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ENERGY UNCERTAINTY: IMPLICATIONS FOR THE FOOD SUPPLY CHAIN

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Introduction

Energy uncertainty is present in many decisions by managers of individual business operations throughout the economy. Food businesses are especially aware of the importance of energy to their cost structure. Food processing, and to some extent farming, are considered to be energy-intensive sectors of the economy.

Measuring production in an economy can be insightful in terms of relationships among various industrial groups. A technique known as input-output modeling accounts for the interdependence of production activities for the many different industries comprising an economy. An input-output model is a representation of the flows of economic activity among sectors within a region. The model captures what each business or sector must purchase from every other sector to produce a dollar's worth of goods or services.

The agenda for this presentation is to examine energy use trends in the U.S., analyze the economic contribution of the food and agriculture supply chain of the U.S. economy, and finally to estimate the potential cost of energy price increases from supply disruption on the food supply chain.

Trends in Energy Use

- Total energy demand is projected to increase from 98.2 to 133.2 quadrillion British thermal units (Btu) between 2003 and 2025, an average annual increase of 1.4 percent, in a scenario where the U.S. economy grows at an average annual rate of 3.1 percent (DOE). Although energy consumption has increased steadily since 1950, per capita energy consumption has increase more slowly. Per capita energy consumption reached a peak of 360 million Btus in 1978/79 and was 338 in 2003.

- U.S. petroleum demand will become increasingly dependent on imports. In 2025, net petroleum imports are expected to account for 68 percent of total petroleum demand, up from 56 percent in 2003 (DOE). Energy imports have increased rapidly since the mid-80s.
- Energy use by source is mostly dependent on fossil fuels.
- Industrial and transportation sectors of the economy are the largest annual consumers of energy in the U.S. Trucks account for most of the use within the transportation sector.
- The average annual world oil price, measured as the U.S. average refiners' acquisition cost of imported crude oil (RAC), in real (inflation-adjusted) year 2003 dollars will rise from $27.73 per barrel in 2003 to $35 per barrel in 2004, and then is expected to decline to $25 per barrel by 2010. This is because new domestic and imported supplies will enter the market by then (DOE).
- Projected average growth in output and energy use by sector between 2003 and 2025 are interesting. Agriculture growth is expected to be 1-2% annually while energy consumption grows annually at somewhat less than 1%. General manufacturing, is expected to grow at annual rates of 2-3% while energy consumption grows 1-2%. Food processing is expected to experience growth at just over 2% in both output and energy consumption.

Measuring the Size and Economic Contribution of the Food Supply Chain

Measuring interdependencies and linkages can reveal how much of each industry's output is consumed by other industries and how much is available for final consumption. USFOOD is an input-output model constructed so as to define the supply chain of the food and related agricultural cluster of the economy as consisting of five major sectors or components, all vertically linked and interdependent in an economic sense. The five major components comprising the cluster are *farm inputs and machinery, farm production, processing of food and forestry products, wholesaling and retailing of food and forestry products,* and ultimately the *food service sector.*

A diagram of the simplified economic linkages among the five food and agriculture-related components of the cluster is provided in Figure 1. The four elliptical shapes of the diagram represent final demand components for the output of the other five stages. The arrows indicate primary or secondary economic flows, in terms of dollars of output, from one sector that becomes input to another sector.

Economic measures of interest derived for each sector of the economy from the input-output model include total employment, income, contribution to gross domestic product, and the total dollar value of output. Each of these economic indicators measures different, yet related, linkages among the various sectors of the economy. For purposes of the model, income here is

the money earned from production and sales. Thus, income includes personal income (wage and salary income) as well as income of sole proprietor's profits and rents. It is not just wage income.

Another useful indicator from input-output models is the "multiplier." Input-output models are driven by final consumption or final demand. Industries respond to meet demands directly or indirectly (by supplying goods and services to industries responding directly). Each industry that produces goods and services generates demands for other goods and services. These other producers, in turn, purchase goods and services. These "indirect" purchases (indirect effects) continue until "leakage" from the region (such as imports, wages, or profits) stop the cycle.

