Economic growth and electricity consumption: Auto regressive distributed lag analysis

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Abstract
Knowledge of the direction of causality between electricity consumption and economic growth is of primary importance if appropriate energy policies and energy conservation measures are to be devised. This study estimates the causality relationship between electricity consumption and economic growth in per capita and aggregate levels. The study uses the price and income elasticities of total electricity demand and industrial demand by using the auto regressive distributed lag (ARDL) method for some developed and developing countries, including the US, UK, Canada, Japan, China, India, Brazil, Italy, France, Turkey and South Africa. There is evidence to support the growth hypothesis for the US, China, Canada and Brazil. There is evidence to support the conservation hypothesis for India, Turkey, South Africa, Japan, UK, France and Italy.

Keywords: growth, development, electricity consumption, ARDL
Jel codes: C13, C22, O40, Q41, Q43

1. Introduction

The analyses are examined from the end of the 1950s, not only technical change and variety but also the theoretical development line of analysis will be seen. At first, the studies were started at the extent of energy consumption then were disintegrated into sub- components like energy, electricity and oil consumption and their relations with GDP and/or economic growth were investigated. The factors standing in the rear of the intensive examinations on electricity are the importance of electricity usage in the transition of an economy from an agricultural society to the industry and service society, the increase of the usage of electricity in accordance with sectoral change and transition in production quality, the increase in life quality and the act of economic progress as a medium.

The experience of developed countries shows that the electricity sector played a crucial role in their economic development not only as a key input in their industrial development but also as a key factor in improving the quality of life of their people (Rosenberg, 1998). There is a stronger correlation between electricity use and wealth creation than there is between total energy use and wealth (Ferguson *et al.*, 2000). For developing countries it has also been found out that there is a significant correlation between export diversification and per capita electricity consumption and electricity production per worker (ECA, 2004).

The aim of this study is to estimate the relationship between electricity consumption and economic growth, per capita electricity consumption and per capita income, growth in industry and electricity consumption in industry, electricity consumption and electricity price, electricity consumption in industry and electricity price in industry by the Auto Regressive Distributed Lag (ARDL)) method in some developed countries such as the USA, UK, Japan, Italy, France, Canada and developing countries; Brazil, China, India, South Africa and Turkey. Finding whether there are elasticity differences or not among analysed countries and the direction of causality relations are the other analysed points.

This study can be defined as complementary to the previous empirical papers. However, it differs from the existing literature for some aspects. First, as being distinguished from the previous works, it employs not only the cointegration and Granger causality methods but also the ARDL method in order to clarify the direction of relationship with elasticities of electricity intensities. Second, it tries to discover the relationship between industrial production and electricity consumption in the industrial sector for both developed and emerging economies in terms of causalities and price elasticities. Furthermore, although studies in the literature based on GDP and aggregate electricity consumption or their per capita levels (hence found different results in terms of cointegration and causality), it analyses electricity consumption and economic growth both aggregate and per capita levels at the same time in order to clarify this difference. Thus, it utilizes ARDL method together with cointegration relationship, causality relationship and elasticities; it extends the empirical literature of energy intensity both to the electricity subcomponent and industry production as being first study in the literature.

In the first section of the study, the survey of the elasticity, demand forecasting and causality literatures will be presented to have insights about the magnitudes of relationship between electricity consumption and growth and to make comparisons between the literature and the results of this study for validation of the findings. Econometric theory is identified in the second section. The third section consists of the empirical results while the last section includes conclusions and policy implications.

2. Causality, electricity demand forecast and elasticity literature

2.1 Elasticity and demand forecast studies

Houthakker (1951) mainly focused on electricity consumption in the UK found income elasticity as 1.17 and price elasticity as -0.89 for 1937-38 in his study which he applied to 42 provincial towns. Cross price elasticity of gas was found to be 0.21 and he didn't comment whether the elasticity is for a short or long run. Fisher and Kaysen (1962) examined the residential and industrial electricity demand in the United States and they calculated the elasticity by emphasizing the difference between long and short run. Baxter and Ress (1968) and Anderson (1973) focused on industrial electricity demand. Houthakker and Taylor (1970), Wilson (1971) focused on residential electricity demand. Wilson (1971), using cross-section analysis in his study, found the long run price elasticity as -1.33 and income elasticity as -0.46.

Cargil and Mayer (1971) approached to the issue in the context of peak-load custom in their study which they examine the total system. This work was important as it was the first in this area. Mount et al. (1973) calculated the elasticity by panel data method. Using panel data method was the novelty of the study (see Table 1).

In Table 2, we present summary statistics on some elasticity estimates for commercial and industrial sectors. Pindyck (1979) found that the price elasticity of industrial and commercial electricity demand for Japan, Sweden and Germany was 0.12. At 0.16, France was the country that had highest elasticity in the sample. All of the elasticity values were below 1. The elasticities in Norway and the Netherlands were close to Hosoe and Akiyama (2009) estimated the price elasticity of industrial and commercial electricity demand for Japan as 0.12 and 0.56 respectively. In studies on the US and UK, elasticities were estimated to be close to zero or negative. Qin (2003) estimated that elasticity for China was 0.444 for the industrial and commercial sectors.

2.2. Causality studies

Rasche and Tatom (1977), Kraft and Kraft (1978), Berndt (1978), Akarca and Long (1980), and even Proops (1984), Yu and Hwang (1984) are first studies among others which examine the relation between variables depending on energy economy framework.[1] Kraft and Kraft (1978) found the relation between energy consumption and GNP for the 1947 – 1974 period as one way from GNP to energy consumption by using Sims causality analysis. Akarca and Long (1980) continued with the analysis by eliminating the data of 1973 and 1974. Yu and Choi (1985) found causality relation from energy consumption to gross national product in the Philippines, unidirectional causality from gross national product to energy consumption for South Korea. However, they found no causality relationship between gross national product and energy consumption for the USA, UK and Poland. Erol and Yu (1987) found the bi-directional causality relation between energy consumption and GDP for Japan, from energy consumption to gross national product for Canada, from gross national product to energy consumption for Germany and Italy, and no causality for England and France. Yu et al. (1988), found no relationship between energy and GNP, and between energy and employment, using the Granger method in the United States.

Many authors have expanded and diversified these pioneering studies. energy consumption has disintegrated into its subcomponents and the relation between GDP and these subcomponents were investigated like oil and electricity consumption. The studies that have examined electricity consumption and economic growth in causality framework can be seen in Table 3. As can be seen in the table, different results have been obtained regarding the direction of causality. The differences in the causality results allows for four hypotheses: 1) the 'neutrality hypothesis' (if no causality exists between

GDP and energy consumption, then energy consumption is not correlated with GDP; 2) the 'conservation hypothesis' (the unidirectional causal relationship moves from GDP to energy consumption); 3) The 'growth hypothesis' (the unidirectional causal relationship moves from energy consumption to GDP); and 4) the 'feedback hypothesis' (if there is a bi-directional causal relationship between GDP and energy consumption).[2]

3. Econometric methodology

In this paper, the ARDL approach to cointegration involves two steps for estimating a long-run relationship. The first step is to investigate the existence of a long-run relationship among all variables. Long run coefficients were estimated according to the ARDL model's results. If there is a long-run relationship (cointegration) among variables, the second step is to estimate the following long-run and short-run models. The ARDL analyses are applied where the variables of the model are of mixed order of integration. The ARDL model for the standard log-linear functional specification of a long-run relationship between variables with an OLS estimation technique is as follows:

$$\Delta\theta = \alpha_0 + \sum_{i=1}^{m} \beta_i \Delta\theta_{t-i} + \sum_{i=1}^{m} \phi_i \Delta\psi_{t-i} + \delta_1\theta + \delta_2\psi + \varepsilon_{1t} \quad (1)$$

$$\Delta\psi = \alpha_0 + \sum_{i=1}^{m} \beta_i \Delta\psi_{t-i} + \sum_{i=1}^{m} \phi_i \Delta\theta_{t-i} + \omega_1\psi_{t-1} + \omega_2\theta_{t-1} + \varepsilon_{2t} \quad (2)$$

where Δ and ε_{1t} are the first difference operator and the white noise term, respectively. The ARDL method estimates the regressions to obtain the optimal lag length for each variable. An appropriate lag selection is based on the Akaike Information Criterion (AIC). The bounds testing procedure is based on the joint F-statistic or Wald statistic that tests the null hypothesis of no cointegration. The joint significance of coefficients for lagged variables is tested with F statistics calculated under the null.

