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The high price of green energy: Adjustments in general equilibrium

Henry Thompson [a,*]

[a] *Department of Economics, Auburn University, Auburn, USA*

ABSTRACT

The high price of energy due to green energy policy will cause adjustments across the US economy predicted in the present general equilibrium model that includes energy Btu input with capital and labor to produce manufactures and services. This same model in trade theory examines the effects of a tariff on an imported factor of production such as a natural resource or capital. Corresponding error correction estimates of the reduced form equations of the model in annual 1970-2018 data prove robust and suggest model modifications. A parametric approach to noncompetitive pricing based on unit cost diminishing with output brings the model much closer to the estimates. Manufactures are revealed to have a higher degree of noncompetitive pricing than services. Assuming constant elasticity of substitution production, a weak degree is revealed to provide the best fit to the error correction estimates. The high price of green energy will cause an inelastic decrease in energy input resulting in increased energy revenue. Outputs of both sectors fall, more in manufactures due to its energy intensity. The capital return and wage also fall given the weak substitution of capital and labor relative to the price of energy. The wage rises slightly in the model but falls considerably in the error correction estimate. The only clear winner is energy input with increased revenue. The government owns a large share of hydrocarbon reserves and will benefit from a higher price of energy.

KEYWORDS

Green energy policy; general equilibrium; income distribution

* Corresponding author: Henry Thompson
E-mail address: henry.thompson@auburn.edu

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1. Introduction

The high price of energy due to the restrictions and taxes of green energy policy will lead to adjustments across the US economy predicted in the present general equilibrium model of production combining energy Btu input with capital and labor with manufactures and services output. The same model in trade theory predicts the adjustments to a tariff on an imported factor of production in Jones and Ruffin (1975), Thompson (1983), Ruffin (1985), and Ethier and Svensson (1986). In the present application, the price of energy increases due to green energy policy.

The model is gauged by error correction estimates of its reduced form equations based on annual 1970-2018 data. The error correction technique of Engle-Granger (1987) is based on short term errors in an economic process corrected toward the long term relationship as developed in Enders (2014). The present data is publicly available from the Bureau of Economic Analysis BEA (2020), Census Bureau (2019), and Energy Information Agency EIA (2019). Exogenous variables include prices of manufactures and services, the level of fixed capital assets, and the labor force with the price of energy Btu input. The endogenous variables are outputs of manufactures and services, the capital return, the wage, and the level of energy input.

The theoretical model is built with the average factor shares of income and industry shares of inputs in manufactures and services. The model assumes a Constant Elasticity of Substitution (CES) production function of Arrow, Chenery, Minhas, and Solow (1961) developed in Sato (1967), Kmenta (1967), Takayama (1993), and Shimamura (1999). The CES production function generalizes Cobb-Douglas to any degree of the Allen (1938) partial elasticity of substitution. The present revealed degree of CES provides the best fit to the error correction estimates.

The factor price equalization property of the present model implies changes in the levels of capital or labor should not affect the capital return or wage. In the error correction estimates, these effects are robust. The model is modified with the parametric approach to noncompetitive pricing in Thompson (2003) bringing these factor price adjustments much closer to the estimates. Unit cost is decreases in output consistent with decreasing average cost. Stronger noncompetitive pricing in manufactures provides better fit to the estimates.

Previewing results, the high price of energy causes an inelastic decrease in energy input decreasing manufactures and services outputs and the capital return. The wage rises slightly in the model but falls considerably in the estimate. The only clear winner with green energy policy is energy input with increased revenue.

Section 1 reviews the present general equilibrium model of production with an exogenous factor price and introduces the parametric noncompetitive pricing. Section 2 presents the error correction estimates of the reduced form equations. Section 3 analyzes sensitivity of the model to degrees of noncompetitive pricing and CES. Section 4 compares the feasibility of model results and estimates. Section 5 discusses refining and extending the present model followed by the Conclusion.

