INTERNATIONAL TRADE ADMINISTRATION

Manufacturing and Services Economics Brief

Energy Costs and Export Performance

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Executive Summary

This economics brief presents a simple model of international trade that generates predictions about the effect of energy costs on export performance that are consistent with economic theory and available data. I calibrate the model to publicly available data for the U.S. manufacturing sector, first for the three-digit industries in the U.S. manufacturing sector and then on a more disaggregated basis for relatively energy-intensive six-digit manufacturing industries. Then I use the model to quantify the contribution of the rise in energy prices in each industry between 2002 and 2006 to the growth in the industry's U.S. manufacturing exports over this time period.

The economic model in this brief demonstrates that energy prices have had a significant effect on the export performance of the U.S. manufacturing sector. The increase in energy prices between 2002 and 2006 limited the expansion of exports over that time period. The effects vary across industries based on energy intensities and the price elasticities of demand for U.S. products in foreign markets. The total impact on U.S. non-petroleum manufacturing exports during this period was a reduction in exports of approximately $11.5 billion per year. In other words, the increase in the industries' exports would have been approximately $11.5 billion per year higher absent the increase in energy prices. The industry-level elasticity estimates can also be applied on a prospective basis to evaluate the effect of a policy-related change in energy prices on U.S. export performance.

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Introduction

Reducing energy prices can significantly improve the export performance of U.S. manufacturing industries. However, measuring the magnitude of these economic benefits can be complex. It requires an estimate of the contribution of energy costs to production costs and an estimate of the price elasticity of an industry's products in export markets. The latter depends on the U.S. industry's share of export markets and the extent of international product differentiation.

This economics brief presents a simple model of international trade that generates predictions about the effect of energy costs on export performance that are consistent with economic theory and available data. I calibrate the model to publicly available data for the U.S. manufacturing sector, first for the three-digit industries in the U.S. manufacturing sector and then on a more disaggregated basis for relatively energy-intensive six-digit manufacturing industries. Then I use the model to quantify the contribution of the rise in energy prices in each industry between 2002 and 2006 to the growth in the industry's U.S. manufacturing exports over this time period.

Overview of the Data and Analytical Framework

There were significant increases in the energy costs of U.S. manufacturing industries between 2002 and 2006. The Manufacturing Energy Consumption Survey (MECS) for 2002 and 2006 report the dollar value of each industry's energy costs. The MECS was administered in 1985, 1988, 1991, 1994, 1998, 2002, 2006, and 2010.[1] 2006 is the most recent year for which the aggregated results of the survey are publicly available. I supplement this information on energy costs and consumption with information on the value of shipments and the cost of materials and payrolls from the Annual Survey of Manufactures.[2]

[1] The survey is sponsored by the Energy Information Administration in the U.S. Department of Energy and is administered by the Bureau of the Census in the U.S. Department of Commerce. The 2002 and 2006 survey results are available online at www.eia.gov/emeu/mecs/contents.html.

[2] The survey results for each year are available online at https://www.census.gov/programs-surveys/asm.html.

The volume of energy consumption per production worker hour indicates the energy intensity of an industry. Among the NAICS three-digit non-petroleum manufacturing industries, the Chemicals, Paper Manufacturing, Primary Metals (including steel and aluminum), and Non-Metallic Mineral Products (including cement) industries are the most energy-intensive in 2002 (Table 1).

Table 1: Energy Intensity of Each Non-Petroleum Manufacturing Industry

NAICS Three-Digit Industry	Thousands of BTUs per Production Worker Hour in 2002
Food Products (311)	492
Tobacco and Beverages (312)	603
Textile Mills (313)	454
Textile Product Mills (314)	210
Apparel Manufacturing (315)	61
Leather and Allied Products (316)	105
Wood Product Manufacturing (321)	422
Paper Manufacturing (322)	2,969
Printing and Related Support Activities (323)	101
Chemicals (325)	6,558
Rubber and Plastic Products Manufacturing (326)	232
Non-Metallic Mineral Products (327)	1,381
Primary Metals (331)	2,661
Fabricated Metal Product Manufacturing (332)	167
Machinery (333)	123
Computer and Electronic Products (334)	173
Electrical Equipment (335)	251
Transportation Equipment (336)	178
Furniture (337)	70
Miscellaneous Manufacturing (339)	74