The null hypothesis of no cointegration among the variables in Equation 1 is $H_0 : \delta_1 = \delta_2 = 0$ against the alternative hypothesis $H_0 : \delta_1 \neq \delta_2 \neq 0$. In Equation 2, the null hypothesis of no cointegration is $H_0 : \varpi_1 = \varpi_2 = 0$ against the alternative hypothesis $H_0 : \omega_1 \neq \omega_2 \neq 0$. One set of critical values assumes that all variables in the ARDL model are I(0), while the other is calculated on the assumption that the variables are I(1).[3]

A vector error correction model, which was used to analyse the short run relationships among the variables, was constructed as follows:

$$\Delta\theta = \alpha_0 + \sum_{i=1}^{m} d_{1i}\Delta\theta_{t-i} + \sum_{i=0}^{n} d_{2i}\Delta\psi_{t-i} + d_3 ECM_{t-1} + e_t \quad (3)$$

$$\Delta\psi = \alpha_0 + \sum_{i=1}^{m} d_{1i}\Delta\psi_{t-i} + \sum_{i=0}^{n} d_{2i}\Delta\theta_{t-i} + d_3 ECM_{t-1} + e_t \quad (4)$$

where residuals, e_t, are independently and normally distributed with a zero mean and constant variance, ECM_{t-1} is the error correction term resulting from the long-un equilibrium relationship, and d's are parameters to be estimated. For example, d_3 is a parameter indicating the speed of adjustment to the equilibrium level after a shock. This parameter shows how quickly variables converge to equilibrium, and it must have a statistically significant coefficient with a negative sign. The F statistics on the lagged explanatory variables of the ECM indicate the significance of the short-run causal effects. Peseran and Peseran (1997) argued that it is important to ascertain the constancy of the long-run multipliers by testing the above error correction model for the stability of its parameters.

As Narayan and Smyth (2009) argue, after estimating the long-run model in order to obtain the estimated residuals, the next step is to employ the following error-correction based on Granger causality model. However, according to Bahmani-Oskooee and Alse (1993), if the variables are cointegrated the standard Granger Causality test results will be invalid. In this case, Vector Error Correction model should be a starting point of the causality analysis.

The advantage of using an error correction term to test for causality is that it allows testing for short-run causality through the lagged differenced explanatory variables and for long-run causality through the lagged ECM_{t-1} term. A statistically significant ECM_{t-1} term determine long-run causality running from all the explanatory variables towards the dependent variable (Dergiades and Tsoulfidis, 2011**)**.

This approach is implemented in our study since the variables are cointegrated. *p*th-order vector error correction model is given by equation in below:

$$\Delta Z_t = \alpha + \sum_{i=1}^{p} \phi_i \Delta Z_{t-i} + \lambda ECM_{t-1} + \eta_t \quad (5)$$

η_t are independently and normally distributed with zero mean and constant variance. Rejecting the null hypotheses about the insignificance of error correction term in equation 5 indicates that EC does Granger cause Y and Y does Granger cause EC, PCEC does Granger cause PCY and PCY does Granger cause PCEC, IPY does Granger cause IPEC and IPEC does Granger cause IPY.

Table 1: Unit root test for the variables

Level		*First difference*		*Level*		*First difference*	
Japan				**Italy**			
Y	-2.13	ΔY	-3.73	Y	-0.91	ΔY	-5.02
EC	-1.39	ΔEC	-5.71	EC	-0.12	ΔEC	-6.89
PCY	-2.10	ΔPCY	-3.48	PCY	-0.45	ΔPCY	-7.02
PCEC	-0.11	ΔPCEC	-4.83	PCEC	-0.98	ΔPCEC	-8.11
IPY	-0.73	ΔIPY	-3.74	IPY	-1.02	ΔIPY	-7.10
IPEC	-1.65	ΔIPEC	-4.06	IPEC	-1.45	ΔIPEC	-3.89
ECF	-1.02	ΔECF	-5.14	ECF	-1.02	ΔECF	-4.01
IPECF	-2.15	ΔIPECF	-4.06	IPECF	-1.11	ΔIPECF	-5.00
USA				**Turkey**			
Y	-1.57	ΔY	-6.17	Y	-1.09	ΔY	-8.02
EC	-1.70	ΔEC	-3.97	EC	-1.20	ΔEC	-7.56
PCY	-0.18	ΔPCY	-4.61	PCY	-1.00	ΔPCY	-3.99
PCEC	-0.20	ΔPCEC	-4.30	PCEC	-0.92	ΔPCEC	-4.78
IPY	-1.29	ΔIPY	-6.78	IPY	-1.45	ΔIPY	-9.01
IPEC	-1.12	ΔIPEC	-6.58	IPEC	-1.03	ΔIPEC	-5.01
ECF	-106	ΔECF	-5.98	ECF	-1.68	ΔECF	-8.01
IPECF	-1.18	ΔIPECF	-4.87	IPECF	-1.07	ΔIPECF	-7.12
UK				**Brazil**			
Y	-1.78	ΔY	-7.80	Y	-0.95	ΔY	-4.37
EC	-0.78	ΔEC	-8.56	EC	-1.61	ΔEC	-6.46
PCY	-0.90	ΔPCY	-5.12	PCY	-1.46	ΔPCY	-3.94
PCEC	-1.70	ΔPCEC	-6.10	PCEC	-0.61	ΔPCEC	-5.70
IPY	-1.09	ΔIPY	-4.50	IPY	-0.85	ΔIPY	-7.56
IPEC	-1.71	ΔIPEC	-3.99	IPEC	-1.02	ΔIPEC	-8.16
ECF	-1.09	ΔECF	-5.00	**China**			
IPECF	-1.23	ΔIPECF	-9.00	Y	-1.47	ΔY	-5.89
ECF	-1.09	ΔECF	-5.00	EC	0.96	ΔEC	-3.52
IPECF	-1.23	ΔIPECF	-9.00	PCY	1.18	ΔPCY	-4.46
India				PCEC	2.49	ΔPCEC	-3.97
Y	-1.29	ΔY	-5.82	IPY	-1.60	ΔIPY	-4.35
EC	-2.16	ΔEC	-4.50	IPEC	-1.18	ΔIPEC	-3.51
PCY	-1.52	ΔPCY	-4.53	ECF	-0.02	ΔECF	-5.08
PCEC	-1.45	ΔPCEC	-4.58	IPECF	-1.92	ΔIPECF	-3.78
IPY	-1.30	ΔIPY	-5.99	**South Africa**			
IPEC	-1.25	ΔIPEC	-8.79	Y	-1.11	ΔY	-5.78
France				EC	-1.75	ΔEC	-4.89
Y	-2.02	ΔY	-4.06	PCY	-2.00	ΔPCY	-6.78
EC	-0.08	ΔEC	-5.89	PCEC	-1.78	ΔPCEC	-7.85
PCY	-1.12	ΔPCY	-3.05	IPY	-0.98	ΔIPY	-5.80
PCEC	-0.01	ΔPCEC	-4.91	IPEC	-1.001	ΔIPEC	-6.11
IPY	-0.09	ΔIPY	-5.78	ECF	-1.785	ΔECF	-4.98
IPEC	-1.93	ΔIPEC	-4.72	IPEC	-1.136	ΔIPEC	-5.30
ECF	-0.99	ΔECF	-7.05				
IPECF	-0.58	ΔIPECF	-5.95				
Canada							
Y	-1.72	ΔY	-3.49				
EC	-1.60	ΔEC	-4.74				
PCY	-1.63	ΔPCY	-3.51				
PCEC	-1.07	ΔPCEC	-4.37				
IPY	-0.85	ΔIPY	-5.78				
IPEC	-1.00	ΔIPEC	-4.58				
ECF	-1.10	ΔECF	-6.85				
IPECF	-1.41	ΔIPECF	-3.06				

