Azam Amjad Chaudhry[1]

PANEL DATA ANALYSIS OF CROSS-COUNTRY ELECTRICITY DEMAND

Using a unique panel dataset of 66 countries, this paper looks at the elasticity of electricity consumption with respect to per capita income and average electricity price. The analysis is performed for 66 countries in the sample as well as for the subsamples based on country size (in terms of GDP) and in terms of location (region). The analysis found that as income per capita increases, consumption of electricity per capita will increase (at the rate of 0.65% increase in per capita consumption of electricity for every 1% increase in per capita income) at a relatively uniform rate. The results also show that the elasticity of electricity demand is higher for high income countries while the elasticity of electricity consumption with respect to income per capita for middle and lower income countries is not significantly different from the global average. The elasticity of demand for European and Asian countries is not significantly different from the global average, but the elasticity of per capita electricity demand is significantly lower in the countries of American subcontinent.
Keywords: *electricity demand; income; price.*
JEL Classification Codes: Q40, Q43, Q47.

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АНАЛІЗ ПАНЕЛЬНИХ МІЖКРАЇНОВИХ ДАНИХ ЩОДО ПОПИТУ НА ЕЛЕКТРОЕНЕРГІЮ

У статті на вибірці 66 країн розглянуто еластичність споживання електроенергії з урахуванням доходів на душу населення і середньої вартості електроенергії. Аналіз виконано для вибірки 66 країн, а також для підвибірок за розміром країни (обсягом ВВП) і з точки зору розташування країни (регіону). Аналіз показав, що зі збільшенням доходу на душу населення вжиток електроенергії на душу населення збільшується (0,65% збільшення вжитку електроенергії на кожен 1% збільшення доходу на душу населення) з відносно постійною швидкістю. Результати також показують, що еластичність попиту на електроенергію вища для країн із високим рівнем доходу, тоді як еластичність вжитку електроенергії по доходу на душу населення для країн з середнім і низьким рівнем доходів істотно не відрізняється від середньосвітового показника. Еластичність попиту в європейських і азіатських країнах істотно не відрізняється від середньосвітового показника, а еластичність попиту на електроенергію на душу населення значно нижча в американських країнах.
Ключові слова: *попит на електроенергію; дохід; вартість.*
Форм. 2. Табл. 6. Рис. 5. Літ. 19.

Азам Амджад Чаудхри

АНАЛИЗ ПАНЕЛЬНЫХ МЕЖСТРАНОВЫХ ДАННЫХ ПО СПРОСУ НА ЭЛЕКТРОЭНЕРГИЮ

В статье на выборке 66 стран рассматривается эластичность потребления электроэнергии с учетом доходов на душу населения и средней стоимости электроэнергии. Анализ выполнен для выборки 66 стран, а также для подвыборок на основе размера страны (по объему ВВП) и с точки зрения расположение страны (региона). Анализ показал, что с увеличением дохода на душу населения потребление электроэнергии на душу населения увеличивается (0,65% увеличения потребления электроэнергии на каждый 1% увеличения дохода на душу населения) с относительно постоянной скоростью.

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Результаты также показывают, что эластичность спроса на электроэнергию выше для стран с высоким уровнем дохода, в то время как эластичность потребления электроэнергии по доходу на душу населения для стран со средним и низким уровнем доходов существенно не отличается от среднемирового показателя. Эластичность спроса в европейских и азиатских странах существенно не отличается от среднемирового показателя, но эластичность спроса на электроэнергию на душу населения значительно ниже в американских странах.
Ключевые слова: *спрос на электроэнергию; доход; стоимость.*