2. The general equilibrium of production with an exogenous factor price

The comparative static factor proportions model in trade theory developed in Chipman (1966), Jones and Scheinkman (1977), and Takayama (1982) is stated in the comparative static system,

$$\begin{pmatrix} \sigma & \lambda \\ \theta^T & 0 \end{pmatrix} \begin{pmatrix} \widehat{\omega} \\ \hat{x} \end{pmatrix} = \begin{pmatrix} \hat{v} \\ \hat{p} \end{pmatrix} \tag{1}$$

Percentage changes in factor prices $\widehat{\omega}$ and outputs $\hat{x}$ are in the endogenous vector. The exogenous vector includes factor input levels $\hat{v}$ that are held constant in the comparative static analysis. Output prices $\hat{p}$ are assumed at world levels due to international competition. The system matrix σ includes factor price elasticities σ, factor employment shares λ, and factor payment shares θ across the two sectors. The first equation captures adjustments in output levels and factor prices to exogenous changes in the levels of the factor of production. The second equation captures the adjustments in factor prices to exogenous output prices assuming cost minimization and competitive pricing.

In trade theory, the model with an exogenous factor price is motivated by a tariff on an imported factor of production. The present application treats the increase $\hat{e} > 0$ in the price of energy as exogenous due to green energy policy. The increase in the energy price decreases energy input $\hat{E}$ affecting output levels and factor prices.

The present model in (2) treats changes in energy input $\hat{E}$ as endogenous and in price $\hat{e}$ as exogenous. Noncompetitive pricing is introduced by the parameters φ_M and φ_M with unit cost affected by output,

$$\begin{pmatrix} \sigma_{Kr} & \sigma_{Kw} & 0 & \lambda_{KM} & \lambda_{KS} \\ \sigma_{Lr} & \sigma_{LW} & 0 & \lambda_{LM} & \lambda_{LS} \\ \sigma_{Er} & \sigma_{EW} & -1 & \lambda_{EM} & \lambda_{ES} \\ \theta_{KM} & \theta_{LM} & 0 & \varphi_M & 0 \\ \theta_{KS} & \theta_{LS} & 0 & 0 & \varphi_S \end{pmatrix} \begin{pmatrix} \hat{r} \\ \hat{w} \\ \hat{E} \\ \hat{x}_M \\ \hat{x}_S \end{pmatrix} = \begin{pmatrix} \hat{K} - \sigma_{Ke}\hat{e} \\ \hat{L} - \sigma_{Le}\hat{e} \\ -\sigma_{Ee}\hat{e} \\ \hat{p}_M - \theta_{EM}\hat{e} \\ \hat{p}_S - \theta_{ES}\hat{e} \end{pmatrix} \tag{2}$$

The endogenous vector includes percentage changes in energy input $\hat{E}$ with the capital return $\hat{r}$, wage $\hat{w}$, and outputs $\hat{x}_M$ of manufactures and $\hat{x}_S$ of services. Exogenous changes include the energy price $\hat{e}$ with endowments $\hat{K}$ of capital and $\hat{L}$ of labor, and prices $\hat{p}_M$ and $\hat{p}_S$ of the two goods.

Each of the endogenous variables is a function of all exogenous variables in the model. The comparative static results of the model are compared to corresponding error correction estimates of the five equations in (2).

This same model with competitive pricing $\varphi_M = \varphi_M = 0$ is solved in Thompson (2018). Competitive pricing constrains unit cost to price according to $p_j = \Sigma_i w_i a_{ij}$ where a_{ij} represents the cost minimizing input of factor i per unit of good j = M, S. Noncompetitive pricing in Thompson (2003) introduces a parameter $\psi_j > 0$ tying unit cost to the level of output,

$$p_j = \sum_i W_i a_{ij} + \psi_j x_j \tag{3}$$

There is competitive pricing if $\psi_j = 0$. If $\psi_j > 0$ the level of output x_j drives a wedge between price p_j and unit cost $\Sigma_i w_i a_{ij}$ in the general equilibrium. Price searching behavior is implicit in (3). The revealed parameter ψ_j is selected by the best fit of the comparative static results from (2) to the corresponding error correction estimates.

