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Sectoral Effects of a World Oil Price Shock: Economywide Linkages to the Agricultural Sector

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The effects of a world oil price shock on U.S. agriculture are analyzed in an economywide environment. We use an input–output model to analyze the direct and indirect cost linkages between energy and other sectors of the economy. Then, to allow sectoral output adjustment and the effects on the U.S. current account, we use the U.S. Department of Agriculture/Economic Research Service Computable General Equilibrium (CGE) model to analyze the sectoral effects under three different macro adjustment scenarios. The effects on agriculture are not limited to the direct and indirect energy costs. Exchange rate or foreign borrowing adjustments to higher oil import costs and government support programs for agriculture also matter.

Key words: computable general equilibrium, energy, farm programs, oil price.

Introduction

The U.S. economy has had to adjust to a number of large swings in the world price of oil over the past 20 years. The effects of these swings on the agricultural sector, and on the cost of government programs designed to support agriculture, are difficult to assess a priori. Based on partial-equilibrium cost studies, agricultural production techniques in the United States are found to be energy-intensive. Higher energy prices should raise the cost of production, leading to lower output and lower farm income. However, given an inelastic demand for farm products, lower production could result in prices (and hence farm income) increasing more than costs. Such a rise in prices would lower the cost of some agricultural support programs, partly offsetting the beneficial effect on farm income. Even in a partial-equilibrium framework, there are a number of countervailing forces at work.

Agriculture is linked to other sectors through flows of intermediate inputs and to the world economy through trade, both of which complicate analysis since these general-equilibrium linkages may be empirically important.[1] Agricultural output is used largely as an intermediate input by other sectors, and agriculture buys inputs such as chemicals, which are made using energy-intensive technologies. While agriculture is directly energy-intensive, the net impact of a rise in the price of energy depends on the relative energy intensiveness of agriculture compared with other sectors, taking indirect linkages into account as well. International trade also is important for agriculture in the United States. For example, higher U.S. oil import payments might result in a depreciation of the dollar, which would, other things equal, stimulate agricultural exports.

Assuming that direct linkages are relatively strong and that agriculture is in fact energy-intensive, we would expect to see an increase in the price of oil followed by higher input costs, lower production, higher prices, and an uncertain effect on net farm income. Table 1 presents data for the periods after the 1973 and 1979 shocks. A cursory review of table

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Table 1. Selected Farm Sector Variables after 1973 and 1979 Oil Price Shocks

Variable	1973 Shock				1979 Shock			
	1973	1974	1975	1976	1979	1980	1981	1982
Nominal Net Farm Income[c] ($ billion)	34.4	27.3	25.5	20.2	27.4	16.1	26.9	23.5
Real Net Farm Income[a] ($ billion 1982)	69.4	50.5	43.1	32.0	34.9	18.8	28.6	23.5
Exports Index[f] (1967 = 100)	154	165	147	167	NA	NA	NA	NA
Exports Index[d] (1977 = 100)	NA	NA	NA	NA	120	143	135	140
Imports Index[g] (1967 = 100)	136	137	118	136	NA	NA	NA	NA
Imports Index[e] (1977 = 100)	NA	NA	NA	NA	115	107	107	105
Production Index[b] (1977 = 100)	93	88	95	97	111	104	118	116
Total Cash Receipts[c] ($ billion)	89.5	92.9	89.7	96.0	132.9	141.0	143.5	146.1

NA = Not applicable.
Sources: USDA, *Agricultural Statistics,* 1988: [a] table 531, [b] table 565, [c] table 583, [d] table 690, [e] table 691; *Agricultural Statistics,* 1977: [f] table 766, [g] table 767.

1 suggests that the farm sector responded as expected to the 1973 and 1979 oil price shocks—production fell, nominal cash receipts rose, and nominal and real net farm income fell. However, other forces were also at work; specifically, 1974 and 1980 were drought years. In a drought, output falls and prices rise. Oil prices and weather were in league during 1974 and 1980, so we cannot separate their effects. The effect on agricultural trade is less confounded. During 1973–80, higher oil prices were associated with higher U.S. agricultural exports (Stallings et al.), with the major causal chain operating through increased world liquidity.

When empirical observation fails to predict the outcome of different forces, models can be used to provide a simulation laboratory for doing controlled experiments, which an unkind nature did not provide. As in the experiments reported in Hickman, Huntington, and Sweeney, we use controlled experiments across models to evaluate selected model assumptions. Two model frameworks are employed. First, a linear, fixed price, input–output model is used to analyze the direct and indirect cost linkages between energy and other sectors. Second, a nonlinear, flexprice, computable general equilibrium (CGE) model, separating the energy sectors, is used to analyze the sectoral effects of a world oil price shock under different macro adjustment scenarios.

Using linear programming, Penn et al., as well as Dvoskin and Heady, have performed similar experiments. Dvoskin and Heady found that doubling the energy price leads to a 5% reduction in demand for energy by agriculture and a 12% increase in the cost of agricultural production. Penn et al. found that a 65% reduction of crude petroleum imports leads to a 2.8% reduction in agricultural production. Neither of these LP models allows for price adjustments or takes into account such general equilibrium effects as changes in the value of the dollar or the balance of trade.

Using a CGE model similar to the one used here, de Melo, Stanton, and Tarr looked at the effects of a 25% increase in tariffs on imports of crude oil and gas. A comparable result reported in their study was the economywide employment relocation. They found a relocation of 153,000 work-years. We find a relocation of 718,000 work-years (4.7 times greater) from an oil price shock which is 4.3 times greater than their 25% tariff increase (our $40 a barrel scenario discussed below).

Energy Intensiveness of Agriculture

Table 2 presents two measures of energy intensiveness based on input–output data. The first column presents the share in total costs of the direct purchases of energy inputs (crude oil, refined petroleum, and electricity and natural gas). This direct measure can be seen as indicating the effect on individual sectors of changes in energy prices in the short run in a partial-equilibrium framework, without any adjustment in other input prices (which themselves depend on energy).

Table 2. Cost/Price Increases from Oil Price Shock

Sectors	Direct Total Energy*	Direct and Indirect Energy Requirements: Crude Alone	Crude and Refined
		(% change)	
Dairy	.017	4.1	6.8
Livestock	.017	4.9	8.0
Cotton	.063	5.9	9.2
Food Grains	.045	3.6	6.3
Feed Crops	.056	4.6	7.8
Oilseed Crops	.028	2.6	4.6
Sugar	.028	2.8	4.9
Other Crops	.039	3.1	5.3
Meat Processing	.007	4.0	6.4
Dairy Processing	.014	4.0	6.2
Grain Milling	.016	4.0	6.2
Prepared Feeds	.011	4.0	6.4
Corn Milling	.070	6.7	10.1
Sugar Processing	.051	6.8	10.2
Oilseed Milling	.017	3.5	5.4
Miscellaneous Foods	.028	5.2	8.0
Resources	.061	5.0	7.6
Crude Oil and Gas	.133	100.0**	100.0**
Construction	.037	4.6	7.8
Petroleum Refining	.483	45.1	100.0**
Chemicals	.104	9.7	14.3
Other Nondurable Manufacturing	.030	4.5	6.8
Other Durable Manufacturing	.043	4.9	7.3
Metal Manufacturing	.041	4.7	6.8
Machinery	.013	2.3	3.3
Other Electrical	.017	3.4	5.0
Consumer Electrical	.020	3.7	5.7
Transportation Equipment	.010	3.0	4.4
Electric and Gas	.527	42.6	46.4
Trade and Transportation	.062	4.5	7.7
Finance	.016	5.6	6.5
Services	.032	6.5	8.4

* Direct energy requirements is the sum of the I/O coefficients for the three energy sectors: crude oil, refined petroleum, and electricity and gas. They are in units of billions of dollars per $1 billion of output.
** Assumed.

The energy sectors are the heaviest direct energy users. The chemical and rubber products sector, which includes subsectors that use petrochemicals as a manufacturing input as well as an energy input, is the next heaviest direct user of energy in production. Next come the agricultural sectors. The various crop sectors (especially cotton, food grains, and feed crops) and some of the agricultural processing sectors (corn milling and sugar processing) are more dependent on energy than the other goods-producing sectors in the model.

The next two columns in table 2 present variants of an input–output based measure of direct and indirect sectoral energy requirements.[2] This measure accounts for the transmission of changes in energy prices to changes in intermediate costs in all sectors. Sectors with low direct energy requirements may still be affected by increased energy prices because they purchase other inputs that use energy intensively (for example, fertilizer in agriculture). This approach can be seen as being more long-run, because it is assumed that the entire sectoral cost structure has time to adjust to the change in energy prices, and represents a step toward general equilibrium analysis.