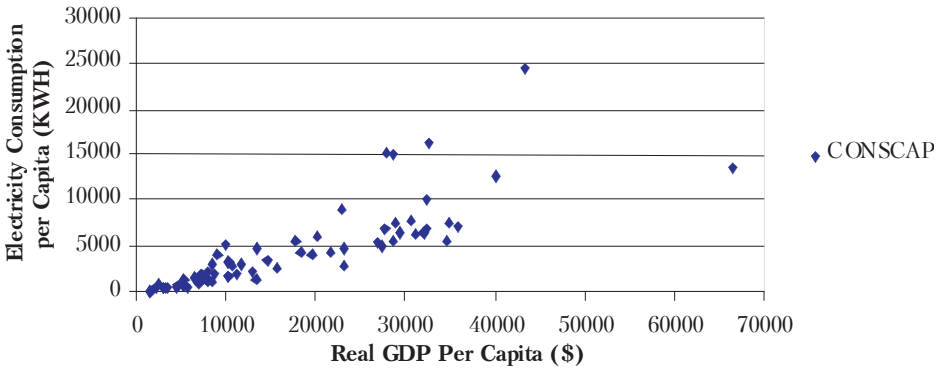
I. Introduction. Both economists and policy makers are concerned with determining the potential gap between electricity supply and electricity demand across countries, especially since the demand for electricity is increasing significantly in developing countries. As countries rapidly expand electricity generating capacity, there can be serious environmental, economic and social consequences. Also, while policy makers aim to fulfill the current level of demand, it would be a critical mistake to try and aim towards the target of energy consumption today. Rather, they should be formulating a strategy to meet the potential energy demand in the next 4–5 years.

The purpose of this paper is to look at cross-country evidence to determine what happens to the total demand for electricity as per capita GDP increases. Using a unique panel dataset of 66 countries, the elasticity of electricity consumption with respect to per capita income and average electricity price is calculated. The analysis is performed for all 66 countries in the sample as well as for the subsamples based on county size (in terms of GDP) and in terms of country location (in terms of region). The reason for performing various estimations is to see differences in income and price elasticities over different sized economies as well as across different geographic regions.

The setup of the paper is as follows: Section II provides a brief background on the cross-country electricity demand. Section III provides the literature review on electricity consumption and economic growth. Section IV presents the fixed effects model estimated and discusses the results. Section V contains the conclusions.

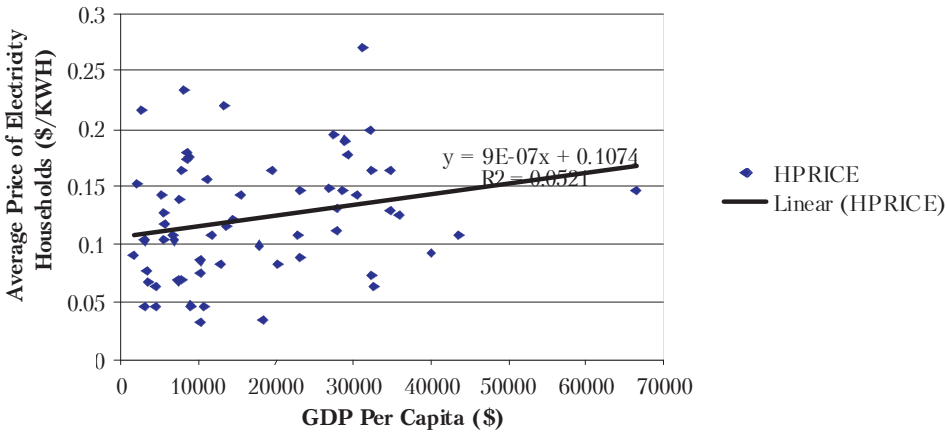
II. Cross-Country Analysis of Demand for Electricity. Across countries, there is little doubt that economic growth is accompanied by the rise in the demand for electricity. But while most analyses have focused on whether economic growth Granger causes electricity demand or vice versa, the analysis in this paper focuses on the elasticity of electricity demand with respect to economic growth and average electricity prices across countries.

