Do Primary Energy Resources Influence Industry Location?

By Jason P. Martinek and Michael J. Orlando

By choosing to locate in a particular place, firms create employment opportunities for workers living there. And the wages they pay increase demand for local goods and services, creating additional job opportunities and further increasing the tax base. Consequently, state and local governments go to great lengths to encourage firms to locate within their boundaries.

States compete for industrial activity in a variety of ways. Publicity campaigns raise awareness of local endowments of natural resources, climate, and other indigenous advantages. A favorable business tax climate and indirect payments in the form of relief from income and property taxes also lure prospective employers. Finally, public investments in education, roads, and other municipal services valued by commercial interests may make one state more attractive than another.

In recent years, volatility in energy markets due to deregulation and events in the Middle East has increased the role that energy resource endowments may play in firm location. Thus, economic development agencies in energy producing states have highlighted their natural advantages as a way to attract and retain businesses. Yet there is scant evidence that firms base location decisions on the availability of primary energy resources, such as coal, oil, and natural gas.

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This article explores the role of primary energy resources in industry location. It examines the relationship between state energy supplies and employment in energy-intensive industries and suggests there is a limited relationship between the production of primary energy resources and industry location. State energy supplies are associated with the location of only the most energy-intensive industries. In other energy-intensive industries, firm location decisions appear largely unresponsive to state energy conditions.

Section I summarizes a range of theories that attempt to explain the location of economic activity and the role that primary energy resources may play in the firm location decision. Section II identifies the energy intensity of regions and industries and then analyzes the relationship between the location of employment in energy-intensive industries and the location of primary energy resources. Section III discusses the potential implications of state primary energy resource conditions for economic development policy.

I. ENERGY AND THE LOCATION OF ECONOMIC ACTIVITY

As firms choose where to locate, they must balance a number of energy and non-energy related features of regions, technologies, markets, and local governments. The cost and availability of primary energy resources are likely to be especially important for firms that are intensive users of energy in producing or distributing their products.

Factors that guide the location of industry

In general, the factors that lead economic activity to locate in a particular place include natural advantages, scale economies, and government policy. These factors determine the cost and benefits of alternative locations for business activity.

Natural advantages. Perhaps the most obvious reason for firms and individuals to locate in a particular place is to benefit from unique attributes of that place, otherwise known as natural advantages. A historical examination of many city locations suggests that some unique regional feature played an important role in their formation. For

example, shipbuilding requires deep, calm waters with access to the ocean. These are features of coastal Maine that allowed Bath to become the ship-building capital of the New World (Snow).

As the economy has moved from a manufacturing to a service orientation, one may be tempted to conclude that natural amenities have become a less important factor in firm location. Improvements in transportation and other technologies would seem to allow firms to move to areas that lack natural advantages in production, perhaps to take advantage of a local supply of labor. Indeed, the kind of activity that takes place in a region continues to reflect that region's natural advantages (Kim; Rappaport and Sachs). Moreover, if amenities valued in production have become less important, the location of those valued in consumption have become more so. As a result, the Sun Belt and the Front Range of the Rocky Mountains are home to some of the fastest growing cities in the United States, reflecting worker preferences for moderate climates and recreational amenities.

Scale economies. A second set of factors that guide the location of industry are scale economies. Scale economies refer to cost savings associated with increasing the amount of economic activity conducted in a particular place. Cost savings realized by a firm as it increases its own scale of operations are known as internal economies. Those realized by a firm as others increase their scale of activity are known as external economies.