Column 2 of table 2 indicates the rise in intermediate costs of production given a doubling of the crude oil price. Note first that the cost price of petroleum refining rises by 45%, which roughly reflects the share of crude petroleum in total refining costs (.414 of the .483 coefficient in column 1 is crude oil requirements). That is, in a market in which prices reflect costs, the price increase for refined products will be about half that of crude petroleum. One might assume a less-than-competitive market structure in refining, and so consider that the price of refined products would increase by more than would be justified by the share of crude petroleum in the cost of refined products.

In table 2, column 3, we assume that the refined petroleum price also doubles. In this case, we treat the prices of both crude petroleum and refined products as exogenous. The effect on other sectors is to raise their costs, since the assumed increase in the price of refined products is roughly twice that resulting from (direct and indirect) cost increases (column 2).

The crop sectors are still relatively energy-intensive, but indirect linkages begin to exert different influences. The feed crops and cotton sectors use relatively more nitrogen fertilizers and agricultural chemicals, inputs with a petroleum base. These sectors are affected more by the crude oil shock than oilseed crops, a sector dominated by soybeans, legumes which produce much of their own nitrogen. When the output price of the refining sector also doubles, the indirect effects are more variegated. The crop sectors have a proportionately greater increase in costs than other sectors, and so appear to be more sensitive to assumptions about price linkages between petroleum and refining than the other sectors.

These input–output based measures consider only the effect of price changes on sectoral costs that work through intermediate-input linkages. They take no account of changes in demand or of substitution possibilities. They also take no account of feedback mechanisms working through macro variables, such as the exchange rate. To consider these additional relationships, we turn from input–output analysis to CGE modeling.

The Structure and Properties of the CGE Model

This section gives a brief overview of the structure and properties of the CGE model used in the analysis. A more complete description of the basic U.S. Department of Agriculture/Economic Research Service (USDA/ERS) CGE model can be found in Robinson, Kilkenny, and Hanson. The model is an expanded version of the basic model. It includes 32 sectors, incorporates alternative functional forms, and includes an explicit treatment of farm programs.[3]

The model described is the one used for the experiments. We also report sensitivity experiments designed to explore how robust the results are with respect to alternative specifications of some elements of model behavior. In the sensitivity analysis, we allow for increased factor mobility in agriculture, alternative treatments of farm programs, alternative assumptions about inflation and full employment, and substitution of coal for petroleum in the production of electricity.

Major Features of the CGE Model

A CGE model simulates the working of a market economy in which prices and quantities adjust to clear markets for products and factors. Our CGE model simulates the behavior of optimizing consumers and producers, includes the government as an explicit agent, and captures all transactions in the circular flow of income.

The model has 32 sectors, each producing a composite commodity that can be transformed into an export good or a commodity sold on the domestic market. Each sector's output is produced according to a constant elasticity of substitution (CES) production function using two primary inputs: labor and capital. The agricultural crop sectors also use land. Intermediate inputs are used in fixed proportions to output. Sectoral input demands are derived from first-order conditions for profit maximization.

The 32-sector aggregation includes eight agricultural production sectors, eight agricultural processing sectors, three energy sectors, 10 other manufacturing sectors, and three services sectors. The disaggregation of agricultural production and processing into 16 sectors allows us to represent the essential characteristics of the farm programs and capture many of the linkages among the agricultural production sectors, between them and the agricultural processors, and with the rest of the economy. The three energy sectors, reflecting the detail available in the national I/O accounts, are crude oil and natural gas, petroleum refineries, and electric and gas utilities.

Our analysis is relatively short-run; we assume that aggregate employment is specified exogenously and that the real wage adjusts to clear the labor market. There is assumed to be no supply response by domestic oil producers to price changes, nor is there any fuel substitution in intermediate demand for energy.[4] We also make factor mobility assumptions that are consistent with the short-run perspective. We fix capital by sector, which dampens the supply response to the price shocks. We also keep land in agriculture fixed by sector (crop).[5]

Aggregate domestic demand has four components: consumption, intermediate demand, government, and investment (including inventory accumulation). Household expenditure functions are derived from a Cobb–Douglas utility function, yielding fixed nominal expenditure shares. Each household pays income taxes to the government and saves a fixed proportion of after-tax income. Intermediate demand is calculated from sectoral output, using fixed input–output coefficients. For the government, real aggregate spending on goods and services is fixed and its sectoral composition is given by fixed shares. Inventory demand by sector is a fixed proportion of domestic output.

Aggregate investment is "savings-driven." The difference between aggregate savings and inventory demand represents the funds available for purchasing new capital goods (fixed investment). Expenditure on investment goods by sector is a fixed share of the total funds available for investment, giving investment demand by sector of destination. Investment demand by sector of origin is translated from investment demand by sector of destination by using a capital composition matrix.

Aggregate savings is the sum of household saving, enterprise-retained earnings plus capital consumption allowance, government saving, and foreign saving. Household saving is a fixed fraction of after-tax income. Enterprise retained earnings is a fixed fraction of after-tax income, while the capital consumption allowance is a fixed fraction of capital stocks. Government saving is the difference between government revenue (the sum of the household income tax, enterprise profit tax, social security tax, tariffs, and excise taxes) less government spending on goods and services and transfer payments. Foreign saving is the balance of trade in goods and nonfactor services.

The model contains a balance-of-trade constraint in that the value of imports at world prices must equal the value of exports at world prices plus foreign savings, net remittances, and net foreign borrowing by the U.S. government. In the CGE model, two alternative equilibrating mechanisms are specified. First, the real exchange rate adjusts to achieve equilibrium given an exogenously specified balance of trade. Second, the exchange rate is exogenous, and foreign savings adjust to achieve equilibrium. We use both approaches to reflect alternative macro scenarios.

The model incorporates imperfect substitution between imports and domestic goods, using the Armington assumption. Domestic demand is for a "composite commodity," which consists of imports and domestically produced goods. They are combined according to a constant elasticity of substitution (CES) aggregation function. The equilibrium ratio of sectoral import demand to domestic demand for domestic goods is a function of their relative prices, the elasticity of substitution, and share parameters.

There is a parallel treatment of export supply, with imperfect transformability between production for domestic and foreign markets at the sectoral level. Each sector produces a composite commodity that can be transformed into an export or a commodity sold on the domestic market. The transformation is according to a constant elasticity of transformation (CET) function. The equilibrium ratio of export supply to domestic supply depends on their relative prices, the elasticity of transformation, and share parameters.

This treatment of imports and exports partially insulates the domestic price system from changes in world prices of sectoral substitutes. The model also makes the "small country" assumption on the import side, assuming that the United States cannot affect world prices of its imports. On the export side, we assume downward-sloping world demand functions for four U.S. agricultural exports: cotton, food grains, feed crops, and oilseed crops. All other exports have exogenous world prices.

The CGE model solves only for relative prices. We choose as the numeraire price index the gross domestic product (GDP) price deflator, so all nominal values are relative to a fixed GDP deflator. Given the choice of numeraire, the model solves for all factor returns, prices, and the real exchange rate that clear the markets for factors and products, and equilibrates the balance of trade.

Modeling Agricultural Programs

The USDA/ERS CGE model includes a fair amount of detail in the agricultural sectors. The model also explicitly incorporates government programs to support agriculture. A number of agricultural models simulate such programs by using a fixed ad valorem price wedge. Kilkenny and Robinson (1989, 1990) argue that this approach is often inadequate, failing to capture the effect of policy changes on program costs and producer incentives. Instead, we model several of the programs individually, including the deficiency payment program, export subsidies, and import quotas. The intent is to capture the essential institutional features of the various programs.[6]

Deficiency payments in the model apply to cotton, food grains, and feed crops. We simplify by assuming an exogenous participation rate. Producers participating in the program, having set aside the requisite acres, receive a target price for the commodities produced, rather than the market price. Equilibrium production levels are in response to the fixed target price rather than to the market price. As long as the market price remains below the target price, changes in production costs and market demand only influence the market price, while the target price remains the signal that controls production. The deficiency payment program distorts producer behavior in a way that is not captured by a fixed wedge.

Export subsidies are modeled for food grains, feed crops, meat processing, grain milling (flour), and soy milling. The export subsidy is treated as an ad valorem wedge between the world price of U.S. exports and the export price received by domestic producers. We assume that the export subsidy rate does not change in response to the oil price shock.

Import quotas are modeled for dairy processing and sugar processing. Given an exogenous level of real imports and a fixed world price, there is an endogenous premium or tariff-equivalent wedge between the world price and the domestic import price. We assume the quota-constrained level of real imports remains the same in the experiments, and that the premium rate is determined endogenously.

