and local government purchases. The second step in model formulation includes determination of sector output of two groups, namely the non-energy "demand determined" output sectors and the energy "supply determined" output sectors, following procedures used by Ekholm, Schreiner, Eidman, and Doeksen (4). Third, sector output estimates are utilized to derive state economic projections including income, employment, government revenues and expenditures, and gross state product. Fourth, projected output of the non-energy sectors, direct energy requirements of the processing sectors, direct energy requirements of households and government, and projected production of state energy are used to determine state energy utilization and trade by energy source. Finally, impact analysis compares alternative growth rates in energy production and efficiencies in energy utilization with baseline projections.

Disposition of Output

The energy-based state simulation model consists of five final demand sectors and 81 processing sectors, of which 77 are demand-determined non-energy sectors and four are supply-determined energy sectors. Output of non-energy sectors is assumed to follow the standard input-output solution, and are thus a function of final demand. Output of the energy sectors is independently determined and fed into the simulation and input-output model. To identify the structure of this system, the disposition of the output equation is partitioned into submatrices representing the demand-determined non-energy sectors and the supply-determined energy sectors.

The system for the disposition of output can be written as two equations:

$$X_1 = A_{11} X_1 + A_{12} X_2 + D_1 + T_1$$

$$X_2 = A_{21} X_1 + A_{22} X_2 + D_2 + T_2$$

The first represents the disposition of output for the demand-determined non-energy sectors, measured in dollars. The second represents the disposition of output for the supply-determined energy sectors, measured in British Thermal Units (BTU) of energy.

The output of the supply-determined energy sectors, X_2, is exogenously determined. It is not affected by the level of output of the demand-determined non-energy sectors, X_1. The two matrix equations are solved independently on the basis of final demands, ($D_1 + T_1$) and D_2, and the predetermined energy sectors' output, X_2.Given X_2 as exogenous data A**[sub 11]** and A**[sub 12]** as parameters of the model from the direct coefficients matrix, and ($D_1 + T_1$) as the final demand for the demand-determined sectors, the solution for the output of the non-energy sectors can be derived from the equation for the disposition of X_1:

$$X_1 = (I-A_{11})^{-1} A_{12}X_2 + (I-A_{11})^{-1} (D_1 + T_1)$$

where I is an identity matrix.

This model specification differs from the "standard input-output solution." Final demand for the demand-determined non-energy sectors is "adjusted" to include the requirements of the supply-determined energy sectors.

$$T_2 = (I-A_{22}) X_2 - A_{21} X_1 - D_2$$

If a linear relationship exists between energy use and output level, disposition of output of the supply-determined energy sectors, X_2, is now fully known with energy trade as a residual:

$$T_2 = (I-A_{22}) X_2 - A_{21} X_1 - D_2$$

Energy trade by energy source, T_2, is the residual between estimated energy requirements and energy production by sector. The submatrices A**[sub 21]** and A**[sub 22]** represent the direct energy requirements by energy source of the demand-determined non-energy sectors and the supply-determined energy sectors, respectively. D_2 represents the direct energy requirements of final demand, exclusive of trade, of households, federal government (for defense and non-defense), and state and local government (for education and others). Technological efficiency in energy use and the distribution of energy use by source are assumed constant for the projected period. Alternative assumptions are tested in this study and presented in the following section.

EMPIRICAL RESULTS OF THE STATE ENERGY SIMULATION MODEL

This section presents results of the simulation model. Evaluation with the model is limited at this time to analysis of trends in energy production, consumption, and trade with further use projected in areas of state energy policy analysis. A baseline projection of energy production, consumption, and trade from 1972 to 2000 is presented first. Second, a 25 percent increase in the rate of growth of fossil fuel production (or 25 percent decrease in the rate of decline) is compared to the baseline projection. Third, a 25 percent increase in energy use efficiency by the year 2000 for the final demand sector is compared to the baseline projection.