An output multiplier for a sector, for example, measures the additional value of production from all sectors of the economy when expansion or contraction of output occurs within a sector by addition of firms or from firms exiting a geographic location. Output multipliers can be the basis for analyzing the importance of each industry in terms of its overall influence on the economy.

Other multipliers include income and employment. An income multiplier is a measure of the intuitive notion that income earned by one individual or industry is spent and becomes income to a second individual or industry. In turn, the second individual spends a portion of that income so that it becomes income to yet another individual. The income multiplier relates an increment in the income of one sector to an increment of income of other sectors. When expenditures from one sector increase, the income of other sectors will increase in some multiple of the original increment. Employment multipliers are derived from output multipliers simply by converting from an output to employment base.

Sector Definition

The input-output model captures interindustry economic relationships and provides information on the relative importance of various sectors of the economy. The input-output model is composed of 43 sectors defined in a manner to emphasize agriculture and processed food and forestry products, distribution and retailing of food and forestry products, and food consumption. Many of the 43 sectors are defined based upon the aggregation of similar industries.

Methods

USFOOD, an acronym for United States Food, is comprised of 22 sectors related to food and agriculture and 21 sectors that are based on the general manufacturing and service sectors of the entire economy.

The **USFOOD** model is based on *IMPLAN*, an input-output algorithm for the national economy using non-survey based data (University of Minnesota). *IMPLAN* is based on a procedure

developed by the U.S. Forest Service for estimating input-output models for the United States or subregions (Alward).

Estimates of sectoral activity for final demand, final payments, industry output, and employment for the United States economy are based on the latest data available aggregating the detail for 528 industries of the United States economy. All information within this version of the model is for the calendar year 2000 and is in 2000 dollars. Detail of the methods of input-output modeling for an economy and the methods used for calculations of multipliers may be found in Miller and Blair.

Economic Importance of the Food Supply Chain

An overview of the United States economy in 2000 is shown by the total output, gross domestic product, income and employment for each of 43 sectors, Table 1. The total economic output for United States in 2000 was $7.2 trillion with total employment of nearly 168.5 million persons. The 2000 United States economy generated a gross domestic product (GDP) of $9.8 trillion, and the food and agricultural share of this GDP was $949.6 billion. This means that the food and agricultural cluster of the United States economy generated approximately $9.50 of each $100 in United States GDP in 2000.

The output of the food and related agricultural cluster was $2.1 trillion, or about 12 percent of United State's total economy. The $2.1 trillion represents about $1 of every $8 in output for the entire United States economy. The total output of $2.1 trillion may be divided among the five basic components of the food and related agriculture cluster. The largest component is processed food and processed forestry products, accounting for $865.3 billion of this output, or about 42 percent of the total $2.1 trillion in food and agricultural cluster output. This $865.3 billion is composed of $543.0 billion from food processing and another $322.2 billion from value added forestry processing which includes wood processing, paper, and wood furniture manufacturing. Thus, food processing accounts for about 63 cents of every $1 in output from the total food and forestry-processing sector.

Agricultural production adds about $278.4 billion in output or just over 13 percent of the total output from the food and related agricultural cluster of the United States economy. The largest component within the agricultural production sector is the nursery and horticultural industries, accounting for nearly $49.6 billion in output, or nearly 18% of the output generated by the farming sector.