4. Data and econometric result

4.1 Data

In this study, the relationship between electricity consumption and economic growth, per capita electricity consumption and per capita income, growth in industry and electricity consumption in industry together with price and income elasticities of electricity consumption were analysed by the ARDL method in some developed and developing countries namely, the USA, UK, Japan, Italy, France, Brazil, Russia, China, India, South Africa and Turkey. EC(log(EC)) represents the electricity consumption, Y(log(Y)) represents the GDP, PCEC(log(PCEC)) represents the per capita electricity consumption, PCY(log(PCY)) represents the per capita gross domestic product, IPEC(log(IPEC)) represents the industrial sector's electricity consumption, IPY(log(IPY)) represents the output of industrial sector, ECF represents the electricity prices and IPECF represents the electricity prices in industry. Annual data for the 1978-2010 period was taken from World Bank World Development Indicators, International Financial Statistics of the IMF, IEA,OECD, U.S. Department of Labour: Bureau of Labour Statistics, **:** U.S. Energy Information Administration, Federal Reserve Bank of St. Louis, TEIAS and TURKSTAT.[4]

4.2. Econometric results

4.2.1. Unit root tests

In order to test for the presence of stochastic stationarity in our data, we first investigate the integration of our individual time-series, using the ADF test. There is no need to identify the order of integration of the series before implementing the ARDL method. However, we checked for the unit root in order to compare the ARDL results with the Johansen Cointegration analysis since the latter requires unit root analysis.

The results reported in Table 1 clearly show that unit root test does not reject the null hypothesis for the variables in levels. We further applied the unit root test in the first differences of the variables and the results reject the null hypothesis implying that the levels are non-stationary, and the first differences are stationary.

4.3 Testing for cointegration

Lag length supplying the smallest critical value is determined as the lag length of the model by using Akaike Information Criteria. Models were determined after applying LM test to the all possible models.

The results of the ARDL bounds tests shown in Table 2, suggest the rejection of the null hypothesis of no long run relationship at the 1%, 5% and 10% level (only 10% level for some countries) of significance when *GDP* is treated as the dependent variable and EC is independent variable but treated as its long run forcing variable for China, Canada, Brazil (for Canada in IP and IPEC test). As can be seen from the table, the estimated F-statistics are greater than the upper bound critical values suggested by Narayan (2005) at the 10% level in all countries. As a result, it can be concluded that there exists a strong long run equilibrium relationship between EC and GDP; PCY and PCEC; IP and IPEC; EC and ECF; IPEC and IPECF.

The ARDL cointegration analysis presumes the existence of long-run relationship among variables, that is, one should ascertain the existence of a single cointegration vector prior to the use of the ARDL technique from the available cointegration methods and in the case of many variables, the

Table 2: Bounds testing for cointegration

	F_y (Y-EC)	F_{EC} (EC-Y)	F_y (PCY-PCEC)	F_{EC} (PCEC-PCY)	F_{IPEC} (IPEC-IPY)	F_{IP} (IPY-IPEC)	F_{EC} (EC-ECF)	F_{ECF} (ECF-EC)	F_{IPEC} (IPEC-IPECF)	F_{IPECF} (IPECF-IPEC)
Emerging										
India	2.02	26.4	1.57	8.69	17.7	0.08				
China	8.73	2.05	7.13	1.86	2.96	14.0	12.5	1.06	7.13	0.13
Brazil	21.7	1.54	25.8	2.90	32.5	2.88				
S.Africa	1.16	12.0	1.6	35.3	31.1	1.43	9.15	1.13	8.07	2.07
Turkey	1.178	6.55	1.16	6.65	1.01	5.10	5.31	1.18	6.46	1.45
Developed										
Canada	37.6	2.22	35.6	3.92	12.9	2.31	21.1	0.12	21.08	1.56
France	1.06	6.40	2.64	6.51	6.67	2.00	4.78	1.51	13.01	2.18
UK	2.15	41.5	2.96	16.2	5.42	1.34	5.13	2.48	6.46	1.45
USA	20.9	1.82	6.62	0.31	1.39	61.1	10.1	2.09	6.92	1.25
Italy	1.11	80.5	1.36	20.9	8.32	2.15	35.8	0.17	39.2	1.89
Japan	1.64	6.42	1.29	28.3	1.42	15.9	5.51	2.07	5.88	1.41

Note: Results of the F test which rejects the no long run relationship are underlined.

Table 3: Results of the Johansen test

	(Y, EC)	(PCY ,PCEC)	(IP, IPEC)	(ECF, EC)	(IPECF, IPEC)
			Emerging		
India	r=0 26.48 r≤1 2.86	r=0 27.44 r≤1 0.32	r=0 26.42 r≤1 0.85		
China	r=0 28.84 r≤1 2.23	r=0 36.35 r≤1 1.145	r=0 25.04 r≤1 0.39	r=0 34.35 r≤1 0.99	r=0 42.001 r≤1 1.11
Brazil	r=0 31.73 r≤1 2.04	r=0 38.24 r≤1 2.22	r=0 32.52 r≤1 1.38		
S Africa	r=0 34.41 r≤1 2.57	r=0 29.41 r≤1 1.34	r=0 33.78 r≤1 1.09	r=0 32.45 r≤1 1.87	
Turkey	r=0 28.02 r≤1 2.001	r=0 32.113 r≤1 2.005	r=0 26.15 r≤1 1.01	r=0 37.90 r≤1 2.09	r=0 42.78 r≤1 0.88
			Developed		
Canada	r=0 30.16 r≤1 0.13	r=0 26.29 r≤1 0.41	r=0 30.02 r≤1 1.30	r=0 39.36 r≤1 1.12	r=0 23.36 r≤1 4.956
France	r=0 27.39 r≤1 0.82	r=0 25.38 r≤1 1.23	r=0 115.15 r≤1.971	r=0 29.36 r≤1 1.45	r=0 31.11 r≤1 2.511
UK	r=0 25.22 r≤1 1.82	r=0 26.56 r≤1 1.001	r=0 26.94 r≤1 1.29	r=0 22.18 r≤1 1.12	r=0 35.24 r≤1 1.981
USA	r=0 27.97 r≤1 1.39	r=0 35.45 r≤1 2.425	r=0 26.96 r≤1 2.34	r=0 29.12 r≤1 2.04	r=0 43.62 r≤1 0.004
Italy	r=0 30.85 r≤1 0.46	r=0 52.64 r≤1 2.27	r=0 26.96 r≤1 2.34	r=0 42.72 r≤1 3.09	r=0 43.62 r≤1 0.004
Japan	r=0 37.89 r≤1 1.002	r=0 42.89 r≤1 1.36	r=0 56.25 r≤1 0.14	r=0 56.25 r≤1 0.145	r=0 45.11 r≤1 1.015
CV					

Johansen test is the preferred one. The ARDL and Johansen's techniques to cointegration should not be seen as mutually exclusive, however, as supplementary to each other (Dergiades and Tsoulfidis, 2011).