Model Calibration and Forward Projections

The 32-sector CGE model is calibrated to a 1986 data base.[7] The experiments for the world oil price shock are from a 1991 base solution. The 1991 base is from macroeconomic forecasts made prior to the oil price shock, and that include a number of historical trends for exogenous variables. The economic structure for the 1991 base is given in table 3. The 1991 structure provides the basis for comparing the sectoral effects from the oil price shock, reported as percentage changes from the 1991 base solution.

World Oil Price Shock Scenarios

Starting with this 1991 base solution, we use the CGE model to compare the effects of three alternative changes in the oil price under three different assumptions about the nature of the U.S. economy's macro adjustment to the higher oil prices. Our focus is on

Table 3. Economic Structure of the 1991 Base Scenario

Sector	Labor	Capital	Land	Real Output	Real Exports	Real Imports	Producer Price	Nominal Value Added	Nominal Sector Income
	(%)			(share of output)			(1982 = 1)	($ billion)	
Dairy	.17	.14		.30	0	0	1.18	6.0	5.6
Livestock	.44	.46		.92	.7	2.1	1.29	11.3	9.7
Cotton	.02	.03	3.60	.05	27.8	.1	.92	.9	1.8
Food Grains	.10	.12	20.88	.16	53.0	.8	1.05	8.2	11.3
Feed Crops	.36	.81	51.97	.59	20.6	.8	1.24	37.1	41.9
Oilseed Crops	.17	.31	19.16	.21	39.7	1.1	1.53	18.8	18.4
Sugar	.04	.03	.65	.03	0.0	0	1.17	2.0	1.9
Other Crops	.64	.30	3.74	.35	7.8	20.2	1.19	24.7	24.3
Meat Processing	.31	.20		.97	5.4	6.8	1.24	20.3	20.0
Dairy Processing	.14	.11		.56	1.1	2.3	1.21	11.3	11.1
Grain Milling	.05	.06		.25	10.7	1.1	1.19	5.5	5.4
Prepared Feeds	.04	.05		.21	2.3	.7	1.22	4.5	4.4
Corn Milling	.01	.01		.05	17.6	1.0	1.25	1.0	1.0
Sugar Processing	.09	.05		.23	1.3	5.3	1.36	5.5	5.4
Oilseed Milling	.04	.05		.21	14.1	6.2	1.34	4.5	4.5
Miscellaneous Foods	.72	.36		1.67	1.5	6.0	1.37	41.1	30.9
Resources	.57	.72		.81	10.4	11.2	1.18	36.8	33.3
Crude Oil and Gas	.42	3.17		2.09	0.9	42.7	.74	81.0	67.4
Construction	5.59	.72		6.99	0.0	0	1.26	277.5	270.3
Petroleum Refining	.16	.71		3.10	9.4	13.2	.70	52.5	48.2
Chemicals	1.61	1.51		3.78	9.0	7.5	1.20	129.8	124.0
Other Nondurable Manufacturing	3.87	1.58		4.96	7.0	22.0	1.32	206.0	196.9
Other Durable Manufacturing	2.09	.74		2.42	8.3	17.0	1.30	107.0	103.8
Metal Manufacturing	2.16	1.91		3.77	11.4	15.7	1.21	136.5	131.3
Machinery	1.84	.50		4.01	21.5	11.9	.83	102.0	99.3
Other Electrical	1.86	.93		2.34	19.7	18.4	1.29	107.8	105.9
Consumer Electrical	.95	.48		1.20	43.5	82.2	1.29	55.2	54.0
Transportation Equipment	2.19	1.31		4.47	20.8	24.7	1.30	166.7	160.1
Electric and Gas	.85	6.44		3.20	.3	1.0	1.33	186.5	173.8
Trade and Transportation	24.99	9.97		16.59	5.2	.3	1.36	1,178.5	1,010.2
Finance	6.27	56.92		11.78	1.6	.1	1.50	994.4	836.9
Services	41.24	9.33		21.74	1.2	.1	1.49	1,844.9	1,805.8
Total	100.0	100.0	100.0	100.0	6.3	7.2	1.3	5,865.8	5,418.9
Agriculture	1.9	2.2	100.0	2.6	12.8	3.8	1.2	109.0	114.9
Food Processing	1.4	.9		4.2	3.8	5.0	1.3	93.7	82.7
Energy	1.4	10.3		8.4	3.8	15.9	.9	320.1	289.4
Other Industry	22.7	10.4		34.7	12.0	15.7	1.2	1,325.3	1,278.9
Services	72.5	76.2		50.1	2.6	.2	1.4	4,017.9	3,652.9

Note: Value added is market revenue less intermediate costs. Sector income is value added, less indirect business tax, plus government payments.

counterfactual analysis. We are not seeking to project what macro adjustment will occur or what the world oil price will be. Instead, we analyze the effects of various oil price scenarios and macro adjustment scenarios on sectoral prices, incomes, and production.

The Energy Sectors

The three oil price shocks we consider are a move to \$30, \$40, and \$50 per barrel of crude oil, compared with a base price of \$19.30 per barrel. These changes are modeled by increasing the exogenous world price of petroleum by 55.44%, 107.25%, or 159.07%.[8] We treat refined petroleum products as a separate sector, as well as the electric and gas utilities. We assume that there are close links in the world oil market between crude oil and refined oil product prices. As part of the oil price shock, we also exogenously increase the world price of imported petroleum refinery products by half the percentage increase in the world crude oil price. This change approximates the cost pass-through from petroleum to refined products generated by the input–output model. The world price of exported U.S. refined petroleum products is increased by one-third of the crude oil price shock.[9]

Macro Adjustment Scenarios

We compare results from three alternative macro adjustment scenarios: macros- 1, 2, and 3. Each scenario captures a possible macro policy response to an increase in the cost of petroleum imports.[10] Macro-1 assumes a fixed exchange rate, with foreign borrowing adjusting endogenously to equilibrate the balance of trade after the oil price shock. Under macro-1, the United States can borrow abroad to pay for the greater cost of imports. Macro-2 assumes no change in foreign borrowing (and hence a fixed balance of trade in world prices) and that the exchange rate adjusts to equilibrate the balance of trade. Macro-3 also assumes an exogenous level of foreign borrowing and a flexible exchange rate, but the level of foreign borrowing falls. This scenario specifies an improvement in the U.S. trade balance, under the assumption that other countries are also adversely affected by the oil price shock and that world capital markets become tighter. The macro-3 scenario results in a greater depreciation of the dollar, increase in exports, and reduction in imports than does the more flexible macro-2 scenario.

Most macro projections assume that the oil price shock will generate inflation. The CGE model only determines relative prices, so we keep the GDP deflator fixed in all experiments. In addition, macro projections usually assume that there will be an aggregate employment effect, which again the CGE model assumes away. For sensitivity analysis with the CGE model, we take projections of inflation and changes in aggregate employment from a macro model and include them as part of the oil price shock scenario.

Sectoral Effects of a World Oil Price Shock

Table 4 provides the macro results of the oil price shocks under the three macro adjustment scenarios. In all three scenarios, price changes cause consumer prices to rise relative to the GDP deflator, which remains fixed by assumption, by about .7% for the $30 price of oil, 1.2% for the $40 price, and 1.6% for the $50 price. All scenarios appear to have a similar effect on the government deficit. Higher prices lead to an increase in tax revenue that is greater than the increase in nominal expenditures, and the government deficit falls.

A part of the increase in tax revenue is a windfall profit tax on the three energy sectors, crude oil and gas, petroleum refining, and electric and gas. If the windfall profit tax is not active, and the tax on energy is per unit of commodity such as a gallon of gas, then there is a loss of government revenue of $5.4 billion and the deficit is larger than that presented in table 4 by the same amount.[11] The greater government deficit reduces investment.

Macro-1, the fixed exchange rate scenario, is an extreme case of no depreciation of the dollar (see the first three columns of tables 4, 5, and 6) in the face of an adverse terms-of-trade shock. The result is a 20 to 50% increase in foreign borrowing to pay for the greater cost of imports, an increase of $13.9 to $33.4 billion. This greater foreign borrowing leads to an increase in domestic absorption and a reduction in exports in all categories, except agriculture. The borrowed funds are available for investment in fixed capital formation, leading to a 2.3 to 5.4% increase in domestic investment. Increased savings and investment, in turn, lead to lower aggregate consumption, which leads to lower demand for farm products and lower domestic farm prices. Lower domestic farm prices cause a diversion of supply into the export markets, increasing agricultural exports.