Gross domestic product is another significant measure of economic activity and is a useful measure in comparison of the relative importance of one sector to another. The 2000 United States economy generated a gross domestic product (GDP) of $9.8 trillion, and the food and agricultural share of this GDP was $949.6 billion, Table 1. This means that the food and related agricultural cluster of the United States economy generated approximately $9.50 of each $100 in United States GDP. Of the $949.6 billion gross domestic product contributed by the food and related agricultural cluster, just over 28 percent is attributable to the total food and forestry-processing sector. The largest of the five components of the cluster in terms of gross domestic product is the wholesaling and retailing of food and forestry products sector, accounting for

$436.0 billion, or $1 in $5 of the entire gross domestic product by the food and related agricultural cluster combined, Table 1. Food service accounts for another $333.6 billion in gross domestic product. Finally, the farming sector and the farm inputs and machinery sector account for another 12 percent and 6 percent, respectively, of the gross domestic product. Farm production accounts for over $58.6 billion in gross domestic product while the farm inputs and machinery industries account for $116.2 billion in gross domestic product.

The food and related agricultural component of the national economy contributes over 24 million jobs, or nearly 15% of all employment, Table 1. The wholesaling and retailing component of the food and related agriculture cluster combined with the food service sector account for 6 of every 10 jobs in the cluster, or approximately 15.9 million jobs in total.

Economic Multipliers

Impact coefficients or multipliers are quantitative and summary measures of the total effects that a change in the final demand for a particular sector of the United States economy has on the output, income, employment, or value added. All multipliers reported here, Table 3, and are Type II multipliers. A Type I multiplier measures the direct and indirect effects and takes into account the income and expenditures of households employed in both the direct and indirect businesses within the United States economy.

The output multiplier of a particular sector measures the total change in output generated by a $1.00 change in final demand for the product of a particular sector, Table 2. Multipliers are estimated for income, employment, and gross domestic product. For example, a $1.00 change in final demand for feed grain products generates total economy-wide income of $2.4349, Table 2. Similarly, the employment multiplier for the feed grains sector is 1.7405. Thus, the total employment effect for a $1 million change in final demand is just under 1.7 person-years.

The multipliers are all interpreted in a similar fashion. An example of interpretation for the dairy production sector is provided in this paragraph. In Table 2, the dairy production income multiplier is 2.1678. It means that each $1.00 of income from dairy farms resulting from a change in final demand generates about $2.17 in total economy-wide United States income. The employment multiplier of 3.3647 means that each $1 million change in United States dairy farm output resulting from a change in final demand generates approximately 3.4 person-years change in total employment in United States.

Table 1. United States: Output, Gross State Product, Income, and Employment, 2000.

