Does Energy Cost Affect Long Run Economic Growth? Time Series Evidence Using Chilean Data.

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The Chilean context

Motivation

- A new law, ”Ley 20.257”, which imposes fixed quotas of production from NCRE to electricity generators of the Chilean market.
- Galetovic and Muñoz (2008) have estimated that this will increase the cost to consumers of the Central Interconnected System (CIS) at least by US$ 4000 millions in net present value.
- Based on these estimations, and without subsidies, the price of energy could increase by 6% to 10%, and residential tariffs by 3% to 5%.

The Chilean context

Objective

- Evaluate possible short and long-run effects on economic output of energy price fluctuations
- We consider several energy price indices and different specifications for output, capital and labor series.

Contribution

- This framework of analysis is of interest for low and mid-income countries, which depend on adequate energy policies to foster industrialisation processes and development.

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Theory

Many authors have developed different theories to analyze the role of energy into the economy:

- Saunders (1984; 1992) includes energy as a factor of production and through simulations shows the output's transition from the short to the long term.
- Rasche and Tatom (1981) argue that an energy price shock modifies the optimal usage of the existing stock of capital, modifying the optimal capital-labor ratio, generating an upward shift on the aggregate supply curve, and a decline in potential or natural output.
- Finn (2000) presented a model with three factors of production: capital, labor and energy. An increase in the energy price would affect economic output through affecting energy usage, employment, and capital's future marginal productivity and return, decreasing the stock of capital and investments.
- Other works: Alam (2006), Stern and Cleveland (2004), Stern (1997), Tatom (1979, 1980, 1981), among others.

Empirical Evidence

Many authors have developed different theories to analyze the role of energy into the economy:

- In the U.S, the Solow residual tends to fall when energy price rises, implying a direct link between energy and production (Finn, 1995).
- Rotemberg and Woodford (1996) found that a 1% innovation in energy prices engenders a decline of 0.25% on real output.
- Rasche an Tatoom (1981) found a negative elasticity of output with respect to the real price of energy (elasticities goes from -0.05 to -0.11)
- Bohi (1989) found that energy price shocks have not had a significant importance explaining macroeconomic performance of the U.S and other developed countries.
- Gardner and Joutz (1996) found that the real price of energy is negatively related to output in the US (L.R. elasticity ≈ -0.072).

Empirical Evidence

The bivariate approach: $Y = f(E)$

- Kraft and Kraft (1978) and Akarca and Long (1979) found a causality effect in the US from GNP to energy consumption.
- Erol and You (1987) found a causal relationship running from energy consumption to output in a large set of industrialized countries.
- Yu and Choi (1985), Glasure and Lee (1997), Asafu-Adjaye (2000), Jumbe (2004) and Yang (2000) tested causality in Asian countries, founding unidirectional and bidirectional relations.
- Akinlo (2008) found cointegration between energy and GDP in 15 African countries.
- Chontanawat et al. (2008) found that the causality relationship is stronger in developed countries rather than developing countries.

The multivariate approach: $Y = f(L, K, E)$

- Stern (2000), Ghali and El-Sakka (2004), Soytas and Sari (2006), Lee and Chang (2008), Lee et al. (2008), Narayan and Smyth (2008), Wolde-Rufael (2008, 2009).
- The main conclusion from these studies is that there exists long-run cointegration and causality among the variables.

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The Model

- The relationship between economic growth and the price of energy is based on the aggregate supply channel developed by Rasche and Tatom (1981), and Tatom (1987).
- We employ a neoclassical aggregate production function where energy is included as a factor of production.

$$Y_t = f\,(K, L, E)$$

- The real price of energy enters into the equation trough a "first order condition" for energy employment.
- The log linear form can be written as follow:

$$\ln(Y) = \alpha_0 + \alpha_1 \ln(L) + \alpha_2 \ln(K) + \alpha_2 \ln(P_e)$$

The Model

Data

- Chilean quarterly data from 1986 to 2006.
- The data series are real GDP, total employment (adjusted by seasonality human capital variations), real capital stock (adjusted by intensity of use) and different energy price indices in real terms (p^{ene}, p^{mon}, $Index$).

Methodology:

- The early literature in energy price shocks and economic growth usually estimates this relation via OLS.
- However, regressions of non-stationary time series may produce spurious results by simply apply OLS.
- We address that point following Cointegration and Error-Correction Modeling (ECM) techniques, to estimate the long and short-run relationship between the variables.

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Stationarity

- Cointegration requires series of the same order of integration.
- The order of integration of the series is tested with Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit roots tests.
- We can assume that in the most cases output, capital adjusted by intensity of use, labor and the energy price indices are $I(1)$.