A reduction in the price of energy in the United States can significantly increase an industry's exports. The magnitude of the export expansion increases with the share of energy in the industry's marginal costs of production and with the absolute value of the price elasticity of the industry's products in its export markets (Table 2). The exact formula for the energy cost share is provided in the Technical Appendix.

Table 2: Elasticity of Exports With Respect to the Price of Energy

NAICS Three-Digit Industry	Energy Cost Share (θ_i)	Product Price Elasticity of Export Demand (γ_i)	Energy Price Elasticity of Export Demand (ε_i)
Food Products	0.023	-1.867	-0.042
Tobacco and Beverages	0.016	-0.763	-0.013
Textile Mills	0.045	-2.765	-0.123
Textile Product Mills	0.017	-2.485	-0.042
Apparel Manufacturing	0.011	-2.101	-0.023
Leather and Allied Products	0.013	-2.406	-0.031
Wood Product Manufacturing	0.024	-3.637	-0.086
Paper Manufacturing	0.067	-1.776	-0.119
Printing	0.019	-1.828	-0.035
Chemicals	0.055	-1.128	-0.062
Rubber and Plastic Products	0.033	-1.858	-0.061
Non-Metallic Mineral Products	0.080	-1.560	-0.125
Primary Metals	0.078	-2.756	-0.216
Fabricated Metal Products	0.023	-1.979	-0.045
Machinery	0.011	-1.933	-0.022
Computer and Electronics	0.011	-1.419	-0.016
Electrical Equipment	0.015	-1.767	-0.026
Transportation Equipment	0.008	-2.547	-0.021
Furniture	0.013	-1.901	-0.026
Miscellaneous Manufacturing	0.012	-1.359	-0.016

The product price elasticities of export demand for each of the twenty three-digit industries are increasing (in absolute value) in the elasticity of substitution between competing products from different countries and are decreasing in the U.S. share of total expenditures on the industry's products in export markets. The exact formulas for calibrating these values are also provided in the Technical Appendix. The industries with the highest product price elasticity of export demand are Wood Products, Textile Mills, and Primary Metals (Table 2).

The energy price elasticity of exports (how much the value of exports increase for each percentage point increase in the industry's price of energy) is obtained by multiplying the industry's product price elasticity of exports demand and its energy cost share. The industries with the highest energy price elasticities are Primary Metals, Non-Metallic Mineral Products, Paper Manufacturing, and Wood Products (Table 2). The relative ranking of these industries depends on both the product price elasticities and the energy cost shares, but the energy cost shares usually dominate. Three of the industries with the highest energy price elasticities have the largest energy cost shares. The other two have more modest energy cost shares, but they have the two largest calibrated product price elasticities of export demand.

Estimates of the Historical Impacts for the Three-Digit Industries

All twenty of the industries experienced an increase in energy prices between 2002 and 2006, when measured on a constant-dollar per BTU basis. However, there is substantial variation in the magnitude of the increases across the industries (Table 3). The variation across the industries reflects differences in technologies and fuel mix and differences in the geographic location of the industry's domestic production.

The energy price elasticity estimates provide a measure of the effect of the increase in the industry's energy prices between 2002 and 2006, holding foreign energy prices and other factors fixed. I reported the modeled change in the value of exports as a percentage change and as a constant 2006 dollar value, and I compare these to the historical change in the constant dollar value of the industry's exports between 2002 and 2006 (Table 3). Eighteen of the twenty industries experienced an expansion in exports over the time period, rather than a decline. For

these eighteen industries, the model estimates the amount by which the increase in energy prices reduced export growth. For the two industries with historical declines in exports, the increase in energy prices contributed to the declines, but they are not solely responsible for the declines. The model indicates that the total dollar impact on exports for all of these twenty manufacturing industries was approximately $11.5 billion per year.