	Total Output	Contribution to GDP	Income	Employment
	$ Millions	*$ Millions*	*$ Millions*	*Person Years*
Food & Related Agricultural Cluster				
Farm Inputs & Machinery	**170,075.3**	**58,667.5**	**55,826.9**	**462,776**
Farming	**278,447.1**	**116,230.4**	**108,786.4**	**4,922,796**
Dairy Farms	20,622.0	6,412.4	6,343.5	126,819
Poultry & Eggs	21,789.4	4,553.6	4,467.0	120,790
Cattle Feeding	40,760.5	10,125.9	9,166.9	412,376
Swine	11,771.8	2,003.5	1,777.1	105,758
Miscellaneous Livestock[a]	4,575.0	1,529.1	1,468.1	157,579
Food Grains	6,639.2	2,619.9	2,325.6	120,022
Feed Grains	23,044.6	8,524.4	7,448.5	264,787
Nursery & Horticulture	49,612.8	30,330.4	29,332.1	1,214,437
Fruits & Vegetables	26,723.3	12,156.6	11,564.8	306,683
Oil Bearing Crops	13,857.4	6,042.6	5,426.4	223,956
Misc Crops/Hay/Sugar/Tobacco/Nuts	28,607.9	11,302.5	10,126.4	910,636
Forestry, Fishing, Ag Services	30,443.3	20,629.3	19,339.9	958,953
Processing	**865,264.2**	**269,051.4**	**239,826.0**	**3,638,819**
Food Processing	543,030.8	156,237.2	130,149.6	1,765,530
Processed Meat, Fish & Eggs	124,857.8	21,069.5	20,162.1	566,840
Dairy Processing	60,066.6	13,109.9	12,596.4	149,133
Processed Food & Kindred Products	233,909.4	82,059.0	65,000.1	763,018
Grain Milling & Flour	31,656.3	7,579.5	7,324.8	67,112
Fats & Oils	19,576.2	2,633.9	2,466.0	29,119
Beverage Processing	72,964.5	29,785.4	22,600.2	190,308
Wood/Paper/Furniture Manufacturing	322,233.4	112,814.2	109,676.4	1,873,289
Food & Forestry Wholesale/Retail	**435,992.5**	**324,148.9**	**258,942.3**	**7,056,235**
Food Services[b]	**333,632.0**	**181,472.4**	**159,252.0**	**8,757,266**
Total Food & Ag Cluster	**2,083,411.2**	**949,570.7**	**822,633.6**	**24,837,892**
General Manufacturing & Service Sectors				
Mining	239,357.0	114,920.7	101,745.5	658,395
Construction	1,343,544.3	527,642.6	517,586.3	11,433,428
Textiles, Apparel, Yarn & Leather	195,496.0	69,311.7	67,405.9	1,579,977
Motor Vehicle Equipment	567,078.1	177,596.2	173,798.9	1,871,088
Metal Industries	465,575.1	172,362.6	167,469.9	2,491,271
Chemicals, Plastics & Petroleum	721,170.3	237,175.6	230,208.4	1,970,671
Publishing	226,484.8	104,633.9	101,870.3	1,655,504
Stone, Clay & Glass	97,757.4	43,276.5	41,880.3	604,773
Machinery & Equipment	393,194.7	144,071.7	140,386.8	2,170,862
Technology Industries	623,942.9	254,774.6	248,710.8	2,454,077
Business and Personal Services [c]	1,686,546.8	1,057,859.0	1,018,226.9	24,275,684
Transportation & Communication	1,059,307.0	562,456.2	519,763.3	6,977,960
Electrical, Gas & Sanitary	354,774.0	216,193.0	178,840.5	705,082
Wholesale & Retail Trade	1,403,638.5	1,043,568.1	833,641.2	19,077,967
Financial & Legal	1,536,971.0	1,026,109.4	982,912.7	12,180,033
Real Estate & Development	1,443,780.0	1,059,705.1	880,859.1	3,848,184
Recreation & Amusement	210,697.0	117,928.7	108,790.6	3,920,166
Health Services	865,371.0	572,128.0	562,736.9	12,699,352
Education Services	165,911.0	98,949.7	97,505.7	4,139,801
Government & Non-Profit	1,504,302.0	1,271,315.6	1,271,080.2	27,646,814
Others	8,002.7	2,950.3	2,846.4	1,291,722
Total of Mfg & Service Sectors	**15,112,901.3**	**8,874,929.1**	**8,248,266.6**	**143,652,811**
Total Economy	**17,196,312.5**	**9,824,499.8**	**9,070,900.2**	**168,490,703**

Note: The wholesaling and retailing sector is one sector in the I-O model but is disaggregated in Table 1. *County Business Patterns 2000* is used to estimate the percentage of payroll and employment that belong to the food cluster. The percentage of payroll (23.7) is used to estimate the proportion of food cluster output, gross national product, and income. The percentage of employment (27.0) is used to estimate the proportion of food cluster employment.

a Sheep, goats, horses, and miscellaneous livestock.

b Excludes hotel/motel food service.

c Includes diverse service items such as advertising, cleaning, barber and beauty shops, and funerals.

Source: Computed

Table 2. U.S. Economic Multipliers: Output, Income, Employment, and GDP, 2000.

