THE RELATIONSHIP BETWEEN PER CAPITA ELECTRICITY CONSUMPTION AND HUMAN DEVELOPMENT INDICES

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Abstract— Electricity consumption is regarded as an indication of the country's level of human development and the level of human development measures a country’s performance in key areas. The present paper aims to study the causal relationship between per capita consumption of electricity and 3 selected indices of human development. For this purpose, the data for 30 selected developing countries over the period 1985-2011 were analyzed. The interactions between per capita consumption of electricity and human development indices were analyzed using Hsiao's causality test. The results suggested a two-way causal relationship between per capita electricity consumption and GDP per capita, consumption expenditure per capita, and life expectancy at birth. Therefore, electricity consumption has proven to be essential for economic development and governments should pay a special attention to electricity industry and facilitation of people’s access to electricity.

Keywords— Electricity Consumption, Panel data, Developing Countries, Human Development.

I. INTRODUCTION

People are the real wealth of nations. Human development is the process of expanding the opportunities of people for education, health care, income, employment, etc. The idea of human development emerged with this underlying assumption that human progresses cannot be measured only by income. Many indices have been introduced for human development. Institute of Economic Research in 1972, proposed 9 economic and 9 social indices for human development. In 1990, the UN Development Program for the first time raised the concept of HDI in human development which was based on 5 indices,out of which GDP per capita, life expectancy, and educational achievements account for most of human developments.

As a man-made source of energy, electricity can be produced from primary energy or be converted into the final form of energy using different technologies. In addition, electricity is a clean, easy to use, renewable, and efficient source of energy. Therefore, it is generally assumed that electricity has the broadest applications among other sources of energy and plays a decisive role in social and economic development of countries (Apergis *et al.*, 2011; 770).
For five reasons, electricity service is essential to improve living standards and support human development. When electricity is available, food, vaccines, and medicine can be kept in refrigerator for a long time, so that the living condition will improve. Lighting causes more people to read and, as a result, increases adult literacy rate. In addition, the use of computer, TV, and the Internet increases the ability of people in acquiring information and knowledge. This shows that modern society relies more and more on network-based information and communication technologies. On the other hand, electricity provides extensive use of various household appliances that improves the quality of life. Electricity can substitute traditional energies and consequently improve the quality of environment. The use of electricity can also reduce carbon emissions and limit climate changes. Therefore, electricity usage not only makes the life easier but also saves time. On the other hand, five indices reflect the level of human development in countries. These indices include GDP per capita (the level of economic development), consumption expenditure per capita (an indicator for the quality of life), urbanization rate (social structure), life expectancy at birth, and adult literacy rate (quality of population) (Niu *et al*., 2013; 338).
It is vital to pay a special attention to electricity consumption as it helps boost human development. The present paper aims to study the relationship between electricity consumption and human development in developing countries. The results will reveal the mutual relationship between electricity consumption and human development.

II. DETAILS EXPERIMENTAL

2.1. Materials and Procedures

In economic discussions, in addition to labor and capital, energy is also considered as one of the important production factor. In other words, production is considered a function of the labor, capital, and energy. Also, it is assumed that there is a direct relationship between the use of these inputs and level of production. On the other hand, energy consumption is inversely a function of its price and change in energy price has a major impact on energy consumption and, therefore, GDP. The energy crisis in the West (1973-1974), which was the result of rising prices of energy and skewness of the total economy supply curve to the left, is a prominent example of the influence of energy on economy. Production function is as in Equation 1:

$$Q = f(\mathrm{K, L, E}) (1)$$

In equation 1, Q, K, L, and E, denote GDP, capital input, labor input, and energy input respectively. Also, it is assumed that there is a direct relationship between the use of these inputs and the level of production. This relationship is mathematically as follows:

$$\frac{\partial Q}{\partial K} > 0, \frac{\partial Q}{\partial L} > 0, \frac{\partial Q}{\partial E} > 0 \quad (2)$$

The theory proposed by Brandt and Wood in 1975 states that in total production function, electricity is a factor of production that is hard to separate its relationship with labor input. The production function proposed by them is as follows:

$$Q = f[G(K, E), L] (3)$$

Above function means that energy and capital are combined to create production (G). The combination between production and labor yields product. Therefore, this function suggests that energy consumption affects marginal product of capital without influencing marginal production of labor.

On the other hand, Pindyck (1979) believed that the effect of energy prices on economic growth depends on the role of energy in the production structure. In industries where energy is used as an intermediate input in production, increased cost of energy (reduced energy consumption) affects production facilities and rate and reduces national production. He used total cost function and his analyses are based on the production cost elasticity to energy price:

$$C = C(P_K, P_L P_E, Q) (4)$$

Where, P_K, P_L, P_E, and Q represent capital price, labor, energy, and production rate, respectively.

The first three expressions of Equation 5 from right show the effect of an impulse of energy price on economy. The first expression reflects the direct impact of energy price and indicates that costs increase with increase in energy price which finally leads to reduced production. The second and third expressions refer to indirect impacts of energy price. Whenever there are substitutions relationships between energy, labor, and capital, energy price change would have indirect effects on the cost and thereby the products through replacing it by other inputs.

