Gross State Product and Employment: The Effect of Electricity Prices

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Abstract:

A number of new or pending environmental regulations issued by the federal government are expected to have significant effects on the cost of electric power generation and therefore on the price of electricity. Thus, it is important to gain a better understanding of the relationship between electricity prices and economic outcomes. In this annual report article, we estimate the likely effects of increased electricity prices on production as measured by Gross State Product (GSP) and on employment. Our estimates and simulations indicate that price increases in electricity will have sizable negative effects on Kentucky's GSP and employment growth if the price increases are not accompanied by other changes, such as technological advances, that might alter the consequences of electricity price increases.

Introduction

These regulations generally entail more stringent regulation regarding sulfur dioxide, nitrogen dioxide, particulate matter, lead, ozone, carbon monoxide, water quality, and coal ash disposal.[i] Because these requirements are expected to cause substantial increases in the cost of electricity generation and therefore in the price of electricity, a quantitative examination of the relationship between electricity prices and economic output is warranted. In this annual report article, we estimate the likely effects of increased electricity prices on production as measured by Gross State Product (GSP) and employment.[ii]

In order to ascertain the effects of changes in energy prices on macroeconomic aggregates (i.e. employment and production), we develop and estimate a model based on a partial adjustment mechanism to investigate the dynamic relationship between energy prices and macroeconomic conditions. Using these estimates, we develop policy scenarios and corresponding estimates to produce simulations of the long-run effects of electricity price shocks on state GSP and employment. This exercise should be viewed as "all else constant" simulations in the sense that we assume that only an electricity price increase and no other relevant events, such as technological advance, occurs.

Examining the Relationship among Energy Prices and Production and Employment

In this section we examine the relationship among energy prices (i.e. crude oil, electricity and natural gas), production (measured by gross state product), and total employment. In order to investigate these relationships we adopt an agnostic partial adjustment model to estimate the effect of energy prices on GSP and employment. The partial adjustment model assumes that GSP and employment, after a price shock, adjust to their new long-run values only partially each period, but eventually full adjustment is made.

Formally, the partial adjustment framework is given by the following equation:

$$Y_{i,t} - Y_{i,t-1} = \lambda(Y^* - Y_{i,t-1})$$

where subscripts *i* and *t* indicate state and time, respectively. The variable Y is our macroeconomic variable of interest, either production or employment, and Y^* is the equilibrium level of production or employment. The parameter λ represents the adjustment coefficient. When $\lambda = 1$ there is instantaneous adjustment and when $\lambda = 0$ there is no adjustment, so that $Y_{i,t} = Y_{i,t-1}$.

Solving for $Y_{i,t}$ we get:

$$Y_{i,t} = (1 - \lambda)Y_{i,t-1} + \lambda Y^*$$

From here, we assume that the equilibrium values of production and employment are a function of energy prices, in particular, the prices of crude oil, electricity, and natural gas. So if we let $Y^* = \alpha_i + \beta X_{i,t}$, where $X_{i,t}$ are energy prices and α_i are state-specific intercepts, then we get the following:

$$Y_{i,t} = \lambda\alpha_i + (1 - \lambda)Y_{i,t-1} + \lambda\beta X_{i,t} = \delta_i + \delta_1 Y_{i,t-1} + \delta_2 X_{i,t}$$

The main benefits of this model are its ease in implementation and the lack of need for a complex underlying model. The estimates reveal the equilibrium outcomes of changes in energy prices.

Using annual data from 1970 to 2010 allows us to capture the large historical variations in energy prices and enhances identification of the underlying causal relationships. The cross-state aspect of our data enables us to utilize cross-sectional variations in the prices of electricity and natural gas. Our approach assumes contemporaneous effects of changes in energy prices on state GSP and employment. In particular, we view the price of electricity, natural gas, and crude oil as affecting production and employment. Also, we consider effects on both the level and growth of GSP and employment. To control for other factors that affect production at a point in time or that are unique to each state (such as regulatory issues), we add in state fixed effects and time effects. Additionally, to capture lagged influences, we include lagged values of energy prices as explanatory variables.

From the estimates of these equations, we then conduct a series of policy scenarios in which we perturb energy prices and simulate the changes in production and employment over time. Because carbon-abatement policies typically result in higher-priced electricity, our simulations focus on the effects of an increase in the price of electricity.

Our baseline model includes estimates containing the 48 continental U.S. states, and we estimate a model for a subset of states (labeled Group) similar to Kentucky in energy reliance. Group is constructed based on coal generated as a percent of total electricity and total electricity consumption as a share of real gross state product. We chose states above the 37.5th percentile in order to capture states with similar reliance on energy as Kentucky. These states with their

corresponding values of electricity generated from coal as a percent of total electricity generation and electricity consumption as a share of real gross state product are listed in Table 1.