	Output	Income	Employment	GDP
Food & Related Agricultural Cluster				
Farm Inputs & Machinery	1.9880	2.5837	3.6599	2.0338
Farming				
Dairy Farms	2.1124	2.1678	3.3647	2.0671
Poultry & Eggs	2.3227	3.2890	3.2035	3.2817
Cattle Feeding	2.3128	2.8105	2.5500	2.3001
Swine	2.4644	4.0303	2.9289	3.2100
Miscellaneous Livestock	2.0924	2.1629	1.3631	2.2620
Food Grains	1.9001	2.4372	1.3936	2.3106
Feed Grains	1.9075	2.4349	1.7405	1.9893
Nursery & Horticulture	1.5917	1.5666	1.2940	1.7841
Fruits & Vegetables	1.7538	1.8014	1.7736	2.1143
Oil Bearing Crops	1.8240	1.9668	1.4707	2.0309
Misc Crops/Hay/Sugar/Tobacco/Nuts	1.8567	2.2026	1.2634	2.0427
Forestry, Fishing, Ag Services	1.4941	1.3738	1.1504	1.7062
Processing				
Food Processing				
Processed Meat, Fish & Eggs	2.7350	4.2582	4.8127	3.2133
Dairy Processing	2.4877	4.6827	6.3947	2.3758
Processed Food & Kindred Products	2.0788	3.4519	4.0925	2.2499
Grain Milling & Flour	2.2125	4.2382	7.4393	3.0114
Fats & Oils	2.5077	7.0250	11.5093	4.8739
Beverage Processing	1.9420	3.0980	4.1099	1.9472
Wood/Paper/Furniture Manufacturing	2.0317	2.3908	2.4984	2.4080
Food & Forestry Wholesale/Retail	1.3866	1.3331	1.2673	1.5231
Food Services	1.7614	1.6410	1.2649	1.8318
General Manufacturing & Service Sectors				
Mining	1.7623	2.0633	2.7311	1.9153
Construction	1.9260	1.9493	1.9705	2.1874
Textiles, Apparel, Yarn & Leather	1.8176	2.0822	1.9303	2.0280
Motor Vehicle Equipment	1.9409	2.3800	3.0893	2.0825
Metal Industries	1.9317	2.2061	2.4063	1.9656
Chemicals, Plastics & Petroleum	2.0232	2.6507	3.4215	2.0046
Publishing	1.8797	1.8916	2.0406	2.1151
Stone, Clay & Glass	1.8571	1.9388	2.0671	1.8416
Machinery & Equipment	1.9295	2.0951	2.3688	2.0219
Technology Industries	1.7305	1.8223	2.4640	2.1430
Business and Personal Services	1.5506	1.4239	1.3759	1.8208
Transportation & Communication	1.7982	1.7932	1.9550	1.8858
Electrical, Gas & Sanitary	1.5006	1.9744	2.8562	1.4754
Wholesale & Retail Trade	1.3866	1.3331	1.2673	1.5231
Financial & Legal	1.4961	1.4759	1.5894	1.6560
Real Estate & Development	1.4146	3.1145	2.3970	1.2820
Recreation & Amusement	1.6871	1.6296	1.4543	1.9984
Health Services	1.5134	1.3139	1.3145	1.7673
Education Services	1.6202	1.4178	1.2468	1.9969
Government & Non-Profit	1.2414	1.1154	1.1112	1.5475
Others	1.9015	1.1575	1.0517	4.1227

Note: All multipliers in this table are Type I multipliers.

Source: Computed

Figure 1: Major Linkages in Food Supply Chain
Economic Transaction Flows among Cluster Sectors