In some models especially for South Africa, Johansen cointegration analysis applied to these series as IPECF-IPEC has low value and the series are I(1). Models were investigated whether they have an autocorrelation problem or not and according to the test results there are no autocorrelations.

As it is seen from Table 3, ARDL results are verified by the Johansen cointegration test. Tables 5 and 6 reveal the sufficient arguments for valid long run relations between the variables it possible to forecast the long run relationships and short run dynamic effects by using ARDL approach Pesaran *et al.* (2001). This approach provides a parsimony model. The results in the below table indicate that there is a meaningful relationship between the variables in the long run.

4.4 Long-run and short-run elasticities results

The majority of the studies do not examine the coefficients with respect to both the sign (positive or negative) and the magnitude of the relationship between electricity consumption and economic growth but we analysed long and short run elasticities. The long-run elasticities along with a number of diagnostic tests for the underlying ARDL model are displayed in Table 4. The elasticities are interpreted as usual. The long-run and short-run income elasticities and the long-run and short-run price elasticities can be compared with the results of other studies in Table A1 and A2.

In a study on UK the elasticity between production and industry electricity, consumption is found as close to each other as 0.919 and 0.787.

In a study on France, the income per capita elasticity consequences were positive both in the long run and short run and were greater than 1 in long run. However, the per capita income elasticity of electricity was negative in the long-run. The negative value for the per capita income elasticity was unexpected. In the study done by Narayan, Smyth and Prasad (2007) for G7 countries the income elasticity ranged from -1.450 to -1.563, and price elasticity ranged from -0.2 to -0.4. The income per capita elasticity consequences were negative in the long run and positive in the short run and they were greater than 1.

In a study on Italy, the income per capita elasticity is found for a short run as negative. The elasticity coefficient between the production in industry and electricity usage in industry is found for the long run and short run as negative. In the study done by Pindyck (1979) for 10 developed countries long run elasticity in industrial and commercial sectors in Italy is found as 0.13. Squalli (2007) has revealed consequences for France and Italy with some reasons in his study: an excessive use of energy in unproductive sectors occurred in countries where heavy industries played a significant role in economic growth as in France and Italy, while Germany had the further burden of the reunification. The existence of capacity constraints on generation is particularly relevant in countries with limited energy resource availability (Italy and Finland). These reasons can be effective in the difference of income elasticity.

In a study on Japan, the income elasticity is found for the short run and for the long run were less than 1, and they were close to each other. Using maximum likelihood, Matsukawa *et al.* (1993)

Table 4: Long run coefficients for ARDL

	Y	PCY	EC	PCEC	IPY	IPEC	ECF	IPECF
India	0.304 (11.5)	-0.029 (1.97)			1.11 (5.08)			
China			-0.24 (2.12)	1.013 (11.3)		-2.56 (2.11)	1.013 (3.01)	0.995 (2.51)
Brazil			0.899 (7.94)	0.757 (6.54)		0.761 (7.11)		
S Africa	0.72 (8.23)	1.017 (17.4)			0.305 (14.2)		0.537 (3.69)	
Turkey	1.393 (9.78)	1.42 (2.85)			0.456 (5.86)		0.816 (7.77)	1.007 (2.76)
Canada			0.97 (25.4)	-0.029 (1.97)		0.901 (13.7)	1.039 (7.23)	1.03 (8.08)
France	1.006 (5.21)	-1.624 (2.87)			1.015 (7.64)		0.87 (2.56)	1.016 (2.85)
UK	0.919 (11.3)	0.898 (11.9)			0.787 (2.64)		1.011 (16.5)	0.101 (3.56)
USA			0.641 (2.63)	1.008 (12.2)		-0.056 (2.32)	0.013 (6.89)	1.001 (5.58)
Italy	0.863 (7.44)	0.954 (13.3)			-0.91 (2.95)		1.013 (74.1)	1.017 (104.5)
Japan	0.459 (7.57)	0.93 (5.28)				0.841 (7.02)	0.99 (2.01)	1.007 (2.76)

Note: t statistics are in parenthesis

found the price elasticity for 1980–1988 as -0.37; in different studies done by The Cabinet Office of the Government of Japan in 1981–2005 the income and price elasticity were found, respectively, to be 0.712 and -0441 (2001) 1.121 and -0.468 (2003), 0.911 and -0.373. The price elasticity of electricity demand in industry was found to be greater than 1 in long-run but smaller than 1 for the short run.

In a study on Turkey, the income elasticity for short run was 0.459 and for long run was 1.39. The income per capita elasticity is found for the short run as 0.93 and for the long run as 1.42. Bakırtaş, Karbuz and Bildirici (2000) found the income elasticity of electricity consumption for Turkey to be 3.207, and in other study, Bildirici and Bakırtaş (2007) found it to be 3.73. The elasticity of income in long run was greater than 1. The elasticity coefficient between electricity consumption and reel income was 1.39. There are important differences in their study compared to other works, such as in methodology.

In a study on India, the income elasticities for the short run and long run were both calculated as less than 1. Coefficients of electricity for industry (by using total electricity data) is found as short run coefficient is higher than the long run. According to Cheng's (1997) result, EC and real GDP are not cointegrated for Brazil, and the income elasticity is found as 0.521. According to Modiano (1984), short term price elasticity of the industrial consumption is estimated in -0.45 and that of long term as -1.22. Short term and long term income elasticities have been estimated, to the industrial class, in 0.50 and 1.36. According to Schmidt and Lima (2004), the long term price elasticities of -0.15 to the residential sector and -0.13 to the industrial and long term income elasticities of 1.05 and 1.71 to the residential and industrial sectors for the 1963–2000 periods. According to Carlos, Notini and Maciel (2009), the price elasticity for residential demand is found for the long run as 1.76 and for the short run as 1.06. The income elasticity in industrial sector is found for the long run as 1.31 and for the short run as 0.19.