Figure 1 shows the relationship between electricity consumption per capita and real GDP per capita for the period 1998–2008 and the sample of 63 countries. In it, one can see that during 1998–2008 the countries with higher real per capita GDP had higher levels of electricity consumption per capita. Figures 2 an 3 shows the relationship of the average household and industrial prices of electricity over the period 1998–2009 and the real GDP per capita for the sample of 63 countries. The interesting fact that arises is that across countries there is a positive relationship between average household electricity prices and real income, but a weakly negative relationship between average industrial household electricity prices and real income. So, as real income grows in a country, household electricity prices rise but industrial electricity prices do not.



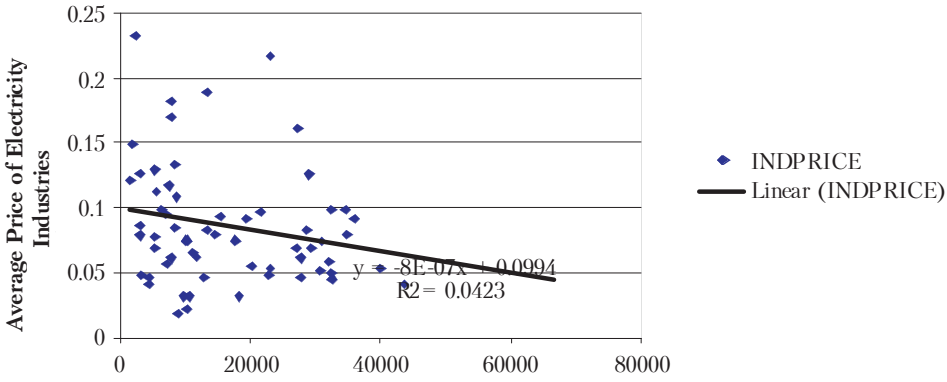
Source: International Energy Agency (2009) and Heston, Summers and Aten (2009).

Figure 1. **Consumption Per Capita of Electricity Across Countries (Average 1998–2008)**



Source: International Energy Agency (2009) and Heston, Summers and Aten (2009).

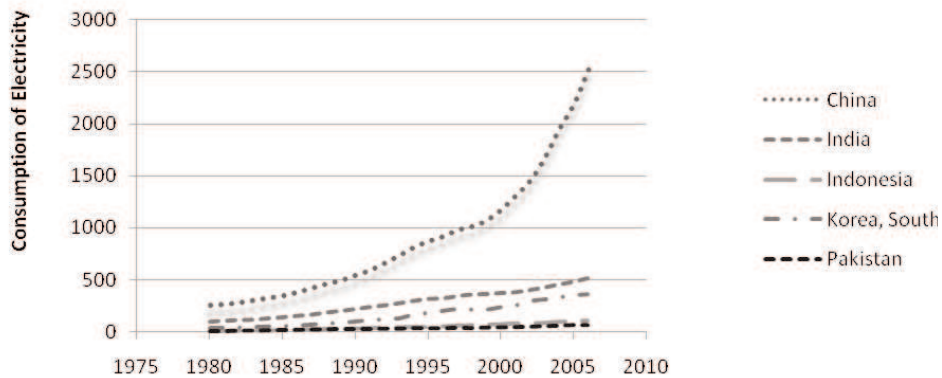
Figure 2. **Average Price of Electricity for Households Across Countries (Using Averages of 1998–2008)**



Source: International Energy Agency (2009) and Heston, Summers and Aten (2009).