Baseline projection

The data on Oklahoma energy production and consumption indicate a strong dependence on conventional sources of natural gas and petroleum products. Trends in Oklahoma energy production were mixed over the 1960 to 1980 period. Crude oil production reached a maximum in 1967 and it has consistently declined to 1980. Natural gas production increased consistently to 1972 after which marginal decreases occurred until 1978. The 1980 production was the same as the 1972 level. Coal production showed little growth until about 1975. Significant growth occurred to 1978 with current production somewhat below the high period. Total Oklahoma energy production decreased by 8.9 percent, from 3,272 trillion BTU's in 1972 to 2,982 trillion BTU's in 1976 (5).

Total energy consumption in the state increased at an average annual rate of 2.8 percent from 1970 to 1975. Consumption of natural gas and gasoline reached a plateau for the period 1978 to 1980 whereas electricity consumption continued to show annual increases through 1980 (3). Uncertainty about long-term trends in energy production and consumption for Oklahoma creates uncertainty about energy available for export from the state.

All the energy statistics by sector are developed from secondary data for the benchmark year of 1972. The principal source of information on energy use by energy source for Oklahoma is from Irving Hoch (6). Data from the U. S. Bureau of the Census (7), the U. S. Department of Energy (8) and the U. S. Department of Agriculture (9), were used to allocate total energy use by energy source to the input-output sectors for Oklahoma. Data on production of petroleum products, natural gas, and coal are obtained from the U. S. Bureau of Mines (10), and quantities of electricity produced are obtained from the Edison Electric Institute (11).

The base year of 1972 presents the pre-energy price increase era. Energy use coefficients may have changed significantly from the base year and would continue to change over any projected time period. However, input-output models using secondary data sources are limited by the available 1972 U. S. technology study (12).

The simulation model requires a number of parameter ratios and growth rates. Values assigned to these parameters are presented in Ghebremedhin (3). The parameters are important because they provide much of the driving force for the model. Improvements in the estimation of these parameters should lead to overall improvement of the simulation model. Ratios used in the model are generally point estimates derived from 1972 base year data. Rates of growth as used in the model are estimated using time series data and a logarithmic exponential function.

Baseline projections of state energy production, consumption, and trade by energy source in trillion BTU's from 1973 to 2000 are presented in Table 1. Petroleum products production is projected to decrease by 1.05 percent annually, whereas natural gas production is projected to decrease only marginally, 0.06 percent annually. Coal production is projected to increase by 1.03 percent annually. Electricity production is assumed to be endogenously determined in the model with a small proportion of total electricity available for export to neighboring states. This export proportion is held constant at the 1972 level. Thus, total en-

TABLE 1. *Projections of state energy production, consumption, and energy surplus by energy source and year in trillions of BTU, Oklahoma, 1973-2000*