Internal economies typically result from high fixed costs of operation that make a larger firm more cost effective than a smaller firm. For example, many service functions delivered inside a firm require some minimum number of workers, regardless of the size of operation. Worker safety and environmental regulations typically require at least one compliance officer at each industrial facility. The number of administrative personnel required to manage employee benefits and payroll may not vary proportionally with the scale of an operation. The per-unit cost of these and other self-sourced services diminishes as firm size increases.[1]

External economies arise in cases where the cost of doing business in a particular location decreases as the activity of other firms in that location increases. This efficiency results from three features typically associated with densely populated areas. Economies of scale in the pro-

duction of transportation and other intermediate inputs allow suppliers to provide goods and services at a lower cost in locations where demand for them is high. Because it is cheaper to search for a job where there are already many jobs, firms may improve their chances of hiring qualified workers by locating in places where other businesses are already established. And since workers exchange work-related information with one another on and off the job, firms may benefit by locating where such learning opportunities are possible.[2]

Government policy. A third factor that guides the location of industry is government policy. Policies that make firms more productive or increase quality of life attract economic activity to an area. Various levels of government make decisions over expenditures and revenues which, in turn, affect incentives for firms to locate in a particular place.

Municipal utilities, roads, and public safety and educational agencies are among the goods and services provided locally. Public expenditures in these areas can attract firms by reducing the cost of doing business. Governments can also invest in recreational and cultural amenities such as parks and museums. To the extent that workers value them, government spending on such amenities will also attract qualified workers. It is now commonplace for municipalities to compete for high-profile employers with targeted tax abatement programs. For example, Southern states have courted automobile manufacturers in an attempt to attract high-paying final assembly jobs.[3]

How energy may affect firm location

Regions with natural advantages in energy provision may be able to attract firms by providing low-cost and reliable supplies of primary energy resources. In industries that spend a significant amount on transportation, however, firms may be less responsive to regional advantages in energy provision.

Natural advantages in energy provision may reduce the cost of energy in a particular location. Certain areas are simply endowed with larger quantities of primary energy resources than are others. Since it is costly to move these resources from one place to another, regional variation in energy supplies will result in regional variation in their costs. This is why, for example, the mill towns of Lowell, Lawrence, and

Holyoke emerged as textile manufacturing cities of colonial New England. These and other locations along small streams allowed millers to make use of the waterwheel, the prevailing power technology of the time (O'Sullivan).

Natural advantages in the production of crude oil and natural gas have made states such as Texas and Oklahoma preferred locations for refining and petrochemical establishments. In these and other energy-intensive industries, primary energy inputs consume a large fraction of total revenue. All things equal, firms in these industries are likely to select a location that offers affordable and reliable supplies of raw materials to minimize their costs of production. Because it is costly to transport primary energy resources, locations with high geologic endowments are likely to offer lower energy costs. Consequently, firms that are intensive users of energy in production can lower their costs by choosing to locate in states with a natural advantage in energy provision.

In some energy-intensive industries, transporting goods between markets and points of production represents a significant cost of doing business. For example, firms in paper products and some metals manufacturing industries incur considerable expenses moving inputs to production facilities. Firms in these and other transportation-intensive industries may reduce their costs by selecting a location that minimizes the distance they must transport inputs and final goods. Consequently, energy-intensive firms that make significant use of transportation services may prefer to locate near their markets rather than near supplies of primary energy resources.[4]

II. STATE ENERGY CONDITIONS AND INDUSTRY LOCATION

Energy-intensive industries can be expected to locate in states with abundant supplies of primary energy resources. The location of employment is shown to be correlated with state energy resources in only the most energy-intensive industries. In other energy-intensive industries, the relationship between location and energy resources is not significant, even controlling for variation in transportation intensity.

Description of data

Analyzing the relation between regional industrial activity and energy conditions requires the use of several economic measures. This section defines regional measures of energy abundance and industrial activity as well as industry-level measures of energy and transportation intensity.

State energy conditions. As noted earlier, states with abundant supplies of primary energy resources have touted this distinguishing attribute in campaigns to attract businesses to their state. Since it is costly to transport energy supplies, firms in energy-intensive industries will value natural advantages in energy provision. Testing this claim requires a region-specific measure of primary energy availability.

