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ENERGY TAXES AND ECONOMIC PERFORMANCE: A REGIONAL GENERAL EQUILIBRIUM ANALYSIS

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Introduction

For much of the past decade and a half, there has been a lively interest in employing taxes to limit energy consumption--either in the aggregate, or particular forms, such as crude oil and gasoline. Interest has also been expressed--at both the federal and state levels--in the potential of energy taxes to raise revenues. But questions immediately arise. How much of an impact on energy consumption will a tax produce? How will it affect the pattern of consumption, say of crude oil as opposed to other energy sources? What will be the impact on performance of the larger economy?

Of course, different taxes will result in different answers to these questions. In this paper we study the impacts of two prototype energy taxes: a general consumption or "Btu" tax (i.e., a uniform tax on all forms of energy consumption) and a more sharply focused "severance" tax (on the extraction of crude oil). Both taxes are considered in the setting of a large energy-consuming and oil-producing region--the state of California. California's economy is at least the eighth largest in the world and is often studied as a "leading indicator" for others. The state is also a major oil producer, accounting for around 1 million barrels per day. By way of comparison with some OPEC producers, this is more than Algeria, about the same as Libya, and a little less than Kuwait.

We use a computable general equilibrium (CGE) model of the economy, with an emphasis on oil and other energy sectors (coal, gas, and electricity). This enables us to trace the impact of the taxes in question on production, for the California economy, which is essentially a price taker with respect to the rest of the world (including the rest of the United States), but at the same time exhibits substantial differences in prices even relative to other regions of the United States.

Formally, we model a "demand plant" producing a composite good i from two "inputs," domestic output (X_i) and imports (M_i), whose prices are PD_i and PM_i, respectively. Assuming constant returns to scale (CRS) in this "production process," the producers' equilibrium condition is

$$P_i = f_i(PD_i, PM_i) \tag{1}$$

where P_i is the price of the composite good and $f_i(\ )$ is unit cost. Using Shephard's Lemma, the market equilibrium (supply = demand) conditions for domestic output and imports, respectively, are

$$X_i = \frac{\partial f_i}{\partial PD_i}(PD_i, PM_i)\, D_i + E_i \tag{2}$$

and

$$M_i = \frac{\partial f_i}{\partial PM_i}(PD_i, PM_i)\, D_i \tag{3}$$

where D_i is total domestic demand for composite good i and E_i is export demand.

Factor markets

Primary inputs, labor and capital, are not produced (in the equilibrium year following introduction of a tax) and not traded, but assumed malleable, i.e., capable of allocation to any sector within the domestic economy (in the long-run equilibrium). A perfectly inelastic supply of a primary input, along with

$$X_{ij} = \frac{\partial c_j}{\partial P_i} (WL,\ WK,\ P)\ X_j. \tag{9}$$

This intermediate demand, along with final consumption and investment demand, makes up total domestic demand for i, D_i in equations (2) and (3).

The cost function $c_j(\ )$ is specified to be of the Generalized Leontief (GL) type. The advantage of this specification is that it allows for differing degrees of substitutability between different pairs of inputs, and even for complementarity. This is particularly important in modeling relationships between energy and other inputs. There is substantial controversy in the econometric literature about energy/capital substitutability, for example, with cross-section studies tending to show a positive elasticity, often greater than unity, and time series studies suggesting a negative elasticity (i.e., that energy and capital are complements, not substitutes in production).[2] Since our model is intended to capture a long-run equilibrium, the cross-section results seem more appropriate, reflecting as they do adjustment periods of many years or even decades to different relative factor prices. The more general point here is that we wish to be free to adopt consensus estimates of the several long-run substitution elasticities, rather than constrain them to be the same, or exactly equal to unity, as in the more traditional CES and Cobb-Douglas specifications, respectively. Another nice property of the GL specification is that it is easily collapsed to the ordinary Leontief, or fixed-coefficient I-O form. This greatly facilitates comparison with the general equilibrium approach employed previously in regional, and much national, modeling.

A CRS GL unit cost function is written

$$c_j = \sum_{i,j} b_{ij}\, P_i^{1/2}\, P_j^{1/2} \tag{10}$$

minus direct taxes) to total factor payments (wages and payments to capital) remains at reference-year levels. The reference year is just the year used to calibrate the model as explained in the next section.

The balance equation is written as

$$(1 + \pi) \sum_{j=1}^{m} (K_j WK + L_j WL) = \sum_{j=1}^{m} C_j P_j \tag{13}$$

where π is the transfer ratio, C_j is household consumption of the jth good, and other symbols are as before. Prices P_j adjust to achieve the reference-year ratio. A fixed exchange rate is the numeraire, and the balance of trade adjusts accordingly (not necessarily to zero).

Calibrating the model

We assume the economy is in equilibrium in the reference year--in our case, 1977. A description of the economy in that year is taken as a solution to the model. We then have a set of input prices and value shares, needed to recover the cost function parameters b_{ij} in equation (12). In addition, we need estimates of the substitution elasticities σ_{ij} specified in (12). A reasonable consensus from the cross-section, or long-run, econometric literature is σ_{KL} = 1.0, σ_{LE} = 0.75, and σ_{EK} = 1.2, describing substitution between capital and labor, labor and (aggregate) energy, and energy and capital, respectively. Lacking better information, we assume this same set of elasticities for all sectors. Interfuel elasticities for oil, gas, coal, and electricity are set at 0.50. This may be a bit low, but it has the computational advantage that a GL function (cost of aggregate energy as a function of the prices of the individual fuels) is CES when all substitution elasticities are 0.50.

Table 1. Uniform energy consumption tax (percent change relative to reference equilibrium).

Experiment	Gross output	Private consumption	Energy use	Oil use
10 percent tax	- 0.4	- 0.2	- 6.9	- 7.1
50 percent tax	- 2.3	- 1.1	-26.2	-27.4
	Electricity use	Gas use	Coal use	
10 percent tax	- 6.9	- 6.8	- 6.3	
50 percent tax	-26.7	-26.1	-24.4	

Table 2. Crude oil severance tax (percent change relative to reference equilibrium).

Experiment	Gross output	Private consumption	Energy use
Low trade elasticity			
5 percent tax	-.1	- .1	- .5
10 percent tax	.1	.0	- .9
High trade elasticity			
5 percent tax	.1	.0	- .6
10 percent tax	.1	.1	- 1.0

	Oil use	California crude oil output	Crude oil imports
Low trade elasticity			
5 percent tax	.2	- 7.4	3.6
10 percent tax	-.3	-14.7	- 7.1
High trade elasticity			
5 percent tax	-.1	-19.4	12.2
10 percent tax	-.1	-37.3	23.4

Footnotes

[1]For a similar approach in the setting of a small, open national economy (Sweden), see Bergman [1].

[2]Prominent representatives of the cross-section literature include Griffin and Gregory [4] and Pindyck [6]; of the time series, Berndt and Wood [2].