Alternatively, the exchange rate can adjust. Macro-2's flexible exchange rate, with no change in U.S. balance of trade, is the middle case of the three macro experiments. There is a .9 to 2.1% depreciation of the dollar, depending on the oil price shock, and a con-

Table 4. Macro Effects from a World Oil Price Shock

	(Macro-1) Fixed Exchange Rate, Flexible Trade Balance			(Macro-2) Flexible Exchange Rate, Fixed Trade Balance			(Macro-3) Flexible Exchange Rate, Reduction in Trade Balance		
Oil Price:	$30	$40	$50	$30	$40	$50	$30	$40	$50
	(% change from base)								
World Oil Price	55.4	107.2	159.1	55.4	107.2	159.1	55.4	107.2	159.1
GDP Deflator	0	0	0	0	0	0	0	0	0
Consumer Prices	.7	1.2	1.5	.7	1.2	1.6	.8	1.3	1.7
Nominal Exchange Rate	0	0	0	.9	1.5	2.1	1.7	2.7	3.6
Macro Balances:									
Domestic Investment Difference:									
Billion Dollars	20.6	35.9	49.2	3.5	6.0	8.2	−12.1	−17.6	−23.6
Percent Change	2.3	3.9	5.4	.4	.7	.9	−1.3	−1.9	−2.6
Foreign Savings Difference:									
Billion Dollars	13.9	24.3	33.4	0	0	0	−12.4	−18.6	−24.9
Percent Change	22.4	39.1	53.7	0	0	0	−20.0	−30.0	−40.0
Government Savings Difference:									
Billion Dollars	2.1	3.6	5.0	2.5	4.3	6.1	2.8	4.9	6.8
Percent Change	3.4	6.0	8.4	4.1	7.2	10.1	4.7	8.1	11.3

comitant increase in aggregate real exports. The lower value of the dollar and higher exports raise consumer and producer price indices, and raise value added for the petroleum sector, but not at the expense of farming. In the United States, depreciation of the dollar is good for agriculture. As in the fixed exchange rate case, the higher cost of production shifts the sector supply curves to the left. But depreciation helps tradable goods sectors, like agriculture, by expanding exports and reducing competitive imports.

Macro-3 assumes that foreign borrowing decreases under a flexible exchange rate regime. The result is a greater depreciation of the dollar and a greater increase in exports than in the macro-2 scenario. The macro-3 scenario is the most beneficial to the crude oil and agricultural sectors.

The required structural adjustments in sectoral production, exports, and income are very sensitive to the assumed macro adjustment scenario. The cost of farm programs is also sensitive to the adjustment scenario. Table 5 provides the sectoral results as aggregates of the 32 sectors in the model, and table 6 presents results for the agricultural sectors and the cost of the farm programs.

First, consider the price linkages among the energy sectors. The world oil price shock occurs to the crude oil sector, whose producer price increases the most. The producer price for domestic crude oil and natural gas increases by about one-half of the world oil price increase, which is much less than the full pass-through assumed in the input–output model. The producer price for refined petroleum products increases by about one-fourth the world oil price shock, or about one-half the increase in the domestic crude price, a result consistent with the input–output analysis. About one-sixth of the world crude oil price increase is passed through to the producer price for the electric and natural gas utilities sector. In the model, these "price transmission" elasticities depend largely on assumptions about sectoral import substitution and export transformation elasticities. They seem empirically reasonable, although they are certainly lower than would occur in a neoclassical trade model or an input–output model in which all domestic and foreign goods are perfect substitutes.

The assumed macro response makes little difference to the effects of the oil price shock on the energy sectors. In all cases, the higher import price for crude oil reduces imports and lowers domestic supply, given fixed domestic production. Lower supply of crude oil leads to lower production of refined petroleum, electricity, and natural gas. With constant

Table 5. Sectoral Effects from a World Oil Price Shock

	(Macro-1) Fixed Exchange Rate, Flexible Trade Balance			(Macro-2) Flexible Exchange Rate, Fixed Trade Balance			(Macro-3) Flexible Exchange Rate, Reduction in Trade Balance		
Oil Price:	$30	$40	$50	$30	$40	$50	$30	$40	$50
	(% change from base)								
Producer Price	.9	1.7	2.4	1.0	1.8	2.6	1.0	1.9	2.7
Agriculture	−.01	−.04	−.1	.4	.8	1.0	.8	1.3	1.8
Food Processing	.2	.3	.4	.3	.6	.8	.5	.8	1.0
Energy	12.5	23.6	34.4	12.9	24.5	35.8	13.3	25.2	36.9
Crude Oil and Gas	28.1	52.8	76.3	29.1	54.9	79.5	30.0	56.4	81.8
Petroleum Refining	14.4	27.4	40.0	14.9	28.4	41.6	15.3	29.2	42.8
Electric and Gas	5.9	11.2	16.3	6.1	11.6	17.0	6.3	11.9	17.5
Other Manufacturing	.4	.7	1.0	.4	.7	1.0	.4	.7	1.0
Services	.1	.1	.1	.1	.1	.1	.1	.1	.1
Production, Real	−.04	−.1	−.1	0	−.1	−.1	0	−.1	−.1
Agriculture	−.1	−.2	−.3	0	−.1	−.1	0	0	0
Food Processing	−.3	−.5	−.7	−.2	−.4	−.6	−.2	−.4	−.6
Energy	−1.9	−3.2	−4.3	−1.9	−3.2	−4.4	−1.9	−3.3	−4.4
Crude Oil and Gas	0	0	0	0	0	0	0	0	0
Petroleum Refining	−2.6	−4.3	−5.5	−2.6	−4.3	−5.5	−2.6	−4.3	−5.5
Electric and Gas	−2.4	−4.3	−6.0	−2.4	−4.3	−6.1	−2.4	−4.4	−6.2
Other Manufacturing	.4	.8	1.0	.4	.7	.9	.3	.6	.8
Services	−.03	−.1	−.1	0	0	0	.0	.0	.1
Value Added, Nominal	0	0	0	.1	.1	.1	.1	.1	.1
Agriculture	−1.0	−1.8	−2.6	−.2	−.4	−.8	.5	.6	.6
Food Processing	−.7	−1.4	−2.1	−.7	−1.3	−2.0	−.6	−1.3	−1.9
Energy	5.7	11.2	16.7	6.0	11.8	17.6	6.3	12.2	18.3
Crude Oil and Gas	37.1	69.8	100.9	38.5	72.6	105.1	39.7	74.7	108.2
Petroleum Refining	−5.0	−8.0	−10.1	−4.9	−7.9	−10.0	−4.9	−7.9	−10.0
Electric and Gas	−4.9	−8.9	−12.3	−5.0	−9.0	−12.6	−5.1	−9.2	−12.8
Other Manufacturing	.1	.1	−.1	0	−.1	−.3	−.1	−.3	−.5
Services	−.4	−.8	−1.1	−.4	−.7	−1.1	−.4	−.7	−1.1
Exports, Real	−.4	−.5	−.6	1.5	2.7	3.8	3.1	5.2	7.2
Agriculture	.1	.2	.4	.5	.9	1.2	.8	1.3	1.9
Food Processing	−.5	−.8	−1.1	1.1	2.0	2.7	2.6	4.1	5.5
Energy	−3.0	−3.9	−4.1	−2.4	−3.0	−3.0	−1.9	−2.4	−2.2
Crude Oil and Gas	−39.0	−57.2	−67.8	−38.9	−57.0	−67.6	−38.8	−56.9	−67.5
Petroleum Refining	−.4	0	.8	.2	.9	1.9	.7	1.6	2.7
Electric and Gas	−12.9	−22.5	−30.5	−11.7	−20.8	−28.4	−10.7	−19.5	−26.9
Other Manufacturing	−.2	−.2	−.2	1.9	3.4	4.8	3.8	6.3	8.6
Services	−.5	−.8	−1.0	1.3	2.4	3.3	3.0	4.8	6.5
Imports, Real	−1.9	−2.9	−3.6	−2.9	−4.7	−6.0	−3.8	−6.0	−7.8
Agriculture	−.1	−.3	−.4	−.5	−.9	−1.2	−.8	−1.3	−1.8
Food Processing	.1	0	0	−1.0	−1.8	−2.5	−1.9	−3.1	−4.2
Energy	−13.0	−20.5	−25.8	−13.2	−20.8	−26.3	−13.4	−21.1	−26.6
Crude Oil and Gas	−13.3	−20.6	−25.7	−13.3	−20.7	−25.9	−13.4	−20.8	−26.0
Petroleum Refining	−13.4	−21.9	−28.1	−13.9	−22.7	−29.1	−14.4	−23.3	−29.8
Electric and Gas	−.1	−.3	−.6	−.3	−.5	−.8	−.4	−.7	−1.0
Other Manufacturing	.7	1.2	1.6	−.6	−1.0	−1.4	−1.7	−2.6	−3.5
Services	0	0	0	−.4	−.7	−.9	−.7	−1.2	−1.6

output and a large increase in producer price, the crude oil sector has a huge increase in value added. The two secondary energy sectors have a fall in value added, because of the higher costs of inputs. The scarce factor gets the rent.