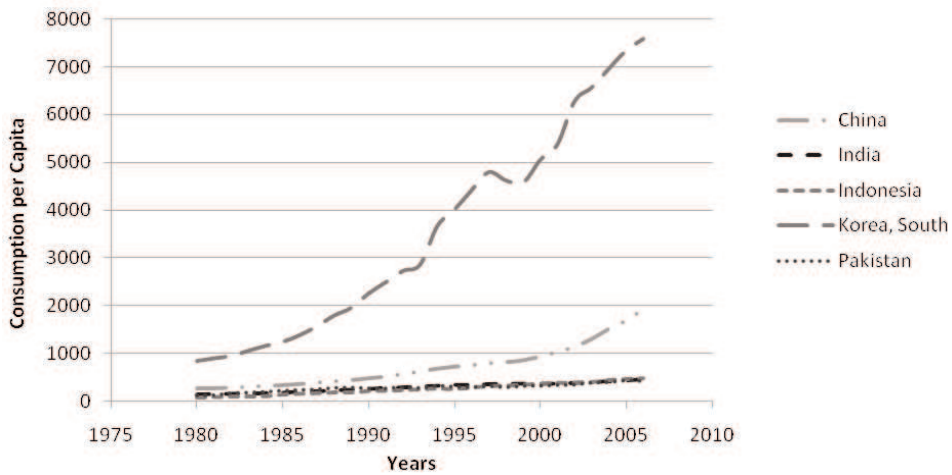
Figure 3. **Average Price of Electricity for Industries Across Countries (Using Averages of 1998–2008)**

Other than the simple fact that electricity demand across countries is dependent on income and electricity prices, another important issue is the question of how countries in different phases of development have different electricity demand patterns. So, if a country is in its early growth stages, there should be significantly less growth in electricity demand than in a country going through rapid industrialization. In order to look at this, Figures 4 and 5 show the total electricity consumption and electricity consumption per capita in 5 Asian countries (China, Indonesia, India, South Korea and Pakistan). As can be seen, there has been a dramatic increase in total electricity consumption in China, while the increases in energy consumption in the rest 4 countries has been at a constant rate. Per capita consumption of electricity is far more revealing: China and South Korea have had dramatic increases in their per capita consumption (primarily due to the increases in industrial output and demand), while per capita consumption in Pakistan, India and Indonesia have grown at about the same rate.



Source: International Energy Agency (2009).

Figure 4. **Consumption of Electricity in the Subsample of Asian Countries** *(bln KWh)*



Source: International Energy Agency (2009).

Figure 5. **Consumption of Electricity pre Capita in the Subsample of Asian Countries** *(KWh)*

Based on the cross-country evidence, there is little doubt that countries at different stages of development tend to have different income elasticities of electricity demand. For this very reason the analysis is performed for all the countries as well as for the subsamples based on income and regional location.

III. Literature Survey. Most of the analyses that have looked at the relationship between economic growth and energy consumption have focused on either one country, or a small subset of countries over time. Thus, most of the previous research on determining the impact of economic growth on energy consumption has used standard time series tools.

At the country level, authors like Altinay and Karagol (2005), Aktas and Yilmaz (2008) and Acaravci (2010) focused on analyzing the causality between electricity consumption and economic growth in Turkey using standard Granger causality tests and they found unidirectional causality running from electricity consumption to GDP growth. Jiahai, Jing and Zhaoguang (2006) used similar Granger causality tests to measure the relationship between electricity consumption and economic growth in China and found bidirectional causality between business cycles and electricity consumption. Lee and Chang (2005) found bidirectional causality between total energy consumption and economic growth and unidirectional causality from electricity consumption to GDP for Taiwan. Ciarreta and Zarraga (2006) and Aqeel and Butt (2001) found unidirectional causality from economic growth to energy consumption for Spain and Pakistan respectively. As the country level studies show, there is no consistent direction of causality between economic growth and electricity consumption.

More recent literature focused on analyzing the relationship between economic growth and electricity consumption for groups of countries. Wolde-Rufael (2006) looked at this relationship for the sample of 17 countries and found mixed results: for 6 countries the author found unidirectional causality from real GDP per capita to electricity consumption per capita, while the opposite causality was found for the 3 other countries. Soytas and Sari (2003) looked at the causality between energy consumption and income in G-7 countries and found unidirectional causality from energy consumption to GDP in 4 of these countries. Chien-Chaing Lee (2005) looked at the sample of developing countries and found causality running from energy to income, as did Masih and Masih (1996). Noor and Siddiqi (2010) used the cointegrated panel analysis to find unidirectional causality from per capita GDP to per capita energy consumption for 5 South Asian countries, while Squalli and Wilson (2006) found that the direction of causality varies across countries for the sample of GCC countries.