Differentiate (3) to find $dp_j = \Sigma_i a_{ij} dw_i + \psi_j dx_j$ where $\Sigma_i w_i da_i = 0$ follows from cost minimization and Shephard's lemma. Converting to elasticity form where $\varphi_j \equiv \psi_j x_j / p_j$ leads to the pricing conditions in (2),

$$\hat{p}_j = \sum_i \theta_{ij} \hat{w}_i + \varphi_j \hat{x}_j \tag{4}$$

Although ψ_j is a constant parameter, the comparative static cost wedge φ_j varies with the state of the economy along with factor shares θ, industry shares λ, and factor price elasticities σ. Profit $\pi_j = (p_j - w_i a_{ij})x_j$ is distributed to owners of firms independently from the factor payments $rK_j + wL_j + eE_j$ that determine unit cost. The market for firm ownership is distinct from the capital market.

The comparative static analysis of (2) starts with the system determinant Δ that is negative based on concavity. Competitive pricing $\varphi_j = 0$ implies the factor price equalization property $0 = \hat{r}/\hat{K} = \hat{w}/\hat{L} = \hat{w}/\hat{K} = \hat{r}/\hat{L}$ as adjustments in factor demands offset factor endowment changes. Noncompetitive pricing $\varphi_j > 0$ implies negative own factor effects $\hat{r}/\hat{K} < 0$ and $\hat{w}/\hat{L} < 0$ as well as positive cross effects $\hat{w}/\hat{K} > 0$ and $\hat{r}/\hat{L} > 0$. For instance $\hat{r}/\hat{K} = (-\varphi_M \varphi_S \sigma_{Lw} + \varphi_M \theta_{LS} \lambda_{LS} + \varphi_S \theta_{LM} \lambda_{LM})/\Delta < 0$ given $\sigma_{Lw} < 0$. Competitive pricing $\varphi_j = 0$ leads to $\hat{E}/\hat{e} = -\Delta_{32}/\Delta < 0$ where Δ_{32} is the negative determinant of the model with three endogenous factor prices. Pricing terms φ_j are restricted to ensure $\Delta < 0$.

Table 1 reports average factor shares θ_{ij} of income and industry shares λ_{ij} of inputs in (2). Labor has about equal factor payment shares θ_{LM} and θ_{LS} in the range of the capital factor share θ_{KM} in manufactures. Capital has a larger factor share θ_{KS} in services. The energy payment share θ_{EM} in manufactures is much larger than θ_{ES} in services. Industry shares λ_{ij} reflect the large size of services. Manufacturing consumes most of the energy Btu input.

Table 1. Factor shares θij and industry shares λij.

θ_{ij}	M	S	λ_{ij}	M	S
K	0.42	0.56	*K*	0.12	0.88
L	0.45	0.42	*L*	0.16	0.84
E	0.14	0.02	*E*	0.58	0.42

Table 2 reports factor intensities derived from ratios of factor shares θ and industry shares λ in Table 1. Energy is about equally intensive relative to both capital and labor in manufactures. Capital is intensive relative to labor and especially relative to energy in services. Labor is intensive relative to capital in manufactures, but relative to energy in services.

Table 2. Factor intensities.

θ	M	S	λ	M	S
K/L	0.93	1.33	*K/L*	0.72	1.05
K/E	3.00	28.0	*K/E*	0.21	2.10
L/E	3.21	21.0	*L/E*	0.28	2.00

Table 3 reports the derived Cobb-Douglas CD factor price elasticities $\sigma_{ik} = \Sigma_j\lambda_{ij}\theta_{kj}$. The own elasticities $\sigma_{ii} = -(\sigma_{ik} + \sigma_{ih})$ ensure homogeneity with zero row sums in the elasticity matrix σ. Factor shares remain constant in the comparative static adjustments in (2) with CD production. Cross price substitution is very weak but own substitution nearly elastic relative to the energy price e due to the small energy factor shares.

Table 3. Cobb-Douglas factor price elasticities.