	Production					Consumption					Surplus				
Year	Petroleum products	Natural gas	Coal	Electricity & hydropower	Total	Petroleum products	Natural gas	Coal	Electricity & hydropower	Total	Petroleum products	Natural gas	Coal	Electricity & hydropower	Total
1973	1,229	1,864	59	107	3,258	325	643	2	77	1,048	904	1,220	57	30	2,211
1974	1,216	1,863	61	111	3,251	332	656	2	79	1,070	884	1,206	59	32	2,181
1975	1,204	1,861	63	116	3,244	343	674	2	82	1,101	861	1,187	61	34	2,143
1976	1,191	1,860	65	121	3,237	355	693	2	85	1,135	836	1,167	63	35	2,102
1977	1,179	1,859	67	126	3,231	367	713	2	89	1,171	811	1,146	65	37	2,059
1978	1,166	1,858	69	131	3,225	381	735	2	92	1,210	785	1,124	67	39	2,015
1979	1,154	1,857	72	137	3,219	396	757	2	96	1,251	758	1,100	70	41	1,969
1980	1,141	1,856	74	142	3,213	41	781	2	100	1,294	731	1,075	72	43	1,921
1981	1,130	1,855	77	148	3,210	428	806	2	104	1,340	703	1,049	74	44	1,870
1982	1,118	1,854	79	154	3,205	445	833	2	108	1,389	673	1,021	77	46	1,817
1983	1,106	1,853	82	161	3,202	464	861	2	113	1,441	642	992	79	49	1,761
1984	1,095	1,852	85	168	3,199	484	891	3	118	1,495	611	961	82	50	1,704
1985	1,083	1,850	87	175	3,196	504	922	3	123	1,552	579	929	85	52	1,644
1986	1,072	1,849	90	182	3,194	526	954	3	129	1,612	546	895	88	53	1,582
1987	1,061	1,848	93	190	3,192	549	988	3	135	1,675	511	860	91	55	1,517
1988	1,049	1,847	97	198	3,191	574	1,024	3	141	1,741	475	823	94	57	1,550
1989	1,038	1,846	100	206	3,191	600	1,062	3	147	1,812	438	784	97	59	1,379
1990	1,023	1,845	103	215	3,191	628	1,102	3	154	1,886	400	743	100	61	1,304
1991	1,017	1,844	107	224	3,191	658	1,144	3	161	1,966	359	700	103	63	1,226
1992	1,006	1,843	110	233	3,192	689	1,188	3	169	2,049	317	655	107	65	1,143
1993	996	1,842	114	243	3,194	722	1,235	3	177	2,138	273	607	110	66	1,057
1994	985	1,841	118	253	3,197	758	1,284	3	185	2,231	227	557	114	68	966
1995	975	1,840	122	264	3,200	795	1,336	4	194	2,329	180	504	118	70	871
1996	965	1,838	126	275	3,204	835	1,390	4	204	2,433	130	448	122	71	771
1997	954	1,837	130	287	3,209	877	1,447	4	214	2,542	77	390	126	73	606
1998	944	1,836	134	299	3,214	922	1,508	4	225	2,658	23	329	130	74	556
1999	935	1,835	139	311	3,220	969	1,571	4	236	2,780	—35	264	135	76	440
2000	925	1,834	143	325	3,227	1,020	1,638	4	248	2,910	—95	196	139	77	317

ergy production is projected to equal 3,227 trillion BTUs in 2000 compared to 3,258 trillion BTUs in 1973, decreasing by 1.0 percent during the simulated period of time. Natural gas is projected to decrease from 1,864 trillion BTUs to 1,834 trillion BTUs over the 1973 to 2000 period. Coal is projected to increase from 59 trillion BTUs in 1973 to 143 trillion in 2000 and electricity from 107 trillion BTUs in 1973 to 325 trillion in 2000. These assumed rates of growth in production of crude petroleum, natural gas, and coal are quite arbitrary and are expected to be highly influenced by factors exogenous to Oklahoma.

Total state energy consumption is projected to equal 2,910 trillion BTUs in 2000 compared to 1,048 trillion BTUs in 1973. Consumption of petroleum products is projected to increase from 325 trillion BTUs to 1,020 trillion over the period of 1973 to 2000, natural gas from 643 to 1,638 trillion BTUs, and coal from 2 to 4 trillion BTUs. Electricity consumption is projected to increase from 77 trillion BTUs in 1973 to 248 trillion BTUs in 2000.

The projected increase in energy consumption for the state is substantial, equalling a 178 percent increase over the 27-year period. For comparative purposes, the 1950 to 1977 period showed an increase of 124 percent for the U. S. as a whole. The baseline projections assume the same efficiency of energy use to output as existed in the base year, 1972. Substantial energy use efficiencies have occurred with increased energy costs and are expected to continue over the projected period. Thus, the baseline projections are gross overestimates of energy consumptions for Oklahoma contrary to the current policies (the Fuel Use Act), which restrict future uses of gas and discourage the use of gas in new large boilers. However, the projection is still useful for comparative analysis as shown in the following sections.