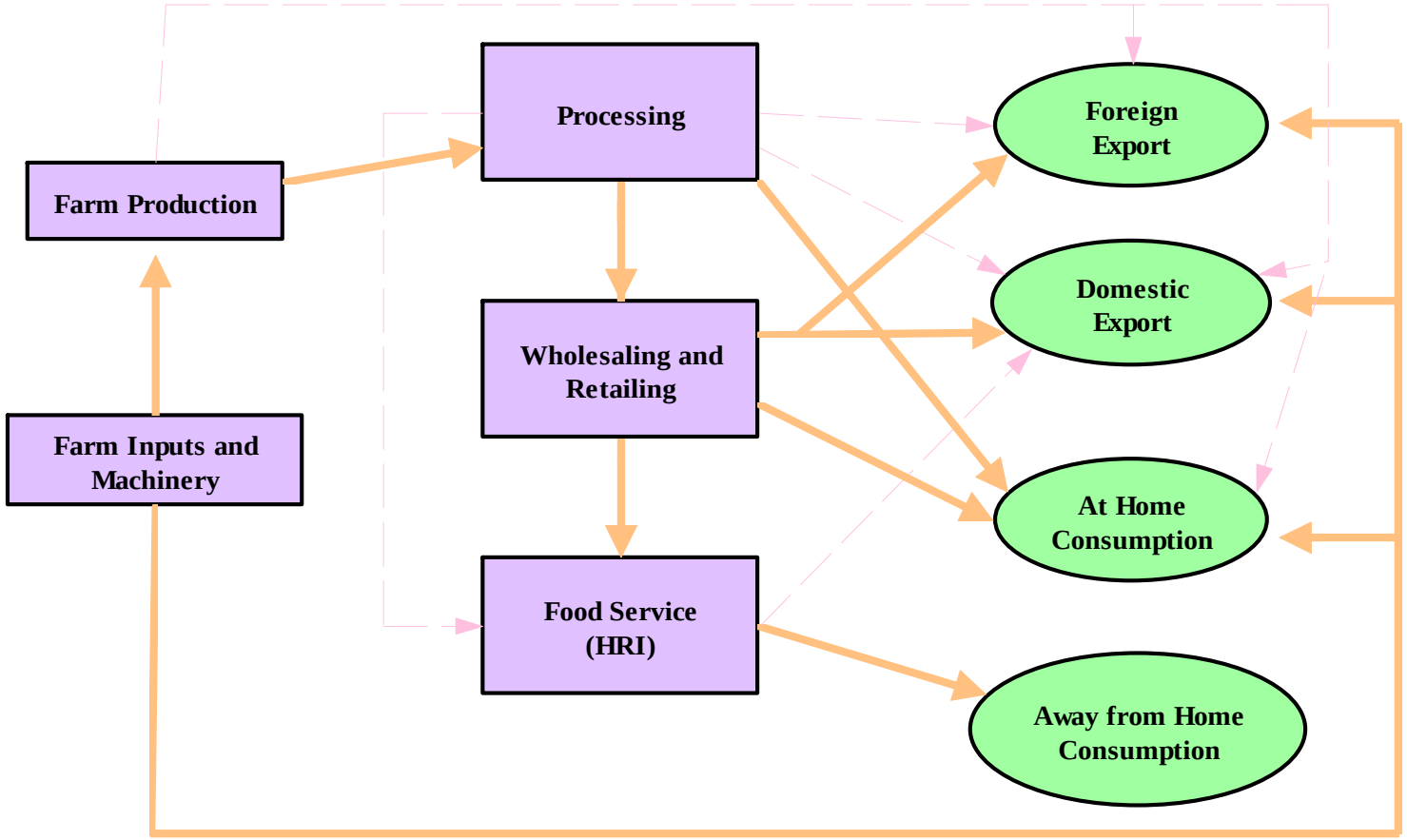
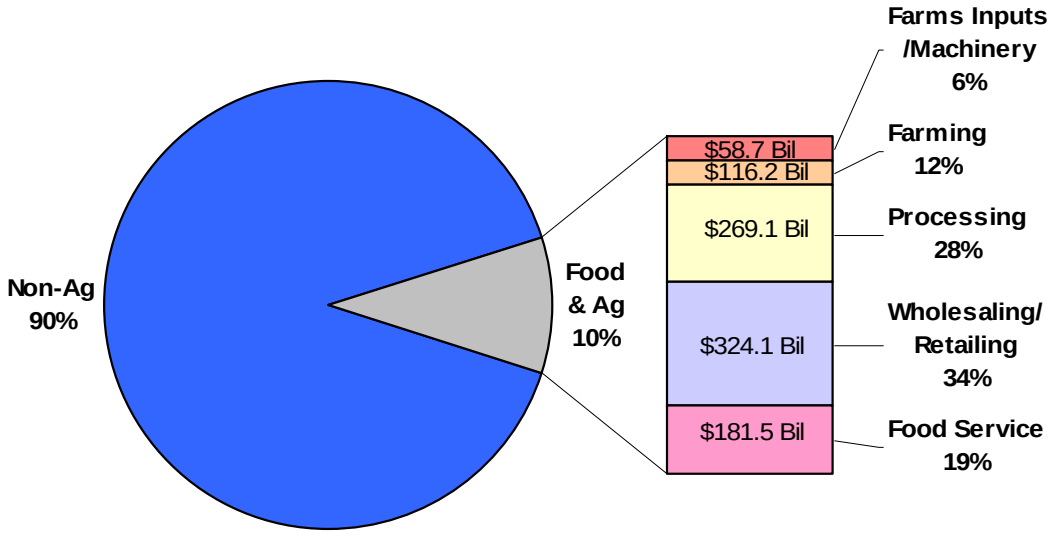