In a study on South Africa, income elasticity is found for the short run and for the long run is smaller than 1. Ziramba (2008) estimated income elasticity as 0.30 and 0.31 for the short and long run during the 1978 – 2005 period in South Africa by the ARDL method. However, depending on the rapid change in the economy, electricity consumption increases rapidly and the increase in elasticity is the reason for this issue. Also, Inglesi-Lotz and Blignaut (2011) explained this point in detail. According to them, South Africa's electricity consumption has increased sharply since the early 1990s. They conduct a sectoral decomposition analysis of the electricity consumption for the period 1993 – 2006, to determine the main drivers of this increase. Their results show that the increase was due mainly to output or production related factors, with structural changes playing a secondary role. As it is expected for an economy that started growing rapidly the last two decades, the dominant force driving electricity consumption is the output changes. The output effect is responsible for 152.364GWh (or 116%) of the total increase in electricity consumption. This effect is to be understood in the light of the fact that South Africa has undergone major political, social and economic changes after 1990, resulting in a sharp increase in economic activity. Moreover, the structural changes in the economy also contributed to the increase in electricity consumption

According to Ziramba (2008), after democratization, economic and social transitions occurred in South Africa. Directly as a result of apartheid policies, poor rural areas suffered from a lack of access to basic services such as electricity. Almost two-thirds of the South African population did not have access to electricity before 1994 (Ziramba, 2008). After 1994, the South African Government dealt with the electricity problem again. The government considered electricity provision as very important for the growth and development of the country (DME, 2003; RSA, 2006). For this reason, the increase of electricity consumption in accordance with economic progress is not surprising. The per capita income elasticities exhibit more elastic structure than the income elasticity calculated by GDP method in South Africa and Turkey.

Table 5 contains the results of the error correction model. The sign of the coefficient of the error correction term must be negative to provide the stability for the model. We expect the coefficient to be negative and smaller than 1. As Narayan and Smith (2006) stated, if the coefficient of the error correction term is smaller than 1, then it means that the system is equilibrating by fluctuating and this fluctuating will decrease in each term and then provide the transition to the equilibrium. ECM coefficients were negative and statistically significant as expected in nearly all of the models. The only exceptions for the ECM term to be positive were the income models for Turkey and France and the industrial sector price models for Canada.

However, those coefficients are close to zero that 0.0003, 0.00004 and 0.0007 respectively.

As the results are closer to zero these values of ECM coefficients are not considered to be a problem. The ECM coefficients for Italy and Brazil in the income model and for Italy in the industrial sector

Table 5: The error-correction representation model

	Coef.		*Coef. t*		*Coef. t*		*Coef. t*		*Coef. t*
					Emerging				
					India				
ΔEC_{t-1}	0.3037 1.56	$\Delta PCEC_{t-1}$	0.11 2.31	$\Delta IPEC_{t-1}$	0.0802 2.0415				
ΔY	0.277 4.123	ΔPCY	-0.167 3.277	ΔIP	-0.63 4.15				
ECM	-0.88 2.012	ECM	-0.019 2.25	ECM	-0.350 1.99				
					China				
ΔY_{t-1}	0.042 1.26	$\Delta PCEC_{t}$	0.1694 0.717	ΔIP_{t-1}	-0.56 2.001	ΔEC_{t-1}	0.02418 2.05	ΔIP_{t-1}	0.0901 245
ΔEC	0.48975 3.612	ΔPCY_{t-1}	.35605 2.558	$\Delta IPEC$	0.1763 3.91	ΔECF	1.698 2.896	$\Delta IPECF$	.5147 2.89
ECM	-0.07 5.32	ECM	-0.13813 2.547	ECM	-0.061 -4.40	ECM	-0.0135 3.876	ECM	-0.00436 3.78
					Brazil				
ΔY_{t-1}	0.038 2.51	ΔPCY_{t-1}	0.899 7.94	$\Delta IPEC_{t-1}$	0.144 1.977				
ΔEC	0.481 2.17	$\Delta PCEC$	0.497 2.99	ΔIP	0.97 3.12				
ECM	-1.105 2.98	ECM	-0.957 3.01	ECM	-0.97 2.87				
					South Africa				
ΔEC_{t-1}	0.8231 2.156	$\Delta PCEC_{t-1}$	0.495 2.789	$\Delta IPEC_{t-1}$	-0.30420 2.6032	ΔEC_{t-1}	0.17 1.989		
ΔY	0.621 8.23	ΔPCY	-2.918 2.568	ΔIP	0.3047 5.68	ΔECF	0.0367 2.78		
ECM	-0.08047 55.42	ECM	-0.918 3.89	ECM	-0.803 2.45	ECM	-0.57 3.001		
					Turkey				
ΔEC_{t-1}	0.745 2.369	$\Delta PCEC_{t-1}$	0.578 2.987	ΔIP_{t-1}	0.695 2.156	ΔEC_{t-1}	0.568 3.891	ΔIP_{t-1}	0.189 2.78
ΔY	0.459 1.996	ΔPCY	0.93 3.55	$\Delta IPEC$	0.9978 4.896	ΔECF	.0.14 6.019	$\Delta IPECF$	.1009 5.896
ECM	0.000036 4.165	ECM	-0.2840 3.3522	ECM	-0.0125 3.120	ECM	-0.184 2.75	ECM	-0.101 4.786

	Coef.		Coef. t		Coef. t		Coef. t		Coef. t
					Developed				
					Canada				
ΔY_{t-1}	-0.936	ΔPCY_{t-1}	-0.0286	ΔIPE	0.966	ΔEC_{t-1}	0.100	ΔIP_{t-1}	0.0901
	2.022		1.96	C	2.66		2.49		2.85
ΔEC	-0.97	ΔPCEC	0.476	ΔIP_{t-1}	1.019	ΔECF	-0.049	ΔIPECF	-0.051
	2.412		2.071		13.7		2.57		2.78
ECM	-0.219	ECM	-0.25	ECM	-0.98	ECM	-0.039	ECM	0.00038
	0.175		23.2		3.19		2.74		2.98
					France				
ΔEC_{t-1}	0.0182	$\Delta PCEC_{t-1}$	0.4585	$\Delta IPEC_{t-1}$	-0.30420	ΔEC_{t-1}	0.116	ΔIP_{t-1}	0.72685
	2.71		2.077		5.412		6.72		3.033
ΔY	.01930	ΔPCY	1.9927	ΔIP	0.0978	ΔECF	-0.2012	ΔIPECF	2.2758
	3.993		2.206		6.85		2.52		3.13
ECM	0.000046	ECM	-0.1493	ECM	-0.15696	ECM	-0.1207	ECM	-0.0167
	3.48		2.1528		3.236		2.85		2.12
					UK				
ΔEC_{t-1}	0.22	$\Delta PCEC_{t-1}$	0.79	ΔIPE	0.293	ΔEC_{t-1}	0.065	ΔIP_{t-1}	0.047
	2.45		2.077	C_{t-1}	0.75		2.503		2.56
ΔY	-0.502	ΔPCY	1.48	ΔIP	0.78	ΔECF	0.1136	ΔIPECF	-.1452
	9.423		6.07		2.15		8.59		2.93
ECM	-0.0696	ECM	-0.376	ECM	-0.34	ECM	-0.05	ECM	-0.0144
	3.61		2.16		2.08		18.6		2.97
					USA				
ΔY_{t-1}	0.0108	$\Delta PCYC_{t-1}$	-0.1953	ΔIP_{t-1}	-0.05621	ΔEC_{t-1}	0.07038	ΔIP_{t-1}	0.4922
	10.2		1.985		2.32		1.19		2.02
ΔEC	0.29846	ΔPCEC	.011353	ΔIPE	0.421	ΔECF	.29079	ΔIPECF	.029
	2.066		8.1712	C	2.86		3.89		2.25
ECM	-0.059	ECM	-0.0835	ECM	-0.04	ECM	-0.994	ECM	-.00769
	2.35		10.72		2.99		2.998		2.98
					Italy				
ΔEC_{t-1}	0.07942	$\Delta PCEC_{t-1}$	0.1248	ΔIPE	0.0986	ΔEC_{t-1}	0.1316	ΔIP_{t-1}	-0.0757
	2.869		2.613	C_{t-1}	2.71		2.450		2.011
ΔY	0.7859	ΔPCY	-1.7626	ΔIP	-0.76	ΔECF	-0.0123	ΔIPECF	-0.016
	2.023		3.06		2.09		2.962		2.60
ECM	-1.27	ECM	-0.4102	ECM	-1.63	ECM	-0.013	ECM	-0.017
	2.18		2.65		2.96		2.89		2.81
Japan									
ΔEC_{t-1}	0.0036	$\Delta PCEC_{t-1}$	0.3724	ΔIP_{t-1}	0.88	ΔEC_{t-1}	0.262	ΔIP_{t-1}	0.532
	1.99		2.78		1.099		2.016		2.011
ΔY	.41945	ΔPCY	0.026	ΔIPE	0.8411	ΔECF	.5302	ΔIPECF	.1739
	4.4980		4.19	C	4.14		2.22		2.19
ECM	-0.3066	ECM	-0.0698	ECM	-0.027	ECM	-0066	ECM	0.00076
	4.3260		2.45		1.999		2.65		2.09