Oklahoma experiences a declining net energy surplus in which total state energy surplus is projected to equal 317 trillion BTUs in 2000 compared to 2,211 trillion BTUs of energy surplus in 1973. The decline in net energy surplus is due to the projected decline in natural gas and petroleum products production and increased consumption of total energy. Oklahoma is projected to have a deficit of 95 trillion BTUs of petroleum products in 2000 compared to a surplus of 904 trillion BTUs in 1973, and a surplus of 196 trillion BTUs of natural gas in 2000 compared to a surplus of 1,220 trillion BTUs in 1973. The net coal surplus is projected to increase from 57 trillion BTUs in 1973 to 139 trillion BTU's in 2000. The surplus in electricity is projected to increase from 30 trillion BTUs in 1973 to 77 trillion BTUs in 2000 and represents marginal exports of electricity to neighboring states.

Increased energy production

Higher energy prices should have stimulated increased activity in energy exploration and development in Oklahoma, and thus increased energy production. Effects of events that are not reflected in the historical trend are not included in projections provided by the Oklahoma simulation model. These events, whether economic or non-economic, may have considerable impact on energy production, consumption, and trade. Further, increased energy production may have impacts on state economic variables such as employment, income, and government revenues and expenditures.

TABLE 2. *Changes in employment, personal income and energy surplus as a result of 25 percent increase in the growth rates of petroleum products and natural gas production, Oklahoma.*

Year	Change in total employment (number)	Change in total personal income (thousands of 1972 dollars)	Increase in energy surplus (trillion BTUs)
1975	370	3,242	10
1980	1,042	9,745	24
1985	1,625	16,701	38
1990	2,036	23,199	50
1995	2,374	29,883	61
2000	2,606	36,259	71

The impact of a 25 percent increase in the growth rates (or 25 percent decrease in the rate of decline) of petroleum products and natural gas production on employment, personal income, and energy trade is presented in Table 2. For instance, total employment is projected to increase by 1,042 in 1980 over the baseline projection, 2,036 in 1990, and 2,606 in 2000. Total personal income is projected to increase by $9,745,000 in 1980, $23,199,000 in 1990, and $36,259,000 in 2000. Total energy surplus is projected to increase by 24 trillion BTUs in 1980 and 71 trillion BTUs in 2000. Surplus in petroleum products is projected to increase by 24 trillion BTUs in 1980 and 69 trillion BTUs in 2000. That for natural gas is projected to increase by 0.4 trillion BTUs in 1980 and 2 trillion BTUs in 2000. Marginal decreases in energy surplus for coal and electricty occur due to direct and indirect effects of increased production of petroleum and natural gas.

Energy exploration and development activities in Oklahoma are well beyond the level projected by the year 2000 under the assumed 25 percent increase in growth rates of petroleum and natural gas production. This suggests that an energy information system as proposed in this paper should prove useful in the analysis of total effects on a state economy from such externally induced effects.

The impact of a 25 percent increase in the growth rate of coal production on total employment, personal income, and energy surplus is presented in Table 3. Total employment is projected to increase by 109 in 1980, 353 in 1990, and 775 in 2000. Total personal income is projected to increase by $1,072,000 in 1980, $4,281,000 in 1990, and $11,539,000 in 2000, in 1972 prices. As a result of the assumed increase in coal production, total state energy surplus is projected to increase by 5 trillion BTUs in 1980 and 35 trillion BTUs in 2000. This is the net effect of an increase in coal production and a marginal decrease in energy surplus from petroleum products, natural gas, and electricity due to direct and indirect effects associated with increased coal production.

Increased energy use efficiency

Energy efficiency in the final demand sectors is assumed to increase by 25 percent in the year 2000 compared to the efficiency in the 1972 base period. The results are presented in Table 4. Total energy surplus is projected to increase by 29 trillion BTUs in 1980 and 269 trillion BTUs in 2000. Surplus is projected to increase in petroleum products by 16 trillion BTUs in 1980 and 148 trillion BTUs in 2000, natural gas by 10 trillion BTUs in 1980 and 91 trillion BTUs in 2000, and electricity by 3 trillion BTUs in 1980 and 30 trillion BTUs in 2000.