Table 3: Growth in Energy Prices and Manufacturing Exports

NAICS Three-Digit Industry	Historical, Total % Change in Exports	% Change in Energy Price	Modeled % Change in Exports	Modeled Change in Exports (Million USD)
Food Products	14.11%	28.12%	-1.18%	-333.6
Tobacco and Beverages	-3.56%	41.22%	-0.52%	-20.7
Textile Mills	2.76%	16.33%	-2.01%	-166.6
Textile Product Mills	21.90%	37.08%	-1.55%	-32.6
Apparel Manufacturing	-38.11%	33.50%	-0.78%	-47.9
Leather and Allied Products	6.69%	56.63%	-1.74%	-39.9
Wood Products	16.05%	147.54%	-12.73%	-539.0
Paper Manufacturing	17.63%	18.14%	-2.16%	-330.7
Printing	14.71%	11.34%	-0.39%	-20.0
Chemicals	48.03%	85.16%	-5.27%	-4,614.4
Rubber and Plastic Products	19.32%	20.15%	-1.22%	-210.8
Non-Metallic Mineral Products	14.99%	40.14%	-5.00%	-337.8
Primary Metals	115.21%	42.13%	-9.10%	-1,568.7
Fabricated Metal Products	28.87%	17.38%	-0.79%	-166.2
Machinery	39.21%	33.43%	-0.72%	-569.5
Computer and Electronics	3.55%	74.66%	-1.19%	-1,554.6
Electrical Equipment	35.90%	33.95%	-0.89%	-205.6
Transportation Equipment	28.09%	21.16%	-0.44%	-617.6
Furniture	30.56%	59.31%	-1.52%	-36.7
Miscellaneous Manufacturing	44.29%	13.43%	-0.21%	-49.6

Estimates of the Historical Impacts for the Six-Digit Industries

I reapply this analysis for eight more disaggregated, relatively energy-intensive, six-digit industries within the Paper, Chemicals, and Non-Metallic Mineral industries. Six of these eight disaggregated industries were analyzed in an earlier Department of Commerce study on energy-intensive, trade-exposed industries.[3] The six-digit industries with the highest export elasticities also have the highest energy cost shares (Table 4).

Table 4: Elasticity Estimates for Energy-Intensive Six-Digit Industries

NAICS Six-Digit Industry	Energy Cost Share (θ_i)	Product Price Elasticity of Export Demand (γ_i)	Energy Price Elasticity of Export Demand (ε_i)
Pulp Mills (322110)	0.113	-1.336	-0.150
Paperboard Mills (322130)	0.167	-1.581	-0.264
Industrial Gas (325120)	0.289	-1.031	-0.298
Plastics and Resins (325211)	0.062	-2.487	-0.154
Nitrogenous Fertilizer (325311)	0.207	-2.433	-0.502
Phosphatic Fertilizer (325312)	0.048	-2.970	-0.144
Glass Containers (327213)	0.182	-1.201	-0.218
Cement (327310)	0.292	-1.057	-0.309

[3] Nicholson, Michael (2010), *Manufacturing and Services Economics Brief No. 1* provides an analysis of trade and employment of the Pulp Mills, Paperboard Mills, Plastics and Resins, Nitrogenous Fertilizer, Glass Containers, and Cement industries. The study also analyzes forty other energy-intensive, trade-exposed industries that are not included in my analysis, because the MECS and/or ASM data are not publicly available.

The three industries with the largest modeled percentage changes in exports are in Chemicals. They have the largest percentage changes in their price of energy and this, rather than the product price elasticities, determines the relative ranking (Table 5). The modeled percentage changes in exports for the six-digit industries (Table 5) are all larger in absolute value than the modeled percentage change for the corresponding three-digit industry (Table 3). The total dollar impact on exports for these eight six-digit industries was approximately $3.6 billion per year.