σ_{ik}	r	w	e
K	-0.46	0.42	0.03
L	0.54	-0.58	0.04
E	0.48	0.44	-0.92

Results are compared for different degrees of Constant Elasticity of Substitution CES scaling the CD elasticities in Table 3. The capital and labor own and cross price elasticities are weak in the range of 0.2 to 0.3. The energy input elasticities relative to the capital return and wage are similar in size. There is almost no substitution of capital and labor relative to the price of energy. The strongest elasticity overall is the own energy elasticity of -0.46.

Exogenous changes in output prices and factor levels K and L are considered in model evaluations along with the energy price. Variations in the degree of CES and the noncompetitive pricing parameters φ_j lead to the best fit of the comparative static results of (2) to the estimates.

3. Error correction estimates of the reduced form equations

Figure 1 shows plots of the exogenous variables including fixed capital assets K, the average price e per Btu of energy, and prices of manufactures p_M and services p_S. These variables are in real terms deflated by the consumer price index. The exogenous full-time equivalent labor force L grows slower and with less variation than fixed capital assets K. The energy price e varies substantially with a peak in 1981 during the energy crisis followed by slow unsteady decline before returning to the higher level in the 2000s. The steady decline in p_M is due in part at least to import competition. The contrasting steady increase in p_S pulls the economy towards services along the expanding production frontier.

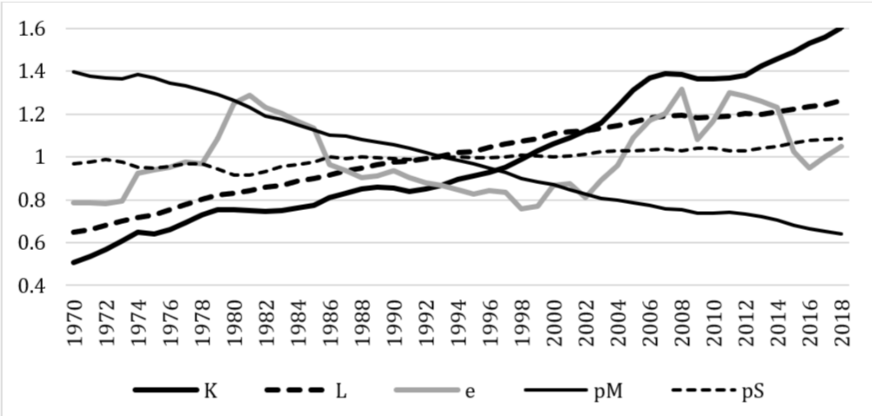

Figure 1. Exogenous variables.

Notes: FIxed capital assets: K, Labor force: L, Energy price: e, Manufactures price: p_M, Services price: p_S.

Figure 2 shows plots of endogenous variables. The real capital return r = i - π is derived as the nominal interest rate i minus the inflation rate π. During the energy crisis r falls slightly before rising and levelling around 2000. The deflated real wage w has less variation than r with early swings before a slow rise. Energy input E declines during the energy crisis before steadily increasing with substantial variation over the sample. Manufactures output x_M rises slowly over the sample with some variation. Services output x_S rises at a higher rate with less variation.

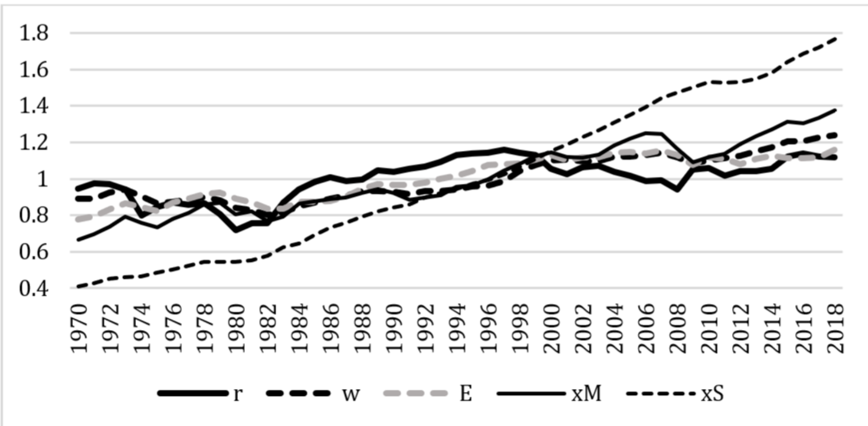

Figure 2. Endogenous variables.