POLICY IMPLICATIONS AND CONCLUSIONS

Economic growth in Oklahoma has increased energy consumption substantially. An energy-based simulation model was developed to project the results of these trends and provide baseline data on energy production, consumption, and trade to the year 2000 (Table 1). These results assume 1972 levels of energy use efficiency. Under these conditions, Oklahoma remains a net exporter of energy by 2000 but only at about 15 percent of the 1973 level of exports.

The most recent surge in state energy exploration and production added a great

TABLE 3. *Changes in employment, personal income and energy surplus as a result of 25 percent increase in the growth rate of coal production, Oklahoma.*

Year	Change in total employment (number)	Total personal income (thousands of 1972 dollars)	Increase in energy surplus (trillion BTUs)
1975	25	239	2
1980	109	1,072	5
1985	215	2,341	9
1990	353	4,281	16
1995	537	7,220	24
2000	775	11,539	35

deal of economic activity to the state. Changes in energy price policies and future growth in energy demand are uncertain and the effects on state economic activity are difficult to predict. The simulation model was used to determine the impact of a 25 percent increase in the rate of growth of petroleum products and natural gas production by the year 2000. Employment may increase over the 1972 base period by more than 2,600 people, total personal income by $36,000,000 and energy surplus by 71 trillion BTUs. With the present (1982) energy boom, Oklahoma far exceeds these assumed rates of change in petroleum and natural gas production. The model, however, could trace the impact of various alternative growth rates.

The energy simulation model was used to show the impact on energy surplus of an assumed 25 percent increase in energy use efficiency for the final demand sectors by the year 2000. Final demand accounted for more than 25 percent of total energy consumption in Oklahoma for 1972. The assumed increase in efficiency in energy use allowed an additional 269 trillion BTUs surplus by the year 2000. This quantity equals about 12 percent of the amount of energy surplus for the state in 1973 and allows for about an 85 percent increase in total energy surplus in 2000, assuming the baseline projections. Increased efficiency in energy use should allow for substantial increases in future energy surplus for the state.

The search for alternative energy sources is of great concern at the present time. With higher energy prices, more options exist now than ever before in meeting energy needs. Such options include energy from coal, nuclear sources, biomass, the sun, geothermal sources, oil shales, tide, wind, and gasohol. Use of these alternative energy sources become more feasible with increased energy prices and tax incentives. Since Oklahoma is one of the major producers of oil and gas, the impact of the development of these alternative energy sources is of critical importance in its economy. The present energy information system should be useful in assessing these impacts.

Oklahoma has been a rapidly growing state. Part of this growth may be due to industries seeking a secure source of energy. Such industries may have other attributes which are considered beneficial or harmful to state policymakers. A social accounting system similar to the one used in this state simulation model should be useful in evaluating such effects of industry location.

The assumptions involved in the present simulation model and the lack of more current data for many components of the present data base limit the usefulness of results for definitive policy analysis. Inability of the model to adjust for exogenous variables, such as variable energy prices and other related price changes, changing government policies, and public attitudes, does not allow much confidence to be placed on predictive power. However, the logic of an energy balance sheet for an energy-producing state such as Oklahoma and the consistency checks provided by input-output should prove useful as one basis for analyzing alternative energy choices.

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TABLE 4. *Increases in energy surplus as a result of 25 percent increase in energy efficiency in the final demand sectors, Oklahoma (trillion BTUs).*

Year	Petroleum products	Natural gas	Electricity & Hydropower	Total
1975		3	1	9
1980	16	10	3	29
1985	33	20	7	59
1990	57	35	12	104
1995	94	58	19	171
2000	148	91	30	269

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