Table 1: Energy Intensive States

States	(1) % of Electricity generate from Coal	(2) Electricity Consumption (bil. BTU) per Dollar of Real Gross State product
Alabama	62.31%	1.94
Arkansas	55.08%	1.65
Arizona	46.09%	1.02
Georgia	64.65%	1.09
Iowa	84.41%	1.13
Indiana	95.07%	1.33
Kansas	72.53%	1.13
Kentucky	**96.84%**	**1.87**
Missouri	82.13%	1.08
Montana	61.25%	1.82
North Carolina	62.10%	1.15
North Dakota	92.84%	1.39
Nebraska	63.41%	1.15
New Mexico	85.43%	1.01
Nevada	53.35%	0.99
Ohio	86.92%	1.17
Oklahoma	64.17%	1.46
Tennessee	64.92%	1.45
Virginia	51.51%	1.00
Wisconsin	70.93%	0.99
West Virginia	98.21%	1.80
Wyoming	95.78%	1.95

The outcomes of interest are the level of production (GSP), the level of total employment, the growth in production (GSP), and the growth in employment. The coefficients in each specification represent percentage change effects.

Tables 2 and 3 show the findings for the production growth and production level equations. Individually, the coefficients provide little insight, but the sum of the current and lagged values provide estimates for the marginal short-run effects. Nevertheless, Tables 2 and 3 display an overall negative relationship between energy prices and production. With respect to crude oil, a price increase in period *t-1* induces a positive impact on contemporaneous growth and level of production followed by a negative impact in period *t*, with the sum of the effects being negative. Also, increases in natural gas prices do not exhibit any contemporaneous effect on growth and level of production, but in period *t-1* an increase in natural gas prices decrease growth and level of production. Finally, electricity prices reveal similar patterns of adjustment to changes in crude oil prices.

Table 2: Growth in Gross State Product, with Current and Lagged Prices

Variables	(1) Baseline	(2) Group Interaction
GSP Growth (t-1)	0.281***	0.276***
	(0.0547)	(0.0542)
Oil Price	-0.0625***	-0.0619***
	(0.00465)	(0.00659)
Oil Price (t-1)	0.0295***	0.0283***
	(0.00336)	(0.00420)
Oil Price (interaction)	_____	-0.00226
		(0.00965)
Oil Price (interaction) (t-1)	_____	0.00323
		(0.00618)
Natural Gas Price	0.00822	0.0145
	(0.0111)	(0.0129)
Natural Gas Price (t-1)	-0.0241**	-0.0274**
	(0.00970)	(0.0129)
Natural Gas Price (interaction)	_____	-0.0120
		(0.0107)
Natural Gas Price (interaction) (t-1)	_____	0.00394
		(0.0102)
Electricity Price	-0.0285	-0.0301
	(0.0202)	(0.0183)
Electricity Price (t-1)	0.0163	0.0265
	(0.0182)	(0.0190)
Electricity Price (interaction)	_____	0.00542
		(0.0404)
Electricity Price (interaction) (t-1)	_____	-0.0222
		(0.0362)
Constant	0.176***	0.174***
	(0.0160)	(0.0184)

Observations	1,872	1,872
R-squared	0.509	0.512
Number of States	48	48

Notes: Robust standard errors in parentheses. Asterisks denote significance at the following levels: *** p<0.01, ** p<0.05, * p<0.1. The interaction variable is the interaction between states that are energy reliant and corresponding prices. These give the added marginal effect of each price on growth in production conditional on states being energy reliant.

Table 3: Total Gross State Product, with Current and Lagged Prices

Variables	(1) Baseline	(2) Group Interaction
GSP Level (t-1)	0.965***	0.965***
	(0.00636)	(0.00698)
Oil Price	-0.0709***	-0.0726***
	(0.00510)	(0.00677)
Oil Price (t-1)	0.0342***	0.0321***
	(0.00518)	(0.00502)
Oil Price (interaction)	_____	0.00168
		(0.0109)
Oil Price (interaction) (t-1)	_____	0.00460
		(0.00477)
Natural Gas Price	0.00523	0.0155
	(0.0114)	(0.0130)
Natural Gas Price (t-1)	-0.0281***	-0.0295**
	(0.00922)	(0.0132)
Natural Gas Price (interaction)	_____	-0.0193*
		(0.0115)
Natural Gas Price (interaction) (t-1)	_____	0.00183
		(0.0116)
Electricity Price	-0.0382*	-0.0424**
	(0.0206)	(0.0187)
Electricity Price (t-1)	0.0231	0.0360*
	(0.0175)	(0.0197)
Electricity Price (interaction)	_____	0.0122
		(0.0398)
Electricity Price (interaction) (t-1)	_____	-0.0291
		(0.0349)
Constant	0.631***	0.626***
	(0.0769)	(0.0838)
Observations	1,872	1,872
R-squared	0.992	0.992
Number of States	48	48