In contrast to the energy sectors, the effects on other sectors in the economy are very sensitive to the macro scenario. For example, with no depreciation of the dollar, increased foreign borrowing generates an increase in aggregate investment, which stimulates indus-

Table 6. Agricultural Effects from a World Oil Price Shock

	(Macro-1) Fixed Exchange Rate, Flexible Trade Balance			(Macro-2) Flexible Exchange Rate, Fixed Trade Balance			(Macro-3) Flexible Exchange Rate, Reduction in Trade Balance		
Oil Price:	$30	$40	$50	$30	$40	$50	$30	$40	$50
	(% change from base)								
Producer Price	−.01	−.04	−.07	.40	.80	1.00	.80	1.30	1.80
All Livestock	.08	.10	.10	.40	.60	.90	.60	1.00	1.40
Food Grains	−.07	−.10	−.20	.80	1.40	1.90	1.60	2.60	3.50
Feed Crops	−.10	−.20	−.30	.60	1.00	1.40	1.20	2.00	2.60
Oilseed Crops	−.20	−.30	−.40	.60	1.00	1.30	1.20	1.90	2.50
All Other Crops	−.02	−.08	−.10	.20	.30	.40	.40	.60	.80
Real Production	−.10	−.20	−.30	−.05	−.09	−.10	.01	−.00	−.01
All Livestock	−.10	−.20	−.30	−.10	−.20	−.30	−.10	−.20	−.30
Food Grains	−.04	−.06	−.08	.01	.02	.03	.05	.08	.10
Feed Crops	−.08	−.10	−.20	−.01	−.03	−.04	.05	.07	.08
Oilseed Crops	−.03	−.04	−.05	.20	.40	.60	.50	.80	1.00
All Other Crops	−.20	−.30	−.40	−.04	−.08	−.10	.08	.10	.10
Real Exports	.10	.20	.40	.50	.90	1.20	.80	1.30	1.90
All Livestock	−.30	−.60	−.80	.80	1.50	2.00	1.90	3.00	4.00
Food Grains	.10	.20	.30	.10	.20	.30	.10	.20	.40
Feed Crops	.10	.30	.50	.50	.90	1.20	.80	1.30	1.80
Oilseed Crops	.20	.50	.70	.60	1.20	1.70	1.00	1.70	2.30
All Other Crops	−.20	−.30	−.30	.80	1.40	2.00	1.70	2.70	3.70
Value Added, Nominal	−1.00	−1.80	−2.60	−.20	−.40	−.80	.50	.60	.60
All Livestock	−.90	−1.80	−2.60	−1.00	−1.90	−2.70	−1.00	−2.00	−2.80
Food Grains	−1.00	−1.90	−2.80	.30	.40	.40	1.50	2.20	2.70
Feed Crops	−1.20	−2.30	−3.30	−.07	−.30	−.60	.90	1.20	1.30
Oilseed Crops	−.50	−1.00	−1.40	.60	1.00	1.30	1.60	2.50	3.20
All Other Crops	−.90	−1.70	−2.50	−.50	−.90	−1.50	−.06	−.40	−.70
Sector Income, Nominal	−.90	−1.60	−2.40	−.40	−.90	−1.30	−.01	−.30	−.50
All Livestock	−1.00	−2.00	−2.90	−1.20	−2.20	−3.20	−1.30	−2.30	−3.40
Food Grains	−.70	−1.30	−1.90	−.40	−.70	−1.10	−.07	−.30	−.50
Feed Crops	−1.00	−1.90	−2.70	−.50	−1.10	−1.60	−.10	−.40	−.80
Oilseed Crops	−.50	−1.00	−1.50	.60	1.00	1.30	1.60	2.50	3.20
All Other Crops	−.90	−1.70	−2.50	−.50	−1.10	−1.70	−.20	−.70	−1.10
Farm Program Costs (Deficiency Payments)	.30	.60	.90	−2.70	−4.60	−6.20	−5.30	−8.50	−11.30
All Livestock	0	0	0	0	0	0	0	0	0
Food Grains	.20	.30	.50	−1.90	−3.30	−4.40	−3.70	−6.00	−8.00
Feed Crops	.50	1.00	1.50	−3.20	−5.30	−7.10	−6.40	−10.10	−13.40
Oilseed Crops	0	0	0	0	0	0	0	0	0
All Other Crops	−.50	−.08	−1.20	−2.70	−4.70	−6.50	−4.70	−7.70	−10.40

tries supplying capital goods. With depreciation of the dollar, there is much less effect on aggregate investment and much more effect on sectors with high-trade shares.

The increases in energy prices hurt the agricultural processing sectors, with lower output and value added, in all macro scenarios. Higher input prices lead to a fall in output and value added, with some increase in output price, but not enough to offset the increase in costs. While there is an increase in exports with depreciation of the dollar, exports are a small share of output in the agricultural processing sectors.

From table 5 (first 3 columns), there is a fall in agricultural value added when there is no depreciation of the dollar. In this case, producer prices are lower, production is lower, and costs of production are higher. With depreciation of the dollar and reduction in the trade balance, the increased agricultural exports offset the increase in input costs. Given the operation of agricultural programs, supply is partly insulated from changes in market prices. The greater export demand for agricultural commodities leads to a higher producer

Table 7. Farm Sector Income for Macro-3 Scenario and $40 Oil Price

	Dairy	Livestock	Cotton	Food Grains	Feed Crops	Oilseed Crops	Sugar	Other Crops
	(difference from base, $ million)							
Market Revenue:								
Domestic Sales	68	893	117	154	779	314	−33	−15
Exports	0	40	17	182	417	374	0	203
Total	68	933	134	336	1,196	688	−33	187
Intermediate Costs:								
Agriculture	166	668	5	16	50	73	0	11
Processed Feeds	23	94	0	0	0	0	0	0
Energy	78	246	50	118	545	101	14	227
Other	1	64	13	26	164	47	1	72
Total	268	1,072	68	160	758	222	15	310
Value Added	−200	−139	66	176	438	466	−47	−122
Less Indirect Taxes	1	16	2	6	22	10	0	3
Plus Government Payments	0	0	−77	−202	−598	0	0	0
Sector Income	−201	−155	−12	−32	−183	456	−47	−125
	(% change from base)							
Production	−.4	−.1	0	−.1	.1	.8	−.6	.2
Domestic Sales	.2	.9	4.5	2.4	1.6	2.0	−1.2	0
Price	.7	1.1	3.8	2.5	1.9	1.8	−.6	0.2
Quantity	−.4	−.2	.7	−.1	−.2	.2	−.6	−.2
Exports	0.0	5.8	1.7	2.9	3.6	3.9	0.0	7.7
Price	0.0	2.7	3.2	2.6	2.3	2.1	0.0	2.7
Quantity	0.0	3.0	−1.5	0.2	1.3	1.7	0.0	4.8
Intermediate Costs	1.2	1.3	2.4	3.6	3.4	3.2	1.8	3.4
Sector Income	−3.6	−1.6	−.7	−.3	−.4	2.5	−2.4	−.5

Notes: Value added is market revenue less intermediate costs. Sector income is value added, less indirect business tax, plus government payments. Government payments include deficiency payments plus export subsidies. The macro-3 scenario assumes a flexible exchange rate and a reduction in the balance of trade.

price and value added increases. The higher market price for agricultural commodities also increases the domestic cost of food. The combined effects of rising energy and food prices increase relative consumer prices (table 4), but not by a large amount. Agricultural commodities represent about 30% of the cost of processed food and, in the Bureau of Labor Statistics' *Consumer Price Index,* food's weight is only about 16%.

Table 6 provides more detail on the agricultural sectors. The adjustment among agricultural sectors is strongly influenced by the way farm programs interfere with the role of market prices as signals to producers. The gain in production is greater for oilseed crops, which have no deficiency payment program or target price, than for food grains or feed crops, which operate under a deficiency payment program with a target price. In this same scenario, deficiency payments fall, value added rises for feed crops, food grains, and oilseed crops, but sector income (value added plus deficiency payments less indirect business tax) falls for food grains and feed crops, which have a deficiency payment program. Only for the oilseed crops sector (which is not treated as having a farm program) does sector income rise. The deficiency payment program serves to insulate supply and sector income from changes in market prices. Livestock consistently loses in all three macro scenarios. Higher input costs lead to a fall in sectoral production, value added, and income.