Table: ADF and PP unit roots tests

Variable	ADF		PP	
	Level Form	**First Differences**	**Level Form**	**First Differences**
gdp	-2.096 (1)	-7.032 (0)***	-2.652 (3)*	-7.036 (3)***
k	-0.690 (1)	-2.374 (0)	-0.973 (6)	-2.359 (2)
k^{in}	-0.002 (9)	-2.016 (8)	0.464 (5)	-3.376 (3)**
labor	-1.835 (1)	-5.589 (0)***	-2.363 (3)	-5.589 (0)***
$labor^{hc}$	-1.991 (0)	-7.810 (0)***	-1.935 (3)	-7.792 (3)***
p^{ene}	-1.967 (4)	-2.700 (3)*	-1.189 (3)	-8.304 (1)***
p^{mon}	-1.975 (4)	-2.572 (3)	-1.174 (3)	-8.296 (2)***
p^{index}	-0.844 (3)	-4.323 (2)***	-0.747 (3)	-8.103 (3)***

Note: Here $***$, $**$, $*$ denote rejection of the null at the 1%, 5% or 10% significant level. The number inside the brackets corresponds to the optimum lag selection for ADF, and the optimal bandwidth for PP.

Cointegration: The long-run relationship by Engle-Granger

- The coefficients of the regressions will represent the long-run, or equilibrium, relationship between the variables (if cointegration exists).

Table: Cointegration results from Engle-Granger procedure

	Dependent Variable (log *GDP*)					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Constant	2.279	2.346	0.503	-2.927	-2.791	-4.212
k^{in}	0.243	0.251	0.427	0.31	0.318	0.551
labor				1.636	1.617	1.252
$labor^{hc}$	1.122	1.111	0.935			
p^{ene}	-0.09			-0.137		
p^{mon}		-0.114			-0.169	
p^{index}			-0.085			-0.107
ADF Test Statistic (Residuals)	-3.274 (0)	-3.334 (0)*	-3.631(0)**	-3.443 (1)*	-2.780 (0)	-3.801(1)**
R2	0.994	0.994	0.995	0.994	0.994	0.994
F-statistic	4413.74	4803.37	5556.03	4077.18	4615.16	4442.32

Note: The sample is 1986Q1 to 2006Q3. Here $***$, $**$, $*$ denote rejection of the null at the 1%, 5% or 10% significant level. The number inside the brackets is the optimum lag selection determined using Akaike's Information Criteria. The ADF framework includes a constant term without trend.

Cointegration: The long-run relationship by Johansen

Background

- Johansen's multivariate approach is based on a VAR structure:

$$y_t = A_1 y_{t-1} + \ldots + A_p y_{t-p} + \beta x_t + \xi_t \tag{1}$$

- Which can be expressed in vector error correction form (VECM):

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \beta x_t + \xi_t \tag{2}$$

- If the coefficient matrix Π has reduced rank $r < k$, then there exists k x r matrices α and β, each with rank r such that $\Pi = \alpha\beta^\top$, where β is the cointegrating vector (long-run relationship).

Results:

- We obtained one Cointegration vector (β):

$$gdp = 2.007 + 0.375k^{in} + 0.914labor^{hc} - 0.162p^{ene} \tag{3}$$

The Dynamic Model: The ECM approach

- It is possible to develop a dynamic model for the short-run relationship following the ECM approach.

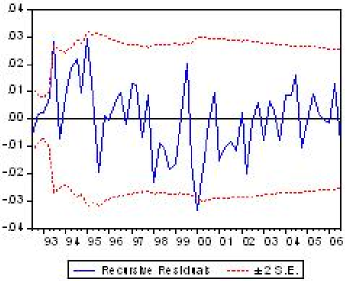
$$\Delta gdp_t = \alpha + \sum_{i=1}^{4} \beta_i \Delta GDP_{t-i} + \sum_{i=0}^{4} \delta_i \Delta labor^{hc}_{t-i} + \sum_{i=0}^{4} \phi_i \Delta k^{in}_{t-i} + \sum_{i=0}^{4} \varphi_i \Delta p^{ene}_{t-i} + ecm_{t-1} + \xi_t$$

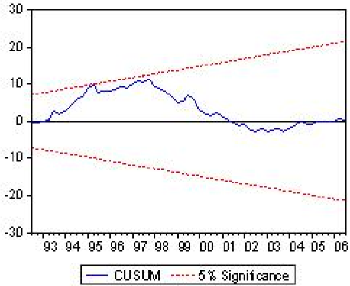
- The estimated coefficients are interpreted as short-run elasticities.
- The parsimonious version of the model is as follow.

$$\Delta y_t = 0.012 + 0.658 \Delta k^{in}_t - 0.790 \Delta k^{in}_{t-4} + 0.149 \Delta labor^{hc}_t - 0.147 labor^{hc}_{t-2} - 0.065 ecm_{t-1}$$

- Energy price is not present in the parsimonious estimation.
- The ECM term means that shocks affects significantly the short-run dynamic behaviour, and the coefficient represents the speed of adjustment toward the equilibrium.

The ECM approach: stability of the parameters.





Note: The left panel shows the recursive residuals about the zero line. Plus and minus two standard errors are also shown. The right panel shows the CUSUM test. This option plots the cumulative sum together with the 5% critical lines.

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Conclusions

- The suggested price elasticity of output to energy price is between -0.085 and -0.16.
- Thus, a permanently raise in energy prices by 10% might decrease the log-run growth rate of output by roughly 1%.
- In the short-run, possibly there are no significant effects.
- Policy-makers should be especially careful on designing energy policies, balancing the negative effects on output and environmental implications.
- Future research on this field should also address the social implications of having higher energy prices (employment, poverty and income distribution).

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