Notes: Robust standard errors in parentheses. Asterisks denote significance at the following levels: *** p<0.01, ** p<0.05, * p<0.1. The interaction variable is the interaction between states that are energy reliant and corresponding prices. These give the added marginal effect of each price on total production conditional on states being energy reliant.

When focusing on energy-reliant states, estimates in column 2 of Tables 2 and 3 show that the effect of oil price increases generate no additional effect on energy-reliant states.[iii] Alternatively, energy-reliant states are affected more by increases in natural gas and, to some extent, electricity prices compared to the national estimates.

Table 4 provides the results from estimating each this specification for employment growth. In column 1, crude oil and natural gas prices exhibit a statistically significant and negative effect on employment growth both in period *t-1* and period *t*. Electricity prices reveal a negative effect in period *t*, but this effect is damped by a positive effect in period *t-1*, though overall effects are negative. Estimates regarding the interactions with the group of similar states do not show statistical significance.

Table 4: Employment Growth, with Current and Lagged Prices

Variables	(1) Baseline	(2) Group Interaction
Employment Growth (t-1)	0.607***	0.604***
	(0.0179)	(0.0180)
Oil Price	-0.0143***	-0.0142***
	(0.00274)	(0.00280)
Oil Price (t-1)	-0.0211***	-0.0204***
	(0.00185)	(0.00201)
Oil Price (interaction)	_____	-0.000577
		(0.00367)
Oil Price (interaction) (t-1)	_____	-0.000846
		(0.00236)
Natural Gas Price	-0.00146	0.00104
	(0.00374)	(0.00402)
Natural Gas Price (t-1)	-0.00401	-0.00750*
	(0.00396)	(0.00426)
Natural Gas Price (interaction)	_____	-0.00711
		(0.00592)
Natural Gas Price (interaction) (t-1)	_____	0.00732
		(0.00504)
Electricity Price	-0.0369***	-0.0342***
	(0.00861)	(0.00793)
Electricity Price (t-1)	0.0326***	0.0316***
	(0.00837)	(0.00810)
Electricity Price (interaction)	_____	-0.00653
		(0.0175)
Electricity Price (interaction) (t-1)	_____	0.00289
		(0.0155)
Constant	0.135***	0.136***

	(0.00983)	(0.0100)
Observations	1,872	1,872
R-squared	0.794	0.795
Number of States	48	48

Notes: Robust standard errors in parentheses. Asterisks denote significance at the following levels: *** p<0.01, ** p<0.05, * p<0.1. The interaction variable is the interaction between states that are energy reliant and corresponding prices. These give the added marginal effect of each price on employment growth conditional on states being energy reliant.

Table 5 shows the findings for the level of employment in the states. They are generally consistent with the results pertaining to the level of GSP. However, the lagged oil price is negative for employment, and the lagged electricity price is higher in magnitude compared to the effect on GSP. Again, Group interaction effects are not statistically significant.

Table 5: Total Employment, with Current and Lagged Prices

Variables	(1) Baseline	(3) Group Interaction
Employment Level (t-1)	0.968***	0.968***
	(0.00466)	(0.00490)
Oil Price	0.0465***	0.0463***
	(0.00600)	(0.00558)
Oil Price (t-1)	-0.0365***	-0.0363***
	(0.00294)	(0.00279)
Oil Price (interaction)	_____	6.76e-06
		(0.00426)
Oil Price (interaction) (t-1)	_____	-0.000534
		(0.00371)
Natural Gas Price	-0.00355	0.00158
	(0.00446)	(0.00500)
Natural Gas Price (t-1)	-0.00693	-0.0105*
	(0.00463)	(0.00572)
Natural Gas Price (interaction)	_____	-0.0117**
		(0.00582)
Natural Gas Price (interaction) (t-1)	_____	0.00711
		(0.00670)
Electricity Price	-0.0458***	-0.0434***
	(0.00983)	(0.00967)
Electricity Price (t-1)	0.0342***	0.0360***
	(0.00817)	(0.00950)
Electricity Price (interaction)	_____	-0.00380

		(0.0210)
Electricity Price (interaction) (t-1)	_____	-0.00456
		(0.0169)
Constant	0.249***	0.250***
	(0.0462)	(0.0479)
Observations	1,872	1,872
R-squared	0.997	0.997
Number of States	48	48

Notes: Robust standard errors in parentheses. Asterisks denote significance at the following levels: *** p<0.01, ** p<0.05, * p<0.1. The interaction variable is the interaction between states that are energy reliant and corresponding prices. These give the added marginal effect of each price on total employment conditional on states being energy reliant.