The fall in value added for other crops can be accounted for by the combination of a high energy intensity and a low export share. The beneficial effect of depreciation of the dollar under macro-2 and macro-3 is not large enough to offset the increase in input costs.

Table 7 provides model results for the eight farm sectors for one experiment, a $40 oil price under macro-3. Production drops for the two livestock sectors and sugar, stays the same for cotton, and increases for the other four crop sectors. Dairy and sugar are particularly vulnerable to oil price shocks. Neither commodity is exported, so there is no stimulus to demand from the more favorable exchange rate. Higher production costs thus lead to lower production, not offset with higher prices. These sectors suffer the largest fall in income (last row, table 7). While livestock is exportable, the export share is small. Sectoral output falls slightly (−.1%) and its price rises (1.1%), but not by enough to offset the increase in costs. Sectoral income declines by a larger percentage than all crop sectors other than sugar.

Cotton experiences an increase in domestic sales due to a rise in price. Output stays constant and there is some diversion of supply from the export market to the domestic market. The depreciation of the dollar increases exports and decreases imports of other nondurables, the sector which includes textiles and apparel. The result is an increase in the demand for cotton. The price rise more than offsets higher intermediate costs, and value added in cotton increases. However, the higher market price causes government deficiency payments to fall. The drop in program support more than offsets the increase in value added, and sector income for cotton drops.

The story for the other program crop sectors, food grains and feed crops, is similar to that for cotton, except that output increases slightly and there is some diversion toward the export markets. Market revenue increases more than intermediate input costs, so value added rises. However, the higher market prices lower deficiency payments, and sector incomes fall.

Of the farm sectors, only for oilseed crops does sector income rise after an oil price shock. Output increases the most, and like grains, prices rise due to increased exports, and the sector experiences an increase in value added. However, unlike grains, the oilseed crops sector gets to keep the increase since there are no government program payments, and therefore no decrease in payments as the price rises.

The percentage changes in intermediate costs (table 7) are comparable to the cost-price increases from the input–output analysis (table 2). We only report the percentage changes in intermediate costs for the agricultural sectors, which are consistently lower than the cost-price increases from the input–output analysis. The greater flexibility in economywide response to the oil price shock from the CGE model over the input–output model significantly alters how the modeled economy responds. The greater flexibility of the CGE model is an attempt to be more inclusive as to how an economy adjusts to shocks.

Sensitivity Analysis

Although the more complete representation of economywide markets and the circular flow of income of a CGE model usually improves on a partial equilibrium modeling of an issue, the representation of a complete real economy within a CGE model requires simplifying assumptions and representations of the economy. Do these assumptions and representations drive our model results or are our results robust to variations of these assumptions? To give our readers a sense of this sensitivity, we chose several potentially crucial assumptions and representations and report the results of experiments designed to assess the sensitivity of the model results to these assumptions and representations. These results are presented in tables 8–10 and are reviewed below. All these sensitivity experiments start from one scenario: $40 oil and macro-3 (flexible exchange rate and a decline in foreign borrowing). All the sensitivity results are compared with the results from this scenario with the base model.

First, we allow for increased factor mobility in agriculture by allowing land to shift among the agricultural crop sectors. Second, we consider an alternative treatment of the deficiency payment farm program, modeling the program with a fixed ad valorem price wedge rather than with a fixed target price. Third, we incorporate a macro forecast for unemployment and inflation. Fourth, we allow for substitution of coal for petroleum in the production of electricity.

Table 8. Sensitivity Analysis: Macro Effects from a World Oil Price Shock

	Macro Scenario: Flexible Exchange Rate with Reduction in Foreign Borrowing				
	Original Scenario	Mobile Land	Fixed Price Wedge	Unemploy- ment and Inflation	Energy Substitution
	(% change from base)				
World Oil Price	107.2	107.2	107.2	107.2	107.2
GDP Deflator	0	0	0	2.2	0
Consumer Prices	1.3	1.3	1.3	3.4	1.2
Nominal Exchange Rate	2.7	2.7	2.7	4.7	2.4
Macro Balances:					
Domestic Investment Difference					
Billion Dollars	−17.6	−17.5	−18.2	−41.6	−18.6
Percent Change	−1.9	−1.9	−2.0	−4.6	−2.0
Foreign Saving Difference					
Billion Dollars	−18.6	−18.6	−18.6	−18.6	−18.6
Percent Change	−30.0	−30.0	−30.0	−30.0	−30.0
Government Savings Difference					
Billion Dollars	4.9	5.0	4.3	−25.1	4.0
Percent Change	8.1	8.4	7.1	−41.7	6.6

Note: Assuming oil price of $40 per barrel.

Mobile Land

The base model assumes that land is fixed by sector; that is, it is not possible to shift acreage to different crops. Some differences in results occur when land is assumed to be mobile across the crop sectors. Allowing land to be mobile increases agricultural supply responsiveness. Because the agricultural sector is a small part of the economy, there is little macro feedback. One macro effect, however, is a $100 million increase in government savings from a reduction in farm program costs. This frees funds for domestic investment (table 8).

Under the $40 oil and macro-3 scenario, there is a 2% increase in acreage devoted to oilseed crops, compared with the results from the fixed-land model (table 10). Both food grains and feed crops lose about .5% of their original acreage. With this shift, production of oilseed crops rises by 1%, but this is offset by a reduction in production of food grains, feed crops, and livestock. The market price for oilseed crops is .9% lower, while market prices rise for the agricultural commodities that had a reduction in acres harvested, most noticeably for feed crops (.3%).

The change in production and price translates into a .1% change in value added for the agricultural sector (about $100 million in 1991 dollars). In terms of sectoral value added, livestock takes a bigger loss, while oilseed crops, food grains, and other crops remain about the same. The feed crops sector gains in value added because producer prices rise sharply. The cost of farm programs falls 1.6 percentage points relative to the results with the fixed-land model. Reduced sector income from the farm programs offsets increased value added, so that sector income stays the same.

Fixed Price Wedge Treatment of Deficiency Payments

We argued that it is important to model farm programs explicitly and not use a fixed ad valorem equivalent. We examine the importance of this treatment by using a fixed wedge to represent the deficiency payment program, rather than specify a fixed target price. Comparing columns 1 and 3 of tables 8, 9, and 10 gives an assessment of the model sensitivity to the treatment of deficiency payments in the model by specifying a fixed ad

Table 9. Sensitivity Analysis: Sectoral Effects from a World Oil Price Shock

	Macro Scenario: Flexible Exchange Rate with Reduction in Foreign Borrowing				
	Original Scenario	Mobile Land	Fixed Price Wedge	Unemployment and Inflation	Energy Substitution
	(% change from base)				
Producer Price	1.9	1.9	1.9	4.0	1.6
Agriculture	1.3	1.4	1.2	3.2	1.3
Food Processing	.8	.8	.8	2.8	.8
Energy	25.2	25.2	25.2	26.3	20.1
Crude Oil and Gas	56.4	56.4	56.4	56.2	43.2
Petroleum Refining	29.2	29.2	29.2	30.5	25.0
Electric and Gas	11.9	11.9	11.9	13.4	9.6
Other Manufacturing	.7	.7	.7	2.9	.7
Services	.1	.1	.1	2.3	.2
Production, Real	−.1	−.1	−.1	−1.3	−.1
Agriculture	0	0	.1	−.4	0
Food Processing	−.4	−.4	−.3	−.9	−.4
Energy	−3.3	−3.3	−3.3	−3.6	−2.1
Crude Oil and Gas	0	0	0	0	0
Petroleum Refining	−4.3	−4.3	−4.3	−4.6	−2.3
Electric and Gas	−4.4	−4.4	−4.4	−4.9	−3.5
Other Manufacturing	.6	.6	.6	−1.7	.5
Services	0	0	0	−.7	0
Value Added, Nominal	.1	.1	.1	1.1	.2
Agriculture	.6	.7	.5	1.9	.6
Food Processing	−1.3	−1.3	−1.2	.3	−1.0
Energy	2.2	12.2	12.2	12.8	9.4
Crude Oil and Gas	74.7	74.6	74.6	73.5	56.3
Petroleum Refining	−7.9	−7.9	−7.9	−6.4	−3.6
Electric and Gas	−9.2	−9.2	−9.2	−8.1	−7.3
Other Manufacturing	−.3	−.3	−.3	−.4	.2
Services	−.7	−.7	−.7	.7	−.5
Exports, Real	5.2	5.2	5.2	3.2	4.6
Agriculture	1.3	1.4	1.7	1.2	1.1
Food Processing	4.1	4.3	4.2	3.7	3.4
Energy	−2.4	−2.4	−2.4	−1.5	3.6
Crude Oil and Gas	−56.9	−56.9	−56.9	−55.1	−48.9
Petroleum Refining	1.6	1.6	1.6	2.4	7.5
Electric and Gas	−19.5	−19.5	−19.5	−18.9	−15.9
Other Manufacturing	6.3	6.3	6.2	3.6	5.2
Services	4.8	4.8	4.8	3.4	4.0
Employment	0	0	0	−1.5	0
Agriculture	.1	.1	.4	−1.0	0
Food Processing	−.6	−.6	−.6	−1.3	−.6
Energy	−10.3	−10.3	−10.3	−11.3	−7.8
Crude Oil and Gas	0	0	0	0	0
Petroleum Refining	−15.2	−15.2	−15.2	−16.3	−8.3
Electric and Gas	−14.4	−14.4	−14.4	−16.0	−11.6
Other Manufacturing	.5	.5	.5	−2.4	.5
Services	.1	.1	.1	−1.0	0