Generally speaking, U.S. states may contain one or more of four primary energy sources: coal, oil, natural gas, and renewable resources. Renewable resources include wind, water, and solar energy used to produce electricity. The number of British Thermal Units (BTUs) of energy produced in each state from these sources, as tabulated by the Department of Energy's Energy Information Administration, is used to summarize state energy supply conditions (Chart 1).

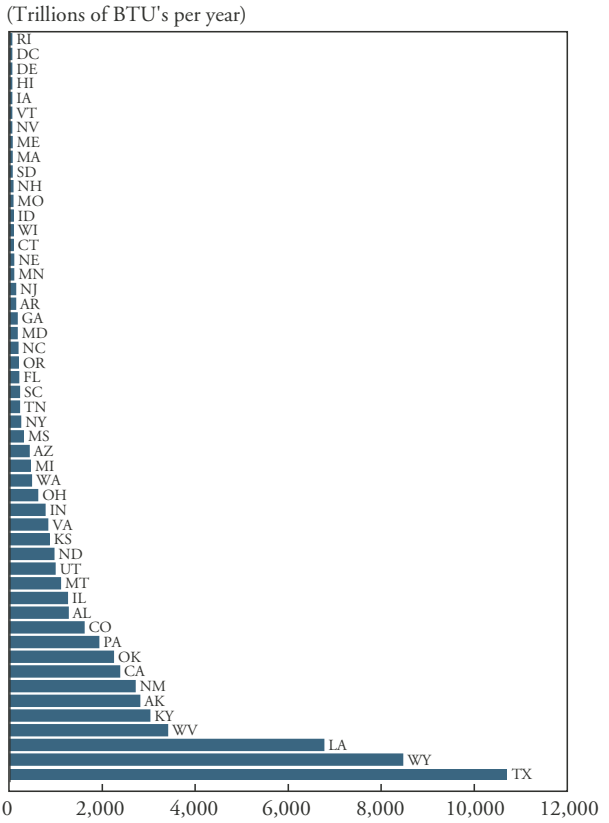
Examining the distribution of primary energy sources in the United States reveals at least two notable features. First, energy-abundant states are those from traditional oil and gas producing regions, including the Gulf Coast, the Southwest, and Alaska, and the coal producing regions of Appalachia and Wyoming. In addition, energy intensity is highly skewed to only a few states. Texas, Wyoming, and Louisiana produce 45 percent of the primary energy produced in the nation. And the top ten energy producing states account for nearly 77 percent of primary energy production.

Energy-intensive industries. Firms use energy in a number of different forms. They may make direct purchases of coal, oil, or natural gas. In addition, they may use electricity and refined petroleum products, which are manufactured from these primary energy sources. The energy intensity of an industry is calculated as the fraction of total industry revenue paid for all energy inputs.[5]

Industries included in the analysis include those that pay greater than 2 percent of total revenue to energy inputs (Table 1).[6] Mining and petroleum and natural gas producing industries are excluded from the

Chart 1

STATE ENERGY PRODUCTION



Source: Energy Information Administration

analysis since location in these industries is determined primarily by the geologic distribution of minerals. Industries that provide transportation services are also excluded from the analysis since the location of employment in these industries is determined by the location of goods to be transported. Sixteen of the 94 industries included in the Bureau of Economic Analysis 1998 Input-Output Accounts incur energy expenditures in excess of the 2-percent threshold. These industries account for 27 percent of total nonagricultural employment.