Policy Scenarios

In this section we explore a number of hypothetical policy scenarios and their effects on production and employment. Throughout these scenarios it is important to keep in mind the difference between a one-time shock and a permanent shock in energy prices. In this analysis, we consider only permanent shocks in the price of electricity. This seems a likely scenario because implementation of energy policies usually persists for many years at a time.

Another important caveat in these scenarios is the strong assumption that the electricity price shock is not accompanied by other changes such as technological advances. Such technological advances could lessen the impact of the shocks. Therefore, our scenarios should be treated as simulations of future conditions under the status quo (except for the shock) rather than forecasts or estimates of future growth.

The policy scenarios are carried out using estimates for all U.S. states (U.S. estimates) and estimates for the group of states similar in energy reliance to Kentucky (Group). The model scenarios are geared to understanding the size of the Kentucky economy.

We assume a baseline growth rate of 3.0% for production and an annual gross domestic product $163.3 billion. The former is the long-run historical growth rate of GDP for the U.S. economy and $163.3 billion was Kentucky's GSP in 2010. Table 6 contains the simulated effects of the 10% and 25% increases in the price of electricity on economic growth and GSP level. These increases in the prices of electricity are hypothetical increases assumed to be induced by policy. Panel A of Table 6 gives the short-run (SR) and long-run (LR) growth rate of production following a 10% and 25% permanent shock to electricity prices.

For the overall (U.S.) estimates, a 10% permanent increase in electricity prices would decrease the production growth rate to 2.88% in the short run and to 2.83% in the long run, all else equal. Using estimates for energy-reliant states, the growth rate would be reduced to 2.80% in the short

run and 2.72% in the long run. Given the linearity of the forecasts, the estimates for the 25% shock to electricity prices are increased accordingly.

Table 6: Policy Scenarios and Production, 10% and 25% Price of Electricity Increase

Panel A: GSP Growth.
Relative to 3.0% Growth

	U.S.	Group
10% Price Incr., SR	2.88	2.80
10% Price Incr., LR	2.83	2.72
25% Price Incr., SR	2.70	2.49
25% Price Incr., LR	2.58	2.30

Panel B: GSP Over Time

	(1)	(2)	(3)
10% price increase	3% gth. Baseline	2.83%	2.72%
5 years	189.31	187.75	186.75
10 years	219.46	215.87	213.57
20 years	294.94	285.35	279.31
25% price increase	3% gth. Baseline	2.58%	2.30%
5 years	189.31	185.48	182.96
10 years	219.46	210.68	204.99
20 years	294.94	271.79	257.34

Notes: The estimates used to develop policy scenarios were extracted from Tables 2. SR=short run, LR=long run

To complement Panel A, Panel B provides simulations of GSP levels over 5, 10, and 20 years. Column 1 gives the baseline results assuming a constant 3% annual growth rate in production over 5, 10, and 20 years. For instance, at a 3% growth rate, GSP would increase from $163.3 billion in year 1 to $189.31 billion in year 5; $219.46 billion in year 10; and $294.94 billion in year 20. Column 2 uses the annual growth rate generated from the long-run 10% increase in electricity price (found in Panel A). Here, at a 2.83% growth rate, GSP would decrease our baseline estimate by $1.56 billion in 5 years; $3.59 billion in 10 years; and $9.59 billion in 20 years. Estimates based off energy-reliant states, which decrease the growth rate to 2.72% would then decrease the baseline estimate by $2.56 billion in 5 years; $5.89 billion in 10 years; and $15.63 billion in 20 years. These results are exacerbated when electricity prices increase by 25% as shown in Panel B. Overall, these results illustrate the substantial impact of electricity price shocks on the economy, especially for energy-reliant states.

Table 7 contains the policy simulations for employment. Again, these are geared to simulate the size of the Kentucky economy. It is assumed that a steady state growth rate of employment is

1% which is the approximate historical, annual growth rate of employment for Kentucky. Also, the baseline level of employment is assumed to be 1,900 thousand, Kentucky's approximate labor force in 2010.