Notes: Capital return: r, Wage: w, Energy input: E, Manufactures output: xM, Services output: xS.

Table 4 reports estimates of the cointegrating equations in natural logs of all variables. There is the expected high residual correlation in Durbin-Watson DW statistics. These coefficients and standard errors enter the derived error correction effects. Endogenous factor prices r and w are strongly influenced by their exogenous levels K and L contrary to the factor price equalization property in competitive trade theory.

Table 4. Cointegrating equations.

	a_0	lnK	lnL	lne	lnp_M	lnp_S	$AdjR^2$ DW EG
lnr	-10.3*** (-4.68)	-0.84*** (-8.88)	0.95*** (9.93)	-0.13*** (-3.40)	0.28** (2.17)	1.83*** (9.13)	0.95 1.23* -4.52*
lnw	6.54*** (3.10)	0.61*** (6.73)	-7.78*** (-8.01)	-0.27*** (-7.30)	-0.37*** (-2.39)	-018 (-0.61)	0.96 1.05* -4.85*
lnE	5.54** (2.23)	0.53*** (4.96)	0.19* (1.72)	-0.29*** (-6.83)	0.16 (1.09)	0.91 (2.62)	0.95 1.01* -3.99*
lnx_M	-0.01 (-0.74)	0.67*** (2.84)	0.96* (1.72)	0.02 (0.26)	0.50 (0.88)	1.36** (2.54)	0.37 1.01* -3.96*
lnx_S	-2.00 (-0.95)	0.08 (0.90)	1.07*** (11.0)	-0.05 (-1.28)	-0.78*** (-6.28)	1.03*** (3.49)	0.99 0.36* -1.56

Capital K has a positive effect on output x_M of manufactures as well as the level of intensive energy input E. The labor force L has a positive effect on both outputs as well as E. A change in the price p_M of manufactures does not have the expected positive effect on x_M. The price p_S of services has positive effects on both outputs and r but no effect on E. Both prices have positive effects on the capital return r. The wage w is not affected by p_S. The negative effect of p_M on w contradicts a popular argument for import tariffs.

The cointegrating effect of an increase in e is a decrease in E with the wage w falling twice as much as the capital return r. Neither output is affected by e noting the weak estimate of manufactures output x_M. The variables except in the x_S equation are cointegrated by the Engle-Granger EG test.

Table 5 reports the error correction estimates in differences including effects of the residuals RES from the cointegrating equations in Table 4. The robust effects of RES provide further evidence of cointegration. The null hypothesis of residual correlation is rejected by the DW statistics except in the Δlnw equation. There is no evidence of residual heteroskedasticity in unreported autoregressive conditional ARCH tests.

The opposite trends of the two outputs x_M and x_S are evident in their constant terms consistent with the 52% decline in x_M/x_S over the sample associated with the 59% decline in their relative price p_M/p_S. The white noise residuals suggest fixed capital assets imbed the substantial technological progress over the sample especially following the energy crisis.

Table 5. Error correction estimates.

	a_0	ΔlnK	ΔlnL	Δlne	Δlnp_M	Δlnp_S	RES	$AdjR^2$ DW
Δlnr	0.01 (1.24)	-0.84*** (-4.41)	0.80* (1.77)	-0.22*** (-3.55)	0.31 (0.66)	2.41*** (5.39)	-0.60*** (-4.11)	0.79 2.07
Δlnw	-0.00 (-0.32)	0.59*** (3.97)	-0.38 (-1.14)	-0.08 (-1.59)	-0.01 (-0.02)	0.44 (1.30	-0.39*** (-3.11)	0.41 1.33*
ΔlnE	-0.00 (-0.36)	0.52*** (3.17)	0.43 (1.13)	-0.04 (-0.70)	0.41 (1.09)	0.03 (0.07)	-0.42*** (-3.79)	0.41 1.58
Δlnx_M	-0.04*** (-2.90)	1.10*** (5.05)	0.86* (1.86)	-0.03 (-0.41)	-0.66 (-1.21)	0.59 (1.24)	-0.61*** (-4.45)	0.57 1.54
Δlnx_S	0.03*** (6.34)	-0.05 (-0.69)	0.61*** (3.62)	-0.02 (-0.95)	0.30* (1.69)	1.05 (6.46)	-0.25*** (-4.22)	0.71 1.42