Note: Assuming oil price of $40 per barrel.

valorem price wedge rather than a fixed target price. A fixed-wedge treatment of the program allows changes in the market price to serve as the price signal for changes in production, rather than the target price. In result, the program costs behave differently after a shock to the modeled economy. The fixed-wedge approach to modeling deficiency payments is used by some modelers, but Kilkenny and Robinson (1989, 1990) argue that it can lead to misleading results. We illustrate the Kilkenny–Robinson point.

Table 10. Sensitivity Analysis: Agricultural Effects from a World Oil Price Shock

	Macro Scenario: Flexible Exchange Rate with Reduction in Foreign Borrowing				
	Original Scenario	Mobile Land	Fixed Price Wedge	Unemployment and Inflation	Energy Substitution
	(% change from base)				
Producer Price	1.30	1.40	1.20	3.20	1.30
All Livestock	1.00	1.10	.90	2.80	1.00
Food Grains	2.60	2.80	2.40	4.60	2.30
Feed Crops	2.00	2.30	1.70	3.90	1.80
Oilseed Crops	1.90	1.00	1.90	3.70	1.70
All Other Crops	.60	.70	.50	2.50	.60
Real Production	0	−.01	.09	−.40	−.02
All Livestock	−.20	−.30	−.20	−.60	−.20
Food Grains	.08	−.20	.30	−.30	.05
Feed Crops	.07	−.10	.20	−.30	.04
Oilseed Crops	.80	1.80	.80	.60	.60
All Other Crops	.10	.06	.20	−.40	.06
Real Exports	1.30	1.40	1.70	1.20	1.10
All Livestock	3.00	2.70	3.20	2.80	2.50
Food Grains	.20	−.30	.70	0	.20
Feed Crops	1.30	.60	1.90	1.20	1.00
Oilseed Crops	1.70	3.70	1.70	1.90	1.40
All Other Crops	2.70	2.50	3.30	2.40	2.30
Value Added, Nominal	.60	.70	.50	1.90	.60
All Livestock	−2.00	−2.20	−1.70	−1.40	−1.60
Food Grains	2.20	2.20	2.10	3.90	1.90
Feed Crops	1.20	1.60	.90	2.80	1.10
Oilseed Crops	2.50	2.40	2.50	4.10	2.20
All Other Crops	−.40	−.30	−.50,	.90	−.20
Sector Income, Nominal	−.30	−.30	.50	.20	−.20
All Livestock	−2.30	−2.60	−2.10	−2.00	−1.90
Food Grains	−.30	−.50	1.70	−.60	−.30
Feed Crops	−.40	−.40	.80	−.60	−.40
Oilseed Crops	2.50	2.40	2.50	4.10	2.20
All Other Crops	−.70	−.60	−.40	.40	−.50
Farm Program Costs (Deficiency Payments)	−8.50	−10.10	.50	−16.80	−7.70
Livestock	0	0	0	0	0
Food Grains	−6.00	−6.80	.80	−11.20	−5.40
Feed Crops	−10.10	−12.20	.30	−20.60	−9.20
Oilseed Crops	0	0	0	0	0
All Other Crops	−7.70	−8.40	.50	−13.00	−6.80
Land		NA	0	NA	NA
All Livestock	NA	NA	NA	NA	NA
Food Grains	NA	−.50	NA	NA	NA
Feed Crops	NA	−.40	NA	NA	NA
Oilseed Crops	NA	1.90	NA	NA	NA
All Other Crops	NA	−.50	NA	NA	NA

NA = Not applicable.
Note: Assuming oil price of $40 per barrel.

The incentive effects for producers of program crops are quite different when a fixed-wedge approach to modeling deficiency payments is used. With this specification, the $40 oil price and macro-3 scenario yields a larger production of food grains and feed crops (by about .2% and .1%, respectively). The increase in market price is less for all sectors. Even though the increase in market price for these sectors is less, a feedback effect from the greater production, the change in price serves as a signal to increase production. Total agricultural value added goes up, but by .1% less than before. The fall in value added for the livestock sector is less, while for the two program crop sectors (food grains and feed crops), the change in value added is slightly less due to a smaller increase in market prices. Total sector income goes up in this case.

The price wedge treatment of the deficiency payment program leads to an increase in deficiency payments, from a reduction of 8.5% to an increase of .5%. The larger deficiency payment compensates sector income for the slight fall in value added. The fixed ad valorem wedge specification leads to a dramatic difference (even a different sign) in the effect of the shock on program costs. This different behavior illustrates the importance of modeling the farm programs explicitly.

The greatest difference in results from these two treatments of deficiency payments is with farm program payments and sector income. These results highlight the problems arising from modeling deficiency payments as fixed ad valorem wedges. Deficiency payments are defined as the difference between a target price and the higher of either the market price or the loan rate, multiplied by a base yield and acreage. A rise in the market price should either have no effect on deficiency payments if the market price was below the loan rate or should reduce deficiency payments if the market price was above the loan rate. When oil price shocks lead to higher program crop prices, the price wedge treatment of deficiency payments leads to a .5% increase in program payments instead of a decrease. This larger deficiency payment compensates for the slight fall in value added, leading to an increase in sector income.

The different policy specifications lead to contrary conclusions about the effect of the world oil price shock on agriculture. The fixed ad valorem price wedge is a misspecification, and the results indicate that it is important to be explicit in the treatment of deficiency payments in the analysis of changes affecting agriculture.

Unemployment and Inflation

This sensitivity experiment concerns the macro adjustment specification. We change the exogenous macro forecast of inflation and unemployment, again starting from the scenario with $40 oil and macro-3. The idea is to capture the fact that real economies have difficulty adjusting the sectoral structure of employment, and that there will be unemployment and inflation after the oil price shock. We assume the GDP deflator goes up 2.2% and the unemployment rate increases by 1.5%.

The model is nearly homogeneous in prices, so that the assumed inflation will have almost no effect on real variables. There are some nonhomogeneities because some government transfers are fixed in nominal terms. Consumer prices rise by 3.4%, which, compared with the same scenario without inflation and unemployment, is nearly the sum of the previous consumer prices and the GDP deflator—the expected result for a homogeneous model. However, the assumed decline in the labor supply does have real effects.

Total real production falls 1.3%, which is less than the change in employment. Labor is reallocated to sectors with greater productivity. Compared with the scenario with no inflation or unemployment, the agricultural sectors, food processors, and energy sectors all take about an additional .4% decrease in production (table 9). Other manufacturing takes the biggest reduction, going from a .6% increase in production to a 1.7% decrease in production. Production of services falls .7% percent.

The decline in real income decreases government tax revenue. Real government expenditure is fixed, so rather than an 8% decrease in the government deficit, there is a 42% increase. This difference reverberates through the system. The fall in domestic investment is larger under this scenario, falling by 4.6% rather than 1.9%, largely due to the change in government saving. Depreciation of the dollar goes from 2.7% to 4.7%, which is less than the difference in price levels, even though foreign borrowing remains the same.

Energy Substitution

A part of producer response to an oil price shock is a substitution among energy sources in intermediate demand. Given the assumption of intermediate demand in fixed proportion to production, our analysis overstates many of the effects from the higher price of petroleum. Keeping to the short-run analysis of this article, we target the largest user of crude oil other than refiners and allow the producers of electricity to substitute the use of coal for crude oil in proportion to the change in relative prices. Coal is a part of the "resource" sector. For the electric and gas sector's intermediate demand for "resource" inputs, coal is the only commodity.