Figure X. U.S. Gross Domestic Product,
Food and Agriculture Cluster, 2000



Total Gross State Product: $ 9.8 Tril Food & Ag Sectors: $949.6 Bil

Energy Price Increase Influence of Food Supply Chain

An important question since 9-11 has become the potential influence of energy disruption on the food supply chain in the United States. Although precise estimates are nearly impossible, one reasonable estimation approach would be to use various economic multipliers from the USFOOD input-output model. The economic costs of energy price shock scenarios, or other scenarios, can be estimated by using various multipliers along with estimates of the influence of the scenario on sectoral output. For illustrative purposes, this approach is applied here to a price shock scenario for crude oil.

Of course, the U.S. economy realizes substantial gains annually from importing relatively low cost oil rather than solely relying on the more expensive domestic crude. The vulnerability of the U.S. to energy disruptions is positively correlated with these factors (GAO, 1997):

- The concentration of world oil production
- Oil intensity of the U.S. economy (ratio of use to GDP)
- Excess world oil production capacity
- The level of world oil stocks
- Energy use in the U.S. economy
- The oil dependency of the U.S. transportation sector.

None of these measures is expected to improve substantially between now and 2025 except for oil intensity. This measure is expected to decline steadily from 9.47 in 2003 to 6.57 in 2025.

The scenario analyzed here is a dramatic increase in the price of oil. A scenario analyzed by GAO in 1997 included a 45% increase in the price of oil. AN econometric model was used to estimate the impact of this rise on the economy's GDP. The total economic impact was estimated at $50 million per year in reduced GDP.

Using this scenario, the USFOOD multipliers can be used to estimate the influence of this scenario on the food supply chain. Using the GDP multiplier for processed food results in an estimate of $16.9 million in GDP within the food supply chain. This represents an 11% reduction the food supply chain GDP. In addition, the employment multiplier for food processing was used to calculate the impact of the scenario on employment. The net result is an estimated loss of 69,200 jobs in the food supply chain as a result of the oil price increase. This is nearly a 4% reduction in jobs within the food supply chain.

Conclusions

Measuring the economic impact on the food supply chain from dramatic crude oil price changes or supply disruptions is imprecise at best. However, a reasonable approach to estimating the influence of various scenarios is to define the food supply chain precisely within the context of an input-output model. Subsequently, the economic impact of various scenarios may be estimated by tracing the influence of changes in GDP within the food supply chain with appropriate economic multipliers.

The scenario analyzed here for illustrative purposes is a crude oil price increase of 45%. The result on the food supply chain is a reduction in chain GDP of about 11% and a loss of 4% of the total jobs. This same approach can be used to estimate the economic influence of other disruptions or shocks to the economy.

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