As the discussion above shows, most of the analyses have focused on either single countries or small groups of countries using standard time series techniques for longer periods of time. What makes the analysis in this paper unique is that it focuses on a much larger sample of countries and looks not only at the relationship between GDP per capita growth and electricity consumption, but also how changes in price affect the per capita demand for electricity.

IV. Fixed Effects Model and Results. The discussion above shows that countries with higher real per capita GDP had higher levels of electricity consumption per capita. The fact that one has data for 66 countries across the period of 10 years means that one can use a simple fixed effects model to estimate the elasticity of electricity consumption per capita with respect to per capita income.

Econometric Model. The basic formulation used to look at the relationship between per capita consumption of electricity, real per capita income and electricity prices is as follows:

$$elect_{it} = \beta_1 pcincome_{it} + \beta_2 prelect_{it} + \eta_i + \varepsilon_{it}, \quad (1)$$

where $elect_{it}$ is the per capita consumption of electricity in country i at time t; $pcincome_{it}$ is the real per capita income of country i in time t; $prelect_{it}$ is the average price of electricity in country i in time t; η_i is the time invariant country specific effect that may be interpreted as the state of technology in country i or level of natural resources; ε_{it} is the idiosyncratic error term that is uncorrelated with the explanatory variables.

The fixed effects (or within groups) estimator is based on the transformed equation in which the country specific effect is eliminated:

$$(electr_{it} - electr_i^{bar}) = \beta_1 (pcincome_{it} - pcincome_i^{bar}) + \\ + \beta_2 (prelect_{it} - prelect_i^{bar}) + (\varepsilon_{it} - \varepsilon_i^{bar}). \quad (2)$$

Under the assumption of exogeneity of explanatory variables, the fixed effects estimators give unbiased estimates of the elasticity of electricity consumption per capita with respect to real per capita income and electricity prices.

Description of the Data. The data used in this analysis is taken from the International Energy Agency's (IEA) *Energy Prices and Taxes, Quarterly Statistics* (3rd Quarter, 2009). The IEA report contains the data on economy wide electricity consumption and average household and industrial electricity prices for 66 countries for the period 1998–2008. The data on population and real per capita GDP are taken from the Penn World Tables (Heston, Summers and Aten, 2009). Excluding the missing data, the panel of 63 countries over the 10-year period is formed.

Empirical Results. The results of the fixed effects estimation for the entire sample of countries are shown in Table 1. Basically, the results show that the elasticity of per capita demand for electricity with respect to per capita income is approximately 0.69. This means that a 5% increase in per capital income in a country will be accompanied by a 3.5% increase in the demand for electricity per capita in that country. Back calculation, if real GDP growth is approximately 5% per year for 5 years and population growth is approximately 2% per year, then electricity demand will increase by approximately 9%. So, if policy makers are looking at projects to meet the current energy shortfall and these projects come on line in about 5 years, they should be looking to meet both current electricity demand plus another 9%.

Table 1. **Estimates of Per Capita Demand for Electricity for All Countries (standard errors are given in brackets)**

Model	Fixed Effects
Log (GDP Per Capita)	0.687** (.104)
Log (Price)	.012 (.025)
Constant	1.59 (1.04)
Number of Countries	63
R^2	0.843
R^2 within	0.616
Parameters	2
Observations	344

* Significant at the 10% level. **Significant at the 1% level.

Analysis of Elasticity Based on Economic Size. In the analysis above, it is assume that all countries have the same price and income elasticities of per capita electricity demand. Instead of making this simplifying assumption, it may be useful to look at how price and income elasticities vary across countries of differing economic size.

The first subset of countries taken was the subset of high income countries (where the definition of high income is taken from the World Bank's definition of high income). Table 2 shows the results for the analysis on high income countries. The results show that the elasticity of per capita demand for electricity is higher for high income countries.