Notes: For the India EC model, the error correction term for the ARDL approach is given by: $EC = EC - 0.304 \times y + 0.481 \times c$

model are greater than 1. The ECM coefficient in Italy and Brazil are -1.27, -1.10 and -1.63. This shows that the speed of adjustment was outside of what we expected. This shows that, the speed of adjustment is more than enough with 127%, 110% and 163% to reach a long run equilibrium level in response to the disequilibrium caused by short run shocks of previous period. Also, the speed of adjustment is very fast for Brazil and South Africa in the per capita income model, for Brazil and Canada in the industrial sector model with ECM coefficients of -0.97 and -0.98 respectively.

4.5 Granger causality results

The ARDL method determines whether the existence or absences of a long-run relationship between per capita electricity consumption and the per capita income, electricity consumption and the real income, electricity consumption in industry and industrial production. However, the method does not indicate the direction of causality. For this reason, we use the Granger causality test to examine the causal relationship between electricity consumption and the real GDP, the per capita electricity consumption and the per capita GDP, IPY and IPEC. The result in Table 9 show that Granger causalities were present implicitly via the ECM; however, the equilibrium indicates the presence of unidirectional causality going from Y or EC; PCY or PCEC; and IPY or IPEC.

The direction of causality for the US is found as EC→Y and PCEC→PCY and IPEC→IPY. This result is consistent with Thoma (2004) for the USA during 1973–2000 EC→Y, Stern (1993), Bowden and Payne (2009) for USA 1947-1994 EC→Y.

For the UK, it is found as Y→EC; PCY→PCEC

Table 6: Results of Granger causality

Countries	$\Delta Y \rightarrow \Delta EC$ / $\Delta EC \rightarrow \Delta Y$	t-Test on ECM / ECT_{t-1}	$\Delta CY \rightarrow \Delta PCEC$ / $\Delta PCEC \rightarrow \Delta PCY$	t-Test on ECM / ECT_{t-1}	$\Delta IPY \rightarrow \Delta IPEC$ / $\Delta IPEC \rightarrow \Delta IPY$	t-Test on ECM / ECT_{t-1}
Emerging						
India	13.73	45.83	4.975	12.15	9.257	8.52
	0.5008		1.2305		0.0351	
China	1.014	43.19	1.017	9.134	0.1151	10.41
	4.771		4.885		6.883	
Brazil	0.0867	17.91	0.1158	9.73	7.972	15.05
	4.9586		4.847		11.968	
S Africa	7.54	18.71	9.447	10.99	6.384	16.76
	0.154		2.328		0.282	
Turkey	14.99	9.66	9.764	26.02	0.1221	13.08
	1.02		1.21		5.3112	
Developed						
Japan	4.827	18.14	9.524	10.61	0.248	9.04
	2.2264		2.0158		6.8505	
Italy	7.980	19.12	9.557	11.8	6.92	15.89
	1.733		2.825		0.968	
France	6.031	20.09	9.846	9.06	5.81	18.05
	1.639		1.64		1.825	
UK	4.97	19.16	16.985	25.05	17.18	11.47
	1.716		1.425		0.774	
Canada	0.71042	18.002	0.092	12.24	17.56	18.81
	8.902		5.478		8.76	
US	0.111	17.04	0.06158	9.52	0.28	12.14
	4.99		6.542		9.94	

In this table, the symbol → shows the direction of causality

and IP→IPEC. Zachariadis (2007) and for the UK from 1960- 2004, found Y→EC.

For Canada, it is found as EC→Y, PCEC→PY and IPEC→IP. Lee (2006), Lee and Chang (2007), Narayan and Prasad (2008) found as neutral; Ghali and El Sakka (2004) for Canada from 1961–1997 found as Y→EC.

For Japan, it is found as Y→EC, PCY→PCEC and IPEC→IP. Lee (2006) for Japan during 1960–2001 found as Y→EC; and Cheng (1998) for Japan from 1952–1995 found as Y→EC. Zachariadis (2007) for Japan 1960-2004 found as Y→EC.

For Italy, it is found as Y→EC, PCY→PCEC and IPY→IPEC. Lee (2006) for Italy during 1960–2001 found as Y→EC.

For France it is found as Y→EC; PCY→PCEC and IP→IPEC. Lee (2006) for 1960–2001 found as Y→EC.

For China, it is found as EC→Y, PCEC→PCY and IPEC→IP. Rafiq (2008) for China supported Shiu and Lam's (2004) findings as EC→Y.

For India, it is found as Y→EC; PCY→PCEC and IP→IPEC. Cheng (1999), Ghosh (2002) and Cheng (1999) found as Y→EC for India during 1952–1995. According to Rafiq (2008), for India in the short-run the direction of causality found was Y→EC. There is no evidence of causality in the long-run.

For South Africa, it is found as Y→EC, PCY →PCEC and IP→IPEC. Rufael (2006) found as neutral.

For Brazil, it is found as EC→Y; PCEC→PCY and IP→IPEC. According to Cheng (1997), the results of the bivariate causality tests, however, identify a causality from *EC* to real GDP without feedback for Brazil.

For Turkey, it is found as Y→EC; PCY→PCEC and IP→IPEC. Lisa and Van Montfort (2007) and Ghosh (2009) found as Y→EC.

In most of the countries; India, Turkey, South Africa, Japan, UK, France and Italy, the causalities are from the GDP to the electricity consumption that supports conservation hypothesis (Y→EC; PCY→PCEC and IP→IPEC). However, for the US, China, Brazil and Canada, causalities are from the electricity consumption to the GDP that supports the growth hypothesis. It is important that two largest economies in the world have similar causality patterns. Moreover, causality from the electricity consumption in the industrial sector to production in the industrial sector is seen only in the US, China, Canada, Brazil (bi-directional) and Japan.

5. Conclusion

There is evidence to support the growth hypothesis for the US, China, Canada and Brazil. In these countries, there is a unidirectional relationship from electricity consumption to real GDP, which means that electricity consumption acts as a stimulus to economic growth. With these findings, energy policies aimed at improving the energy infrastructure and increasing the energy supply are the appropriate options for these countries since electricity consumption increases the income level. Energy conservation policies could hamper social and economic progress when there is a unidirectional relationship between electricity consumption and real GDP.