Replicating the above analysis using employment growth as the macroeconomic variable of interest, Panel A displays the short- and long-run effects of a 10% and 25% increase in electricity prices on employment growth. Not surprisingly, energy-reliant states bear a larger burden in terms of employment following energy price increases than other U.S. states. These scenarios show a long-run employment growth rate of 0.84% for a 10% electricity price increase, compare to a 0.89% growth rate based on total U.S. estimates.

Panel B of Table 7 is similar to that of Table 6, providing simulations of employment over 5, 10, and 20 years. Column 1 gives the baseline results assuming a constant 1% annual growth rate in employment over 5, 10, and 20 years. For instance, at a 1% growth rate, employment would increase from 1,900 thousand in year 1 to 1,997 thousand in year 5; 2,099 thousand in year 10; and 2,437 thousand in year 20.

Column 2 uses the annual growth rate in employment generated from the long-run 10% increase in electricity price (found in Panel A). After 20 years, comparing columns 1 and 2, the increase in employment is 65,500 less following a 10% increase in electricity prices. For a 25% increase in electricity prices, the difference is 158,000 in employment. Energy-reliant states, following a 10% increase in energy prices would find their employment drop by 95,000 and for a 25% increase in energy prices employment would drop by 225,000 after 20 years.

Table 7: Policy Scenarios and Employment, 10% and 25% Price of Electricity Increase

Panel A: Employment Growth.
Relative to 1.0% Growth

	U.S.	Group
10% Price Incr., SR	0.96	0.94
10% Price Incr., LR	0.89	0.84
25% Price Incr., SR	0.89	0.84
25% Price Incr., LR	0.73	0.61

Panel B: Employment Over Time

	(1)	(2)	(3)
10% price increase	1% gth. Baseline	0.89%	0.84%
5 years	1,997	1,986	1,981
10 years	2,099	2,076	2,066
20 years	2,437	2,371	2,342
25% price increase	1% gth Baseline	0.73%	0.61%
5 years	1,997	1,970	1,959
10 years	2,099	2,043	2,019
20 years	2,437	2,279	2,212

Notes: The estimates used to develop policy scenarios were extracted from Table 4

Conclusion

This article looks at the relationship between electricity prices and two measures of economic conditions, GSP and employment. Specifically, we use a partial adjustment model for examining the relationship between energy prices and four measures of economic output: GSP levels, GSP growth, employment levels, and employment growth. We look at this relationship over time and across states nationally, and we also study whether the effect differs for states similar to Kentucky with respect to energy reliance. Across the models and outcomes, we find an expected negative relationship between electricity prices and economic output.

To summarize and illustrate our results, we conduct policy scenarios based on either a 10% or 25% permanent increase in electricity prices. We focus on the estimates for the pooled U.S. states and the energy-reliant states. Because these policy scenarios look only at the price shock and assume no changes in other factors such as technological innovations, these scenarios are simple simulations of future economic output under these assumptions rather than our forecast of expected future conditions. In terms of GSP, we find that a 10% increase in electricity prices would decrease GSP growth from our baseline value of 3% annual growth (without the shock) to 2.88% in the short run and 2.83% in the long run based on the U.S.-wide estimates. The drop in growth is more pronounced for estimates based on energy-reliant states. Turning to employment growth, a 10% increase in electricity prices decreases employment growth rate from the baseline value of 1% annual growth (without the shock) to 0.96% in the short run and 0.89% in the long run, based on U.S.-wide estimates. The resulting reduction in the long-run growth rate in employment growth is larger for estimates based on energy-reliant states (0.84%).

These policy scenarios provide valuable information on the possible effects of electricity price increases. These scenarios illustrate that price increases will have sizable negative effects on Kentucky's GSP and employment growth if the price increases are not accompanied by other changes, such as technological advances, or other factors that might mitigate (or possibly exacerbate) the consequences of electricity price increases.

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[i] See the summary in Max Neubauer, R. Neal Elliott, and Aron Partrick, "Kentucky Electricity and Natural Gas Price and Consumption Forecasts to 2035," American Council for an Energy-Efficient Economy, August 9, 2011 http://energy.ky.gov/Programs/Data%20Analysis%20%20Electricity%20Model/ACEEE%2008_09_11_B.pdf .

[ii] This annual report article is based on a study we conducted for the Kentucky Department for Energy Development and Independence entitled "The Relationship between Electricity Prices and Electricity Demand, Economic Growth, and Employment." That report will be available shortly on the CBER website (http://cber.uky.edu).

[iii] Interaction terms are generated by creating a variable G=1 if states are energy reliant and zero otherwise. This variable is multiplied by each of the price variables to create the interaction term. The interaction terms provides the added marginal effect on energy-reliant states.