Across the estimates in Table 5, the most influential exogenous change is fixed capital assets K followed by the labor force L. The prices of energy input e and services p_S have significant effects only on the capital return r. The wage w and energy input E are only affected by fixed capital assets K and RES residuals. Services output x_S increases only in L while manufactures output x_M increases in K as well.

Table 6 reports the error correction effects with standard errors derived by error propagation calculations. These derived error correction effects include the short-term effects in Table 5 with the error correction effects in Table 4 through the residuals RES. As an example, the elasticity of energy input E with respect to its price e is derived as -0.16 = -0.04 - (-0.42 x -0.29). This inelastic effect reflects the essential role of energy input in the economy. The most consistent error correction effects are for capital K and labor L followed by the energy price e.

Table 6. Derived error correction elasticities.

	K	L	e	p_M	p_S
r	-1.34***	1.37***	-0.30***	0.77	4.11**
	(-5.02)	(2.76)	(-4.72)	(0.30)	(2.19)
w	0.82***	-0.68***	-0.18***	-0.14	0.37
	(4.19)	(-1.92)	(-3.68)	(-0.43)	(1.02)
E	0.74***	0.51**	-0.16	0.48*	-0.37
	(3.39)	(1.73)	(-0.66)	(1.56)	(0.74)
x_M	1.32***	0.11	-0.37***	0.44***	0.01
	(6.01)	(0.80)	(-7.11)	(2.48)	(0.02)
x_S	-0.03	0.89***	-0.03*	0.10	1.31***
	(-0.30)	(3.72)	(-1.44)	(0.54)	(3.02)

4. Model simulations and noncompetitive pricing

The comparative static system (2) is built with the share matrices in Table 1 and factor price elasticities starting with Cobb-Douglas in Table 3. Model simulations are tested for degrees of CES ranging from extremely high 2 to near zero at 0.1. The best overall fit for all comparative static results is CES = 0.5 implying factor price elasticities half the size in Table 3.

The noncompetitive pricing parameters φ_M and φ_S are selected to minimize the difference between the comparative static results and the error correction estimates in Table 6. Results are quite sensitive to the degree of noncompetitive pricing.

Table 7 compares the comparative static elasticities starting with the unrealistic COMP coefficients based on competitive pricing. The OPTφ coefficients based on revealed noncompetitive pricing φ_j provide the best fit to the error correction estimates. The third EC coefficients are the error correction estimates from Table 6 for comparison with insignificant coefficients indicated by brackets.

The degree of CES has little impact on comparative static results, a point developed in Toledo and Thompson (2007). The effects of any exogenous variable on the capital return r and wage w are identical for any degree of CES. Results with the best fitting CES = ½ are reported in Table 7. Cobb-Douglas CD production would double the sizes of the E/e and x_j/e elasticities in Table 7.

Table 8 reports the sum of the absolute differences across all model results and estimates comparing Cobb-Douglas CD with high CES = 2 and low CES = ½. Noncompetitive pricing OPTφ provides much better fit than competitive pricing COMP for outputs and energy input. The overall fit improves steadily as CES decreases from 2 to ½ with little further improvement and worsening as CES approaches zero. The optimal pricing coefficients φ_j indicate a higher degree of noncompetitive pricing in manufactures.

Table 7. Model simulations.