Table 1

ENERGY INTENSIVE INDUSTRIES

Industry	Purchases of energy as a percent of total revenue	Purchases of transportation services as a percent of total revenue
Petroleum refining and related products	46.7	5.2
Agricultural fertilizers and chemicals	11.1	7.4
Electric services (utilities)	10.0	3.6
Industrial and other chemicals	8.1	4.1
Primary iron and steel manufacturing	5.9	5.3
Glass and glass products	4.6	3.8
Hotels and lodging places	4.2	2.5
Stone and clay products	4.2	7.6
Water and sanitary services	3.8	1.0
Plastics and synthetic materials	3.7	3.2
Paper and allied products, except containers	3.5	4.7
Primary nonferrous metals manufacturing	3.4	4.1
Broad and narrow fabrics, yarn and thread mills	2.6	1.9
Retail trade	2.4	.8
Eating and drinking places	2.1	1.4
Rubber and miscellaneous plastics products	2.1	4.0

Source: Bureau of Economic Analysis

Notes: This table lists all industries that spent more than 2 percent of revenues on energy excluding those industries, such as agriculture and government enterprises, for which matching employment data were unavailable. Transportation and extraction industries were also excluded for reasons outlined in the text.

Transportation intensity of industries. Energy-intensive industries that incur significant transportation expenditures may not locate near primary energy resources. Efforts to reduce transportation costs may lead these firms to favor locations near non-energy input and final goods markets. To account for this event, it is necessary to construct a measure of industry transportation intensity. Industries that incur significant transportation costs include those that purchase energy to transport goods and services and those that purchase transportation services from other industries. Data limitations prohibit identification of the former set of industries.[7] The transportation intensity of an industry is therefore defined as the fraction of total revenue paid for transportation services (Table 1).[8]

Location of industrial activity. The final piece of data required for the analysis is a measure of the scale of economic activity for each industry in each state. The number of employees in an industry is a natural measure of industry activity and also reflects development agents' success in attracting jobs. The numbers of employees in each industry and state are obtained from the 1997 Economic Census produced by the U.S. Department of Commerce.

Analysis

A positive relationship exists between the location of primary energy production and employment in the most energy-intensive industries. Among other energy-intensive industries there is a positive correlation between energy supplies and employment in several industries with low transportation intensity. However, a simple regression analysis suggests the correlation between the location of employment in these industries and the location of primary energy resources is not statistically significant.

Analysis of correlation coefficients. Correlation coefficients between the share of total state employment in each industry and state energy production give an indication of the degree to which location decisions depend on the location of energy resources.[9] The average correlation coefficient for the 16 energy-intensive industries considered in this study is 0.13, indicating that the share of employment in energy-intensive industries is positively related to state energy supply conditions (Table 2). Also as expected, the correlation coefficients appear higher in industries with higher levels of energy intensity. In fact, the four highest correlation coefficients are observed in the four industries of highest energy intensity—petroleum refining, agricultural fertilizers and chemicals, electric services, and industrial chemicals.

Beyond these four industries, however, there is considerable variation among correlation coefficients, even among industries with relatively similar levels of energy intensity. For example, correlation coefficients range from –0.05 to +0.20 in industries with energy intensity between 3.5 and 6 percent. And industries with energy intensity between 2 and 3.5 percent have correlation coefficients that range from –0.24 to +0.29.

Table 2

CORRELATION BETWEEN SHARES OF STATE EMPLOYMENT AND STATE ENERGY PRODUCTION

Energy intensity rank	Industry	Correlation
1	Petroleum refining and related products	.74
2	Agricultural fertilizers and chemicals	.39
3	Electric services (utilities)	.29
4	Industrial and other chemicals	.35
5	Primary iron and steel manufacturing	.01
6	Glass and glass products	.03
7	Hotels and lodging places	-.05
8	Stone and clay products	.20
9	Water and sanitary services	.19
10	Plastics and synthetic materials	.15
11	Paper and allied products, except containers	-.20
12	Primary nonferrous metals manufacturing	-.07
13	Broad and narrow fabrics, yarn and thread mills	-.15
14	Retail trade	.16
15	Eating and drinking places	.29
16	Rubber and miscellaneous plastics products	-.24
	Average	.13

Sources: County Business Patterns

One explanation for such wide variation in correlation coefficients in this group is that, outside of industries with very high energy intensity, other factors become relatively important in the firm location decision. As discussed above, energy-intensive firms that incur transportation expenditures may minimize their total costs by choosing a location that minimizes the distance that inputs and outputs must be transported. The present analysis fails to account for interindustry variation in transportation expenditure. Explicit consideration of transportation expenditures may improve assessment of the importance of energy in the firm location decision.