Table 2. **Estimates of Per Capita Demand for Electricity for High Income Countries (standard errors are given in brackets)**

Model	Fixed Effects
Log (GDP Per Capita)	0.787** (.199)
Log (Price)	-0.02 (.042)
Constant	0.711 (2.10)
Number of Countries	37
R^2	0.659
R^2 within	0.552
Parameters	2
Observations	237

* Significant at the 10% level. **Significant at the 1% level.

There is also a possibility that low and middle income countries may have a greater elasticity of electricity consumption than higher income countries, because low and middle income countries may be in the process of rapid industrialization which could have a significant impact on their consumption per capita. The analysis above was also performed for low and middle income countries (based on the World Bank definition of low and middle income countries) and the results are shown in Table 3. As can be seen, the elasticity of electricity consumption with respect to income per capita is not significantly different from the estimates for the entire sample.

Table 3. **Estimates of Per Capita Demand for Electricity for Low and Middle Income Countries (standard errors are given in brackets)**

Model	Fixed Effects
Log (GDP Per Capita)	0.65** (0.113)
Log (Price)	0.036 (0.033)
Constant	1.52 (0.993)
Number of Countries	28
R^2	0.732
R^2 within	0.695
Parameters	2
Observations	117

* Significant at the 10% level. **Significant at the 1% level.

Analysis of Elasticity Across Different Regions. Another interesting analysis would be the difference between the elasticities of electricity demand per capita across different regions. For this purpose the data was divided into 3 categories: European countries, American countries (from the American continent) and Asian countries.

The results of this analysis are shown in Tables 4–6. As the results show, the elasticities for European and Asian countries are not significantly different from the global average, but the elasticity of per capita electricity demand is significantly lower in American countries.

Table 4. **Estimates of Per Capita Demand for European Countries (standard errors are given in brackets)**

Model	Fixed Effects
Log (GDP Per Capita)	0.668** (.127)
Log (Price)	-0.12 (.034)
Constant	1.89 (1.32)
Number of Countries	25
R^2	0.684
R^2 within	0.565
Parameters	2
Observations	186

* Significant at the 10% level. **Significant at the 1% level.

Table 5. **Estimates of Per Capita Demand for Electricity for American Countries (standard errors are given in brackets)**

Model	Fixed Effects
Log (GDP Per Capita)	0.493** (.149)
Log (Price)	-0.004 (.071)
Constant	3.07 (1.50)
Number of Countries	27
R^2	0.890
R^2 within	0.393
Parameters	2
Observations	72

* Significant at the 10% level. **Significant at the 1% level.

Table 6. **Estimates of Per Capita Demand for Electricity for Asian Countries (standard errors are given in brackets)**

Model	Fixed Effects
Log (GDP Per Capita)	0.716** (.187)
Log (Price)	0.066* (.029)
Constant	1.20 (1.72)
Number of Countries	9
R^2	0.859
R^2 within	0.702
Parameters	2
Observations	69

* Significant at the 10% level. **Significant at the 1% level.

V. Conclusions. The analyses in this paper were an initial attempt to understand the long-term relationship between income per capita across countries and the expected growth in electricity consumption per capita. In addition to this, the paper looks at the impact of electricity prices and electricity inputs on manufacturing demand for electricity and manufacturing output.

The main conclusion of this paper is that as income per capita increases, consumption of electricity per capita will increase (at the rate of 0.65% increase in per capita consumption of electricity for every 1% increase in per capita income) at a relatively uniform rate, both because of significant increases in household consumption and eventually higher industrial consumption.

The results also show that the elasticity of electricity demand is higher for high income countries though the elasticity of electricity consumption with respect to income per capita for the middle and lower income countries is not significantly different from the global average. The elasticity of demand for European and Asian countries are not significantly different from the global average, but the elasticity of per capita electricity demand is significantly lower in American countries.

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Стаття надійшла до редакції 11.10.2012.