COMP OPTφ EC	K	L	e	p_M	p_S
	-59.9	47.8	0.66	-1.14	126
r	-0.26	0.21	-0.02	-0.01	0.55
	-1.34	1.37	-0.30	[0.77]	4.11
	57.8	-72.7	0.01	11.7	102
w	0.25	-0.32	0.03	0.05	0.44
	0.82	-0.68	-0.18	[-0.14]	[0.37]
	26.9	36.6	-9.3	152	-39.3
E	0.12	0.12	-0.52	0.66	-0.17
	0.74	0.51	[-0.16]	0.48	[-0.37]
	-2.17	31.6	-17.6	-0.28	-80.9
x_M	-0.01	0.14	-0.09	0.14	-0.35
	1.60	[0.90]	-0.17	-0.49	[0.59]
	92.5	37.7	2.71	37.7	71.1
x_S	0.40	0.16	-0.01	0.16	0.31
	[-0.03]	0.89	-0.03	[0.10]	1.31

Notes: COMP: competitive pricing, OPTφ: noncompetitive pricing, Error Correction insignificant: [EC].

Table 8. Model fit.

	COMP	OPTφ	φ_M	φ_S
CES 2	995	9.33	0.4	0.2
CD	906	8.44	0.8	0.1
CES ½	907	1.28	1.6	0.6

5. Comparing feasibility of model results and error correction estimates

This section compares model results and error correction estimates. Green energy policy is considered along with a lower capital gains tax that would increase K, more open immigration policy, higher import tariffs on manufactures, and global free trade raising the price of services.

Table 9 starts with an increase in the capital stock K by 10% at four times the annual average and more than the sample maximum of 6.7%. Adjustments are smaller in the model except for services output x_S. The estimated elastic decrease in r implies capital income falls. The elastic increases in w and E are due to increased demands. The elastic estimated increase in manufactures output x_M contrasts with the negligible decrease in the model. For services output x_S the lack of an estimated effect contrasts with the increase in the model.

Table 9. Adjustments to lower capital gains tax.

10% K	model	estimates
r	-2.6%	-13%
w	2.5%	8.2%
E	1.2%	7.4%
x_M	-0.1%	13%
x_S	4.0%	[0.3%]

Table 10 reports adjustments to an increase of 5% in the labor force L , over three times the annual average and greater than the maximum 3.3%. Adjustments except for x_M are smaller in the model than in the estimates. The decrease in w is larger in the estimate but does not reverse the increase in labor income. The increased r is especially large in the estimate. Both outputs increase slightly in the model with a much larger estimated increase in x_S. The estimated increase in energy input E is also noticeably larger.

Table 10. Adjustment to open immigration.

5% L	model	estimates
r	1.1%	6.9%
w	-1.6%	-3.4%
E	0.6%	2.6%
x_M	0.7%	[0.6%]
x_S	0.8%	4.5%

Table 11 shows the results of higher tariffs on manufactures leading to an increase in p_M of 20% compared to the sample range from 15% to -20% with near zero mean and 7.6% standard deviation. The decrease in w in the model as well as the insignificant decrease in the estimate undermine a popular argument for tariffs. The capital return r not affected. The increased x_M is much larger in the estimates consistent with the stimulated energy input E. The simultaneous increase x_S in the model is feasible as the production frontier expands with L and E.

Table 11. Adjustments to tariffs on manufactures.

20% p_M	model	estimates
r	-0.1%	[15%]
w	-1.0%	[-2.8%]
E	13%	9.6%
x_M	2.8%	8.8%
x_S	3.2%	[2.0%]

Table 12 shows adjustments to an increase in the price of services p_S by 5% with increased demand for exported services due to global trade liberalization. The sample p_S ranges between ±2.8% with mean 0.3% and standard deviation 1.1%. The increases in r and x_S are much larger in the estimates with other estimated effects insignificant. The increase in w is only slightly less in the model than the increase in r. Energy input E and manufactures output x_M fall slightly in the model.

Table 12. Adjustments to global free trade.