Transportation expenditures are incorporated to investigate the relationship between primary energy resources and energy intensity outside of the most energy-intensive industries. For industries with energy intensity ranging from 2 to 6 percent, the correlation between industry employment and state energy conditions appears higher among the least transportation-intensive industries (Table 3). In this subset of industries,

Table 3

CORRELATION BETWEEN SHARES OF STATE EMPLOYMENT AND STATE ENERGY PRODUCTION FOR SELECTED INDUSTRIES

Industry	Transportation intensity (percent)	Energy intensity (percent)	Employment correlation
Stone and clay products	7.6	4.2	.203
Primary iron and steel manufacturing	5.3	5.9	.007
Paper and allied products, except containers	4.7	3.5	-.202
Primary nonferrous metals manufacturing	4.1	3.4	-.067
Rubber and miscellaneous plastics products	4.0	2.1	-.241
Glass and glass products	3.8	4.6	.031
Average:	4.9	4.0	-.045
Plastics and synthetic materials	3.2	3.7	.152
Hotels and lodging places	2.5	4.2	-.047
Broad and narrow fabrics, yarn and thread mills	1.9	2.6	-.149
Eating and drinking places	1.4	2.1	.288
Water and sanitary services	1.0	3.8	.191
Retail trade	.8	2.4	.160
Average:	1.8	3.1	.099

expenditures on transportation inputs range from 0.8 percent to 7.6 percent of total revenue. On average, the location of employment in the most transportation-intensive industries in this group is negatively correlated with the location of energy supplies (-0.045). In contrast, among the least transportation-intensive industries, the correlation is positive (0.099), even though this group has a slightly lower average level of energy intensity (3.1 percent vs. 4.0 percent).

Regression analysis. The pattern of correlation coefficients reported above suggests regional energy conditions play an important role in the location decisions of some energy-intensive firms. Beyond the most energy-intensive industries, the correlation coefficients suggest that employment in low transportation-intensive industries may also be correlated with the location of primary energy resources. A regression analysis is used to summarize the importance of energy intensity, transportation intensity, and regional energy conditions for industry location.

The following model illustrates the relationship between industry employment and state energy conditions:

$$N_{i,s} = d + a \cdot N_s + b \cdot N_i + c \cdot Q_s + \varepsilon_{i,t}$$

where $N_{i,s}$ is the number of employees in industry i and state s, N_s is total employment in state s, N_i is national employment in industry i, Q_s is total energy production in state s, and $\varepsilon_{i,t}$ is an error term.[10] Including total state employment in the regression controls for the likelihood that larger states will have a larger number of workers employed in all industries. Similarly, national industry employment controls for the likelihood that larger industries will employ a larger number of workers in every state. The parameters *a, b, c,* and *d* are estimated for various combinations of the 16 industries considered in the study.

The regression results from the complete data set suggest employment in a particular state and industry is positively associated with both total state employment and total industry employment (Table 4). However, the regression coefficient on total state energy production, while positive, is not statistically different from zero. The lack of statistical significance suggests that, on average, the location of employment in these 16 energy-intensive industries is not related to the location of energy resources.

The analysis of correlation coefficients presented above, however, reveals a positive relationship in the most energy-intensive industries. The model was therefore reestimated for two subsets of the data. The most energy-intensive industries are the four that incur energy costs in excess of 8 percent of total revenue. The remaining 12 industries are those in which energy intensity ranges from 2 to 6 percent.

In the most energy-intensive industries, industry employment is positively correlated (0.565) with state energy conditions. Moreover, this coefficient is statistically significant (standard error = 0.22). A state with one quadrillion BTUs more energy production than another will have 565 more workers employed in each of the four industries included in the regression.[11] In contrast, in industries with energy intensity between 2 and 6 percent, the regression coefficient on state energy supplies is lower (0.129) and remains statistically insignificant (standard error = 1.64).