There is evidence to support the conservation hypothesis for India, Turkey, South Africa, Japan, UK, France and Italy. The conservation hypothesis is supported if an increase in real GDP causes an increase in energy consumption. The unidirectional causality is running from economic growth to energy consumption. It suggests that the policy of conserving energy consumption may be implemented with little or no adverse effect on economic growth, such as in a less energy-dependent economy. A causal relationship from electricity consumption in the industrial sector to production in the industrial sector is seen only in the US, China, Turkey and Japan. A causal relationship from production in the industrial sector to electricity consumption in the industrial sector is seen only in India, South Africa, UK, France and Italy. Bi-directional relationship is seen in Brazil and Canada.

The results highlight the importance of electricity policy on economic growth, economic development and welfare. The current energy policy and the electricity sector restructuring process should be designed to meet this goal. In Turkey, China, India and South Africa, the appropriate options are energy policies aimed at improving the energy infrastructure, in the context of the elasticity and Granger Causality results, and policies aimed at increasing the energy supply.

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Notes

1. Rasche and Tatom's (1977) study was different from the others. They specified a production function for the United States. They exhibited that the increase of energy prices stimulated the decreasing trends on gross national product by using energy, land, labour and capital.
2. Whether or not electricity consumption positively affects and causes GDP, the relationship is crucial for electricity conservation policies (Narayan and Smyth, 2005b; Ghosh, 2002). If a positive unidirectional causality running from electricity consumption to GDP does not exist then this provides a basis for electricity conservation policies, such as electricity rationing. In the absence of this causal relationship, the implication is that a country does not depend on electricity for growth and development. If a unidirectional causality runs from electricity consumption to GDP then reducing electricity consumption could lead to a decrease in economic growth. This implies that a negative shock to electricity consumption leads to higher electricity prices or electricity conservation policies and have a negative impact on GDP (see Narayan and Singh, 2007). Payne (2010) emphasized bivariate causality tests results. However, a common problem associated with bivariate analysis is the possibility of omitted variable bias, which draws into question the validity of the inferences of a causal relationship. Furthermore, with the exception of the studies by Wolde-Rufael (2006), Squalli (2007), and Tang (2008), the majority of the studies do not examine the coefficients with respect to both the sign (positive or negative) and the magnitude of the relationship between electricity consumption and economic growth In Table 3, results of the studies in the literature are presented. According to the results, 28.10% of the studies supported the neutrality hypothesis; 20.26% of the studies supported conservation hypothesis; 33.01% of them supported the growth hypothesis; and 18.62% of them supported the feedback hypothesis. When these rates are examined in subcategories of developing and developed countries, which involves 65 and 90 countries respectively,10.7% of the studies for developed countries and 30% of the studies for developing countries support the conservation hypothesis, 24.6% of the studies for developed countries and 27.7% of the studies for developing countries support the growth hypothesis, 10% of the studies for developed countries and 20% of the studies for developing countries support the feedback hypothesis and 53.8% of the studies for developed countries and 22.2% of the studies for developing countries support the neutrality hypothesis. According to Payne (2010); the results for the 74 specific countries surveyed show that 31.15% supported the neutrality hypothesis; 27.87% the conservation hypothesis; 22.95% supported the growth hypothesis; and 18.03% supported the feedback hypothesis.

   The fact that analyses of nearly 60% of the countries surveyed provide support for either the neutrality or conservation hypotheses indicates the insignificance of electricity conservation policies such as demand management policies that essentially flattens the demand curve for electricity whereby peak load demand is reduced relative to the average load. These conservation measures will have little or no effect on economic growth for more than half the counties surveyed.

3. The distribution of the test statistics under the null is non-standard, in which critical values depend on the order of integration of the variables involved. Thus, rather than using standard critical F statistic values, the upper (for I(1)) and lower (for I(0)) bounds of the F statistics presented by Peseran et al.i are used. If the computed test statistic exceeds the upper critical bounds value, then the H0 hypothesis is rejected. If the F statistic falls into the bounds, then the cointegration test becomes inconclusive. If the F statistic is lower than the lower bounds value, then the null hypothesis of no cointegration cannot be rejectedThe critical values (CVs) are reported in Narayan (2005) for sample sizes ranging from 30 to 80 observations. Given the relatively small sample size in the present study (31 observations), we extract appropriate CVs from Narayan (2005).
4. Estimated data for 2010.

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Appendix

Table A1: Summary of the literature on price and income elasticity for electricity demand

Author(s)	*Country*	*Period*	*Income elasticity*	*Price elasticity*	*Short-run income*	*Long-run income*	*SR price*	*LR price*
Houthakker (1951)	UK	1937-1938	1.17	-0.89				
Fisher & Kaysen (1962)	USA	1946-1957		< 1				
Houthakker & Taylor (1970)	USA	1947-1964			0.13	1.93	-0.13	-1.89
Wilson (1971)	USA	1960-1970			-0.46		-1.33	
Anderson (1973)	USA	1960-1970		-1.12				
Mount, Chapman & Tyrrell (1973)	USA	1947-1970			0.02	0.2	-0.14	-1.2
Houthakker, Verleger & Sheehan (1973)	USA (up to 250 kwh)	1960-1971			0.15	2.2	-0.03	-0.44
Houthakker, Verleger & Sheehan (1973)	USA (up to 500 kwh)	1960-1971			0.14	1.64	-0.009	-1.02
Halvorsen (1975)	USA	1961-1969			0.47 to 0.54		-1 to -1.21	
Houtbakker (1973)	USA	1961-1971			1.6		-1.0	
Anderson (1978)	USA	1969			1.13		-0.91	
Mountain & Hsiao (1986)	Canada	1983			0.161	0.174		
Bohi & Zimmerman (1984)	USA					-0.2	-0.7	
Matsukawa et al. (1993)	Japan	1980-1988		-0.37				
King and Shatrawka (1994)	UK			substitution elasticity intraday 0.1to0.2 interday 0.01to0.02				
Cheng (1997)	Brazil	1963-1993			0.5218			
Patrick & Wolak (1997)	UK	1991-1995		water supply industry elasticity -0.142 to -0.27				
Silk and Jountz (1997)	USA	1949-1993			0.38	0.52	-0.63	0.48
Bose (1999)	USA				0.88		-0.65	
Bose & Shukla (1999)	India	1985-1994		short-run price elasticities 1.35 in agriculture. 0.65 in residential. 0.45 in large industry. 0.26 in commercial				
Bakırtaş, Karbuz & Bildirici (2000)	Turkey	1962-1996	3.207 (per capita)					
Cabinet Office of Govt of Japan (2001)	Japan	1981-1998	0.712	-0.441				
Filippini & Pachauri (2002)	India	1993-1994	0.658 to 0.689	'-0.16 to -0.39'				
Cabinet Office of Govt of Japan (2003)	Japan	1986-2002	1.121	-0.468				
Espey & Espey (2004)	Canada	1971-2000			0.28	0.97	-0.35	-0.85
Narayan & Smyth (2005)	Australia	1969-2000			0.01 to 0.04	0.32to0.41	-0.26 to-0.27	-0.54 to-0.47
Narayan, Smyth & Prasad 2007)	G7	1978-2003			-1.450 to-1.563		-0.2to-0.4	
Bildirici & Bakırtaş (2007)	Turkey	1970-2007	2.07 (per capita 3.73)					
Cabinet Office of Govt of Japan (2007)	Japan	1986-2005	0.911	-0.323				
Halıcıoğlu (2007)	Turkey	1968-2005			0.37 to 0.44	0.49 to 0.70'	-0.33 to -0.46'	-0.52 to -0.63"
Dergiadis& Tsoulfidis (2008)	USA	1965-2006			0.10	0.27	-0.39	-1.07
Ziramba (2008)	S Africa	1978-2005	0.31	-0.04	0.30	0.31	-0.02	-0.04
Bianco et al (2009)	Italy	1978-2003			0.17		-0.096	
Amusa, Amusa & Mabugu (2009)	S Africa	1960-2007			0.22	1.67	0.04	0.30
Nakajima & Hamori (2010)	USA	1993-2008			(-)	0.38 to 0.85	(-)	from -0.33to-0.14
Dilaver & Hunt (2010)	Turkey	1960-2008	0.15	-0.16				