With the substitution of coal for crude oil in the generation of electricity, there is a 7.8% reduction in the use of petroleum in the generation of electricity and a 2.6% smaller increase in the price of electricity. The price of coal goes up 1% as a result of the greater intermediate demand, while the price of energy in general still goes up, but by 5% less than before.

As compared to the scenario without substitution among energy sources for electricity, there is less devaluation of the dollar (.3% less) and a smaller increase in real exports (.6% less). The impact of the energy source substitution on the rest of the economy is primarily through the macro trade effect from 6% less petroleum imports. The substitution of coal for petroleum reduces the amount and cost of imports, lowering the devaluation of the dollar required to maintain the current trade balance. The impact on prices and real production outside of the energy sectors is insignificant on a percentage change basis.

Are our results robust to variations in our assumptions and representations? Our choice for modeling target prices mattered. Our lack of substitutability between intermediate energy apparently raises more theoretical problems than practical empirical problems, and apparently the significant impacts overlooked by not allowing energy substitution is an overestimate of crude imports—a result more typical of a CGE model than a partial equilibrium analysis. Mobility of crop sector across land inputs mattered, but not to a large degree. Our not considering inflation and employment adjustment mattered, but not in a surprising degree or manner—the necessary caveats are predictable.

Conclusion

Is the effect of a world oil price shock on U.S. agricultural production and income any less ambiguous? We confirmed that, relative to most sectors of the economy, agricultural production techniques are energy-intensive, but energy intensity and the response to the oil price shock vary among agricultural commodities. Based on cost analysis in a partial-equilibrium or input–output framework, the agricultural sectors should lose when there is an oil price shock.

The analysis with the CGE model indicates that agriculture generally loses from an oil price shock, but the story is more complex. Major crop sectors where exports are important (cotton, food grains, feed crops, and oilseed crops) all had an increase in value added after the shock, but in all but oilseed crops the associated decline in government deficiency payments led to a decline in sector income. Given the design of the deficiency payment program, the federal government outlays fall because of higher prices of program commodities. When market prices rise, regardless of cost considerations, deficiency payments are reduced. Thus, while the oil price shock causes market sales of food grains, feed grain, and cotton producers to increase, the increase is not enough to offset the reduced program payments, and sector income falls.

Dairy, livestock, and sugar all experience a decline in output, a rise in price (except sugar), but a decline in value added and sectoral income. In our analysis, the lower production and the demand faced by farm products did not result in farm revenue increasing more than costs. Higher net income results only when macro linkages lead to a depreciation of the dollar and increase in exports, which sustains demand in the face of rising prices.

We found that the government's response to the outflow of dollars to pay for higher priced oil imports matters to farmers. Farmers benefit from depreciation of the dollar. Any policy effort to protect the value of the dollar in the face of an adverse international terms-of-trade shock effectively taxes agricultural exports and hurts farmers.

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Notes

[1] Carter and Youde elaborate on the empirical relevance of these general equilibrium linkages connecting energy prices to agriculture.

[2] See appendix B for derivation of change in unit costs.

[3] A copy of the model, programmed in GAMS, is available upon request. For surveys of agriculturally focused CGE models, see Hertel or Robinson (1990). For a survey of multisectoral models, see Robinson (1989).

[4] We report sensitivity analysis with a variant of the model which allows for the substitution of coal for petroleum in the production of electricity.

[5] We report below on sensitivity analysis with a variant of the model which assumes that land is mobile across the agricultural crop sectors.

[6] Kilkenny documents the modeling of farm programs in the USDA/ERS CGE model. The model also includes the government loan program, including government stocking operations through the Commodity Credit Corporation. In the experiments for this article, however, the market price is always above the loan rate, and, hence, the loan program does not influence the results.

[7] The procedure used to calibrate the model to the base year is described in Robinson, Kilkenny, and Hanson.

[8] Natural gas is classified into the same sector as crude oil, so the crude oil price shock also increases the world price of natural gas.

[9] The exogenous change in world export and import prices differs because of different commodity composition of U.S. refined petroleum exports and imports. We do not exogenously increase the electric and gas utility sector's world price for exports or imports because worldwide a significantly smaller share of output enters world trade.

[10] For example, in the $40 scenario with a flexible exchange rate and reduction in foreign savings, the cost of crude oil and refined petroleum imports increases by $34.3 billion, a 54% increase.

[11] The energy taxes in the model used for the table of results are ad valorem, which approximates the combination of a specific tax per unit of commodity plus a windfall tax which has been used in the past when oil prices have increased. In an experiment of model sensitivity, with the $40 oil price under macro-3, the windfall tax was eliminated and the energy tax was applied per unit of commodity to arrive at the $5.4 billion difference.

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Appendix A: Table of Sector Definitions

	Sector	Description	BEA I/O Code*
1	Dairy	Dairy farm products	1.01
2	Lvstk	Poultry, eggs, meat animals, and misc. livestock	1.02–1.03
3	Cotton	Cotton	2.01
4	Foodgrn	Wheat, rice, and other food grains	2.0201
5	Feedcrp	Corn and other feed crops including hay	2.0202
6	Oilcrops	Soybeans and other oilseed crops	2.06
7	Sugar	Sugarbeets and cane	2.0502
8	Othcrop	Tobacco, fruits, tree nuts, vegetables, misc. crops, and greenhouse and nursery	2.0203, 2.03, 2.04, 2.0501, 2.0503, 2.07
9	Meatmfg	Red meat, poultry, and egg processing	14.01
10	Dairymfg	Dairy processing	14.02–14.06
11	Grainmfg	Flour and other grain mill products	14.14, 14.1501, 14.16, 14.1802, 14.31
12	Feedmfg	Prepared feeds	14.1502
13	Cornmill	Wet corn milling	14.17
14	Sugarmfg	Sugar processing	14.19
15	Soymill	Oilseed mills	14.24–14.27, 14.29
16	Miscfood	Packaged foods and beverages	14.07–14.13, 14.1801, 14.20–14.23, 14.28, 14.30, 14.32
17	Resource	Forestry, fisheries, and mining	3, 5–7, 9–10
18	Petro-gas	Crude oil and natural gas	8
19	Construc	Construction and maintenance	11–12
20	Petro-ref	Petroleum refineries	31
21	Chem-rub	Chemical and rubber products	27–30, 32
22	Othndmfg	Tobacco, textiles, apparel, paper, and printing	15–19, 24–26, 33–34
23	Othdmfg	Wood, glass, stone, and misc. products	20–23, 35–36, 64
24	Metalmfg	Metal products	37–42
25	Machinry	Machinery	13, 43–50
26	Oth-elec	Electrical equipment which is export-intensive, primarily industrial equipment	51.0101, 52–53, 55, 56.03–56.04, 57.01, 57.03, 62
27	Con-elec	Electrical equipment which is import-intensive, primarily for household use	51.0102–51.0104, 54, 56.01–56.02, 57.02, 58, 63
28	Trns-eqp	Motor vehicles and aircraft	59–61
29	Elec-gas	Electric and gas utilities	68
30	Trd-trn	Trade and transportation	65, 69
31	Finance	Finance and real estate	70–71
32	Services	Services, government, and household industry	4, 66–67, 72–82, 84

* The Bureau of Economic Analysis (BEA) I/O codes can be found in *Survey of Current Business* 64(May 1984): 80–84.

Appendix B: Unit Cost Increases in Input-Output

Measuring direct and indirect cost linkages in an input–output model starts from the definition of cost prices:

$$P = A'P + V,$$

where, P is an n-element vector of sector prices, V is an n-element vector of value-added coefficients, and A is an (n, n) direct requirements (input–output) matrix.

A dollar's worth of output in each sector is fully allocated to the intermediate purchases from other sectors and the purchase of primary factors (value-added coefficients). Rearranging the equation above and introducing a value-added price change vector, dw, yields:

$$dp = (I - A')^{-1} \cdot V \cdot dw.$$

Next, treat the sector (crude oil and gas) experiencing the price shock as exogenous and expand V to include the direct requirements row of the now exogenous sector. This treatment allows the estimation of the effect of the oil price shock on cost prices (sectors' prices if all the higher oil costs are passed on to buyers) of other sectors. The matrix A is now of dimension $n - 1$ by $n - 1$ and V is now an $n - 1$ by 2 matrix. In the text, table 2, column 2, shows the changes in cost prices (dp) for a doubling of the oil price [dw is now a two-element vector (1, 2), which leaves the price of value added unchanged and doubles the oil price].

Now assume that the refined petroleum price doubles. In this case, we treat the prices of both crude petroleum and refined products as exogenous. The matrix A is now $n - 2$ by $n - 2$, V is $n - 2$ by 3, and dw is a three-element vector (1, 2, 2). The results are presented in text table 2, column 3.