Table 4

ENERGY INTENSITY AND INDUSTRY LOCATION

Complete data set 16 industries $R^2 = .54$, n = 816	$N_{i,s} = -31.8 + .015 \cdot N_s + .020 \cdot N_i + .238 \cdot Q_s$ (3.90) (.001) (.001) (1.26)
Split data set 4 highest energy intensity industries $R^2 = .51$, n = 204	$N_{i,s} = -5.21 + .002 \cdot N_s + .020 \cdot N_i + .565 \cdot Q_s$ (.837) (.000) (.002) (.219)
Remaining 12 industries $R^2 = .55$, n = 612	$N_{i,s} = -40.7 + .020 \cdot N_s + .020 \cdot N_i + .129 \cdot Q_s$ (5.15) (.002) (.001) (1.64)

Notes: Standard errors are in parenthesis. See Table 2 for industry list.

The correlation coefficients discussed above also suggest that transportation expenditures may be important for understanding the influence of energy in the firm location decision. To examine the importance of transportation considerations for firm location, the model is estimated for subsets of the 12 remaining energy-intensive industries, separating those industries according to transportation intensity. The relative size of the energy supply coefficients from these subsets, with a larger coefficient appearing in the subset with lower transportation intensity, is consistent with transportation intensity mitigating the importance of energy in the firm location decision. However, neither of the coefficients is statistically significant (Table 5). This finding suggests that even after accounting for variation in transportation intensity, the location of employment in the remaining industries is not related to state supplies of primary energy resources.[12]

Table 5

TRANSPORTATION INTENSITY, ENERGY INTENSITY, AND INDUSTRY LOCATION

Select data set	
12 industries	$N_{i,s} = -40.7 + .020 \cdot N_s + .020 \cdot N_i + .129 \cdot Q_s$
$R^2 = .55$, n = 612	(5.15) (.002) (.001) (1.64)
Split data set	
6 higher transportation intensity industries	$N_{i,s} = -7.36 + .004 \cdot N_s + .020 \cdot N_i - .267 \cdot Q_s$
$R^2 = .51$, n = 306	(1.22) (.000) (.002) (.265)
6 lower transportation intensity industries	$N_{i,s} = -74.0 + .036 \cdot N_s + .020 \cdot N_i + .526 \cdot Q_s$
$R^2 = .59$, n = 306	(9.90) (.003) (.001) (2.98)

Notes: Standard errors are in parenthesis. See Table 3 for industry lists.

III. IMPLICATIONS FOR REGIONAL INDUSTRIAL DEVELOPMENT

The analysis presented in this article finds a limited relationship between the location of industrial activity and the location of primary energy resources. These results have implications for economic development strategies which seek to use energy resources as a tool for attracting new employers.

Three main conclusions on the relationship between the location of primary energy resources and industrial activity emerge from the analysis. First, analyzed as a group, employment in the 16 energy-intensive industries does not appear to be associated with the location of primary energy resources. Second, there is a narrow set of industries for which firm location decisions appear to be responsive to state energy conditions. These are the four most energy-intensive industries—petroleum refining, agricultural fertilizers and chemicals, electrical services, and industrial and other chemicals. Third, energy-

intensive industries with low expenditures on transportation services do not appear more responsive to energy resource location than the more transportation-intensive industries.

The findings suggest that successful regional development strategies based solely on the availability of primary energy resources are likely to be limited in scope. This study documents the potential for attracting very energy-intensive industries. Of course, such strategies may also be expected to increase employment in mining and other energy extraction industries. Successful economic development of a broader scope, however, will be based on a range of factors.