LR: Long-run; SR: Short-run

Table A2: Summary of the literature on price elasticity of electricity demand in commercial and industrial sectors

Author(s)	*Year*	*Countries*	*Sectors*	*Short- or long-run*	*Explanation*
Pindyck	1979	Can, Fr, Ita, Jap, Net, Nor, Swe, UK, USA, Ger	Industrial & commercial	For LR; 0.14;0.16; 0.13;0.12;0.07; 0.08;0.12; 0.15; 0.08;012	Price elasticities of industrial & commercial
Bohi & Zimmerman	1984	USA (various utilities)	Residential, industrial & commercial	Residential sector 0.25 Short-run: -0.2 Long-run: -0.7	Difficult to report the price elasticity for either the commercial or industrial sectors.
Matsukawa	1993	Japan	Industry	LR; 0.56	Price elasticities of industrial l
King & Shatrawka	1994	England	Residential & industrial	Substitution elasticity Inter-day: 0.1 to 0.2 Intra-day: 0.01 to 0.02	Between 33 & 50% of participating customers responded totime-varying prices.
Patrick & Wolak	1997	England & Wales	Industrial & commercial	Water supply industry: -0.142 to -0.27	Price elasticities varied across industries; the most price elastic industry was water supply.
Rengan & Megha	1999	India	Large scale industry	LR; 0.45	Price elasticities of industrial & commercial
King & Chatterjee	2003	California	Residential	from-0.1 to -0.4. elasticity of 0.3 was reported	An average own-price
Qin zhenfang	2003	China	Industrial & commercial	0.4443	Price elasticities of industrial & commercial
Taylor et al.	2005	UK	Industrial & commercial	from-0.05 to -0.26	Investigated RTP programs in the UK; larger load reductions were observed during higher priced hours, asindustrial customers gained experience with hourly pricing.
Reiss	2005	California	Residential	-0.39	Developed a model for evaluating the effects of alternative tariff designs on electricity use.
Faruqui & George	2005	California	Residential, industrial & commercial	Substitution elasticity: 0.09	Residential, commercial & industrial customers conclusively reduced peak-period energy use in response to time-varying prices.
Hosoe & Akiyama	2009	Japan	Industrial & commercial	0.09 -0.30 SR & 0.12 -0.56LR	An inter-regional comparison of the estimation results suggests that price elasticity in rural regions is larger than that in urban regions

Table A3: Causality literature

Author(s)	*Country*	*Period*	*Methodology*	*Main Variables*	*Causality*
			Conservation hypothesis		
Magazzino & Cosimo (2011)	Italy	1970–2009	VAR & Error Correction Model	GDP, Energy consumption	Y→ ENR
Ghosh (2002)	India	1950–1997	Granger causality	GDP, Electricity consumption	Y→EC
Zhang & Cheng (2009)	China	1960–2007	Granger Causality	GDP, Electricity consumption	Y→EC
Lise & Van Montfort (2007)	Turkey		Cointegration test	GDP, Electricity consumption	Y→EC
Ghosh (2009)	India	1970–71 to 2005–06	ARDL, Granger causality	GDP, Electricity supply	Y→EC
Zachariadis (2007)	Canada, UK	1960–2004	Granger causality; VAR; Error correction; ARDL	GDP, Electricity supply	Y→EC
Lee (2006)	France, Italy, Japan	1960–2001	VAR,Toda & Yamamoto	GDP, Electricity supply	Y→EC
			Growth hypothesis		
Stern (2000)	USA	1948–1994	Co–integration, Granger causality	GNP, Electricity consumption	EC→Y
Bowden & Payne (2009)	USA	1949–2006	Toda–Yamamoto long–run causality tests, Granger causality	GNP, Electricity consumption	EC→Y
Shiu & Lam (2004)	China	1971–2000	Error–correction model	GDP, Electricity consumption	EC→Y
Yuan, Zhao, Yu & Hu (2007)	China	1978–2004	Cointegration & Error Correction Model	GDP, Electricity consumption	EC→Y
Asafu–Adjaye (2000)	India	1973–1995	Granger causality	GDP, Electricity consumption	EC→Y
Ghali & El–Sakka (2004)	Canada	1961–1997	Co–integration, VEC, Granger causality	GDP, Electricity consumption	EC→Y
Ang (2007)	France	1960–2000	Multivariate causality	GDP, Electricity consumption	EC→Y
Narayan, Smyth (2008)	G7 countries	1972–2002	Panel cointegration	GDP, Electricity consumption	EC→Y
Thoma,M. (2004)	USA	1973–2000	Causality	GDP, Electricity consumption	EC→Y
Bowden & Payne (2009)	USA	1949–2006	Toda–Yamamoto causality test	GDP, Electricity consumption	EC→Y
			Feedback hypothesis		
Bohm (2008)	Germany, Netherlands	1978–2005	Panel cointegration	GDP, Electricity consumption	EC←→Y
Zachariadis (2007)	France, Germany, Italy, Japan	1960–2004	Granger causality; VAR; Error correction; ARDL	GDP, Electricity consumption	EC←→Y
Ghali, El Sakka (2004)	Canada	1961–1997	multivariate cointegration analysis	GDP, Electricity consumption	EC←→Y

Author(s)	*Country*	*Period*	*Methodology*	*Main Variables*	*Causality*
			Neutrality hypothesis		
Wolde–Rufael (2006)	South Africa	1971–2001	Bound test (Toda Yamamamoto)	GDP, Electricity consumption	none
Narayan & Singh (2007)	China	1971–2001	Cointegration, Granger causality	GDP, Electricity consumption	none
Ciarreta & Zarraga (2008)	12 EU countries	1970–2004	Panel cointegration & panel system GMM none;	GDP, Electricity consumption	SR none; LR EC→ Y
Bohm (2008)	France,	1978–2005	Panel cointegration	GDP, Electricity consumption	none
Jobert & Karanfil (2007)	Turkey	1960–2003		GDP, Electricity consumption	none
Yuan et al. (2008)	China	1963–2005	Vector error –correction & Granger causality	GDP, Electricity consumption	none
Zachariadis (2007)	USA	1960–2004	Granger causality; VAR; Error correction; ARDL	GDP, Electricity consumption	none
Lee (2006)	Germany, UK	1960–2001	VAR,Toda & Yamamoto	GDP, Electricity consumption	none
Jobert & Karanfil (2007)	Turkey	1960–2003	Granger causality test	GDP, Electricity consumption	none
Halicioglu (2009)	Turkey	1960–2005	Granger causality, ARDL, Cointegration	GDP, Electricity consumption	none
Payne (2009)	USA	1949–2006	Toda–Yamamoto causality test	GDP, Electricity consumption	none

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