Table 5: Modeled Growth in Exports in Six-Digit Industries

In constant 2006 U.S. Dollars

NAICS Six Digit Industry	Historical, Total % Change in Exports	% Change in Energy Price $\hat{P}$	Modeled % Change in Exports $\hat{X}$
Pulp Mills	17.93%	33.13%	-4.98%
Paperboard Mills	36.98%	49.77%	-13.14%
Industrial Gas	35.92%	103.74%	-30.89%
Plastics and Resins	59.35%	103.53%	-15.93%
Synthetic Rubber	65.27%	46.82%	-4.79%
Nitrogenous Fertilizer	24.40%	101.07%	-50.79%
Phosphatic Fertilizer	39.01%	74.18%	-10.66%
Glass Containers	-2.96%	49.47%	-10.79%
Cement	74.38%	31.41%	-9.71%

Conclusion

The economic model in this brief demonstrates that energy prices have had a significant effect on the export performance of the U.S. manufacturing sector. The increase in energy prices between 2002 and 2006 limited the expansion of exports over that time period. The effects vary across industries based on energy intensities and the price elasticities of demand for U.S. products in foreign markets. The total impact on U.S. non-petroleum manufacturing exports during this period was a reduction of approximately $11.5 billion per year. According to this estimate, the increase in the industries' exports of $622 billion between 2002 and 2006 would have been approximately $11.5 billion per year higher absent the increase in energy prices.

The industry-level elasticity estimates can also be applied on a prospective basis to evaluate the effect of a policy-related change in energy prices on the export performance of the U.S. manufacturing sector. For example, the model provides an analytical tool for evaluating the impact of a country-specific tax or subsidy on industrial energy use, a country-specific improvement in industrial energy efficiency, or national energy resource development (to the extent that it affects the industries' price of energy).

Technical Appendix

This appendix provides the formulas for calibrating the shares and elasticities in Tables 2 and 4. The elasticity of a U.S. industry's exports with respect to its price of energy ($\boldsymbol{\varepsilon_i}$) depends on the industry's energy share of marginal costs ($\boldsymbol{\theta_i}$) and the price elasticity of the demand for the industry's products in export markets ($\boldsymbol{\gamma_i}$). The latter depends on the elasticity of substitution between the industry's products from different countries ($\boldsymbol{\sigma_i}$) and the U.S. share of total expenditures the industry's products in export markets ($\boldsymbol{S_i}$). The formulas are as follows:[4]

$$\gamma_i = (1 - \sigma_i)(1 - S_i) < 0$$

$$\varepsilon_i = \gamma_i \, \theta_i < 0$$

These formulas assume that the change in energy prices is country-specific. If there were parallel changes in the energy prices paid by foreign competitors, then the export elasticity would be lower than the value in this equation.

I calibrate the parameters of this model for each industry using annual measures of each industry's value of exports, imports, and total shipments, and the industry's labor costs, cost of purchased fuel and electricity, and other costs of production in 2002. The formulas are as follows:

$$\sigma_i = \frac{TVS_i}{TVS_i - LCOST_i - MCOST_i}$$

TVS_i is the total value of shipments of industry i, $LCOST_i$ is industry's payroll, and $MCOST_i$ is the industry's total cost of materials.

$$\theta_i = \frac{ECOST_i}{LCOST_i + MCOST_i}$$

$ECOST_i$ is the cost of purchased energy (i.e., purchased fuel and purchased electricity per BTU) of industry i. $MCOST_i$ is the industry's cost of materials.

[4] A more detailed derivation of these formulas is available from the author upon request.

$$S_i = {EXP_i}\Big/{\left[\left(\frac{TVS_i - EXP_i + IMP_i}{GDP_{US}}\right)\sum_{c \neq US} GDP_c\right]}$$

EXP_i is the FAS value of domestic exports of industry i products to all countries, and IMP_i is the total landed duty-paid value of U.S. industry i imports for consumption from all countries in the same year. GDP_c is a measure of Gross Domestic Product in country c from United Nations' annual statistics.

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