Economic development strategies in which local resource endowments play a central role must also reflect how potential changes in energy resource location, production technology, and product demand will influence firm location decisions in the future. While energy reserves themselves are unlikely to relocate, the location of energy production does change over time. Reserves in older producing regions are depleted and new resources may be developed due to discovery of new extraction technologies. Moreover, the relative energy intensity of industries is not fixed. Production processes can become either more or less energy intensive as new technologies allow firms to substitute cheaper inputs for more expensive inputs. Finally, both the location of final demand and the nature of that demand are likely to change over time. These factors can lead to a change in local industrial composition. For example, a shift in relative importance away from manufactured goods and toward services will lead to a decline in employment in energy-intensive manufacturing and lead to an increase in employment in service industries, which are somewhat less energy intensive.

IV. SUMMARY AND CONCLUSION

In light of recent volatility in energy prices, state energy conditions have taken a more prominent role in the regional development debate. This would seem to put energy-rich states at an advantage in the competition to attract new businesses. In fact, energy-rich states have increasingly advertised this feature as one favorable to business. To understand the prospects for success of such strategies, one needs to

know how firms decide where to locate. A number of energy-related factors combine to determine the costs and benefits of alternative locations for firm operations.

This study identifies the narrow set of industries which tend to locate near primary energy sources. The analysis also examines a somewhat broader set of industries that might be expected to locate near regional energy supplies. However, even after controlling for the transportation intensity of these industries, little evidence can be uncovered for a strong relationship between employment in these industries and primary energy resource endowments. Thus, even successful economic development strategies that focus exclusively on natural resource endowments will be limited in the range of industries they attract.

ENDNOTES

[1] Scherer documented internal economies of scale in a number of industries, including steel, aircraft, and automobiles.

[2] Orlando identified external economies associated with knowledge spillovers from industrial research and development activity. More generally, in separate studies, Hanson and Kim found a variety of external economies were important in the development of U.S. metropolitan areas.

[3] A number of empirical studies summarized by Bartik found that policies that improve public services lead to faster local economic growth. Studies by both Helms and Munnell simultaneously examined the revenue and expenditure sides of public policies, finding tax increases that improve public services tend to improve regional economic performance, while those that fund redistributional programs tend to reduce performance. Anderson and Wassmer studied the effectiveness of tax abatement programs and concluded that such programs do not appear to influence the firm location decision. Presumably, firms facing a location decision make their choice prior to tax abatement considerations. They may then solicit promises of tax abatement from competing cities in order to extract a similar program from their initial-choice city.

[4] Government policies may also affect local energy supplies. Tax policy and certain municipal investments, such as investments in transmission and distribution infrastructure, can increase or decrease local availability, thereby affecting local prices and the cost of doing business in a particular area.

[5] Energy intensity is defined as the fraction of total industry revenue paid to the following industries: petroleum refining and related products, gas production and distribution, crude petroleum and natural gas, electric services, and coal mining.

[6] The following analysis was repeated after including industries down to an energy intensity level of 1.5 percent. The findings were unaffected.

[7] Identification of these industries is not possible since doing so would require data that reveals exactly how firms employ their energy inputs, either as inputs to the production process or as inputs to self-provided transportation services.

[8] Transportation intensity is defined as the fraction of total industry revenue paid to the following industries: railroads and related services, motor freight transportation, water transportation, air transportation, and pipelines, freight forwarders, and related services industries.

[9] Correlation coefficients range from -1.0 to +1.0. Variables that tend to move in the same direction will have a positive correlation coefficient while those that move in the opposite direction will have a negative correlation coefficient.

[10] Employment values are in thousands. Energy production values are in quadrillions of British Thermal Units per year.

[11] It is important to keep in mind that the present analysis excludes mining and energy extraction industries. The marginal impact of an increase in primary energy production on employment in these industries is larger than that reported here.

[12] Of course, limitations inherent in the data used in this analysis may be the reason for the inability to find a significant transportation effect. A larger set of industry data and information on the fraction of purchased energy used to provide transportation services in-house may be necessary to definitively rule out a role for transportation in this process.

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