5% p_S	model	estimates
r	2.8%	20%
w	2.2%	[1.9%]
E	-0.9%	[-1.9%]
x_M	-1.8%	[-0.1%]
x_S	1.6%	6.6%

Table 13 turns to the focus on green energy policy assuming an increase of 25% in e. The sample ranges from 15% to -20% with near zero mean and 8% standard deviation. The assumed increase due to green energy policy is about three times the standard deviation. The resulting decrease of -13% energy input E in the model is substantial although energy revenue would nevertheless increase by 12%. The -4% decline in E in the estimate is not significant.

The capital return r falls by -1% in the model and -8% in the estimate. The wage w rises by about 1% in the model as labor weakly replaces energy but falls by -5% in the estimate. The output of manufactures x_M falls by -2% in the model and estimate due to the shrinking production frontier. Output x_S of services falls in the model by -0.3% and by -1% in the estimate.

Table 13. Adjustments to green energy policy.

25% e	model	estimate
r	-0.5%	-7.5%
w	0.8%	-4.5%
E	-13%	[-4.0%]
x_M	-2.2%	-1.7%
x_S	-0.3%	-0.9%

The high price of energy is a boon to the energy sector raising revenue. Green energy policy lowers and redistributes income away from capital and very likely away from labor as well. The output of energy intensive manufactures falls as does the output of services to a lesser extent.

6. Refining and extending the general equilibrium model

The present ambiguous adjustment in the wage suggests disaggregating labor to reveal potential winners and losers across skill groups. Results would likely differ for skilled versus unskilled labor as a number of theoretical and applied papers have shown. Clark, Hofler, and Thompson (1988) found very different effects of tariffs across wages of eight labor skills.

Separating machinery and equipment in fixed capital assets would also refine the present model. Another refinement would be sector specific capital to provide more detail on income redistribution as some capital returns would rise as others fall.

On the product side, resource-based and energy-intensive manufactures could be separated. In the services sector, energy-intensive transport could be separated. While definitive theoretical results are more challenging adding factors and goods, simulations yield definitive predictions supplemented by estimation of reduced form equations.

A regional trade model would reveal different effects depending on locations of energy resources. Mining is a major part of alternative energy battery production. Regions with wind and sunlight benefit from windmills and solar cells. Regions with ports and financial centers are also relevant. Manufacturing regions would stand to lose. Regions with hydrocarbon production would experience increased revenue due to the unintended consequence of effective price searching behavior by the hydrocarbon industry.

Another refinement is to include the endogenous supply of alternative energy. The theoretical framework related to the present general equilibrium of production is provided by the model of import competing supply in Thompson (2016). The high price will stimulate green energy production with nuclear the only source to meet baseload demand given present technology. The critical issue is the elasticity of alternative energy supply in the general equilibrium.

Another refinement is to introduce more flexible production functions such as the translog that are sensitive to elastic substitutes and complements. If energy and capital prove complements as some studies suggest, the high price of green energy would lower capital utilization. The own wage effect would then be elastic suggesting labor income would fall even if the wage increases. Sensitivity analysis based on estimates could identify the revealed factor price elasticities for the general equilibrium model.

7. Conclusion

The present applied general equilibrium model and error correction estimates on average predict a 25% increase in the price of energy will lower energy Btu input by -8%, manufactures output by -2%, and services output by -1%. Declining marginal products would lower the capital return by -5% and the wage by -2%. The only winner is energy input with an 17% increase in revenue.

While advocates of green energy policy tout the jobs created by new technology, the present results question this optimism. Fixed capital assets in the present estimates successfully imbed the substantial technological progress following the energy crises starting in the early 1970s. The present model and estimates spanning half a century on average predict the high price of green energy will lower the demand for labor.

It should be pointed out that hydrocarbon reserves belong in large part to the government suggesting a conflict of interest determining green energy policy. The involvement of state and local governments in the energy sector has a long history. The franchised state monopolies in electricity are the result of lobbying by larger firms wanting protection from small scale competition during the first half of the 20th century as examined by Reutter and Thompson (2005). The state governments obliged recognizing the reliable tax base of franchised monopolies. Green energy policy will benefit the owners of energy resources including the government that owns a large share of hydrocarbon reserves.

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Conflict of interest

The author claims that the manuscript is completely original. The author also declares no conflict of interest.

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