On the other hand, GDP is the most important factor in energy consumption growth. GDP growth and its subsequent impact on increased level of public welfare leads to an increase in electricity consumption. Electrical energy demand greatly depends on economic strength and its growth, because high economic growth will cause higher employment and increased population working in industrial and service units. In addition, electrical energy demand would increase with increase in per capita income and, consequently, increased public welfare and willingness and ability of people to buy electrical home appliances. This ultimately leads to higher electricity consumption, although this should be judged cautiously, because in countries where economic growth is high and consumption management process is implemented properly, high rate of GDP growth will not result in electricity consumption increase. For instance, a GDP growth of 7.8% in China in 1998 was followed by only 2.8% increase in electricity consumption (Stoll, 1989; 180). Energy is necessary for the majority of human activities either directly (as fuel) or indirectly (to create light, movement, etc.) (Stern, 2011; 37). Life expectancy at birth refers to the average number of years that a newborn can expect to live. Life expectancy depends on many factors such as medical progresses, reduction of absolute poverty, and technological advances. Electricity is one of the most important technological advances that increases life expectancy through the use of electronic devices (The United Nation, 2008). White and Kellick (2001) state that increased energy consumption in society decreases poverty and reduced poverty leads to increased longevity.

According to Pindyck (1991) and Bernanke (1983), there are three mechanisms for the influence of energy price on consumer expenditure. According to the first mechanism, rising energy prices reduce households' optional income and, as a result, they would spend less money to buy goods and services after paying energy bills and household's consumption expenditure will reduce. Based on the second mechanism, changes in energy price may cause uncertainty about the future price of energy and this makes consumer postpone the purchase of durable goods and reduce their consumption expenditure. Hamilton (1998) believes that, unlike the first mechanism, the effect of uncertainty is restricted to the consumption of durable goods. According to the third mechanism, even when the purchase decision is reversible, changes in uncertainty may affect all forms of consumption. Immediately after increase in energy prices, consumers increase their precautionary savings. The effect of this savings, which is not usually mentioned in literature, seems to play an important role in analyses. In addition, Davis (1987) and Hamilton (2005) showed that price change may have indirect effects on the patterns of consumer expenditure. Consumption pattern may change under the influence of uncertainty and operational costs.

2.2. Previous studies

Kanagawa and Nakata (2008) studied accessibility of electricity in rural areas and socioeconomic effects of electricity in 21 developing countries by using energy access model. The results of their study showed that electricity consumption has a significant relationship with GDP and HDI (Human Development Index).

Kofi Adam (2011) studied the causal relationship between electricity consumption and economic growth in Ghana in the period 1971-2008. The results of Toda and Yamamoto causality test indicated that there is a one-way relationship between economic growth electricity consumption.

Javid and Awan (2013) Long-term relationship between real per capita GDP and electricity consumption in Pakistan in the period 1971-2008 by using VECM model. The results suggested that there is a long-term one-way causal relationship between electricity consumption and real per capita GDP.

Niu *et al.* (2013) studied the relationship between electricity consumption and five human development indices in 50 countries The results showed that there is a long-term two-way causality between electricity consumption and five human development indices including GDP per capita, consumption expenditure per capita, urbanization rate, life expectancy at birth, and adult literacy rate.

2.3. Research methodology

In general, Granger causality test is used for testing the causal relationship between macroeconomic parameters. In summary, according to this test, if the past values of time series can significantly predict the values of X_{t+1}, then it can be stated that Y is the ranger cause of X and vice versa. In other words, Granger causality test is a kind of bivariate vector self-regression test as follows:

$$x_t = \alpha_0 + \sum_{i=1}^{m} \alpha_i x_{t-i} + \sum_{j=1}^{m} \beta_j y_{t-j} + u_t \quad (5)$$

$$y_t = \sigma_0 + \sum_{i-1}^{m} \sigma_i x_{t-i} + \sum_{j-1}^{m} \delta_j y_{t-j} + v_t (6)$$

Where, X_t and Y_t are time series and U_t and Y_t denote the disturbing sentences of two regressions. *t* also shows the time and I and j are the number of lags. In this test, the null hypothesis is $H_0 = \beta_J = \delta_J = 0$ and according to the alternative hypothesis, at least for some of the j value, $\beta_J \neq 0$and$\delta_J \neq 0$. In other words, the null hypothesis indicates lack of causality relationship between two variables of X_t and Y_t and the alternative hypothesis suggests the existence of at least one one-way causality relationship between them. In equations 6 and 7, if the coefficients β_J and δ_J are significantly equal to zero, then there is a one-way causality relationship from Y to X. If statistically $\beta_J \neq 0$ and $\delta_J \neq 0$, then there is a causality relationship from X to Y. In recent years, Granger causality tests have been less used because of their objections and new tests are being used. One of these new test is Hsiao Causality Test which is a modified version of Granger test. It should be noted that Granger causality test is very sensitive to the selection of optimal lag length. If in this test the length of selected lag is less than the length of optimal (real) lag, the results would be biased and if the length of selected lag is more than the length of optimal (real) lag, the estimated parameters would be inefficient. However, selection of improper and incorrect lag length in this test would bear non-negligible problems in the model. Hence, the use of this test for determining causality relationship is not reliable.

To resolve this problem, Hsiao (1981) proposed a systematic self-regression method for selection of optimal lag length for each of the regression equations 6 and 7. In fact, this method is a combination of Granger Causality Test and Akaike's Final Prediction Error (AFPE) which is known as Mean Square Prediction Error (MSPE). Thus, the bugs of Granger Causality Test were resolved and it is reliable for causality tests.

Since the new method of Hsiao is used to determine the causality relationships between electricity consumption per capita and human development, Hsiao Causality Test will be explained here. The modified Granger Causality Test (Hsiao) consists of two steps. In the first step, self-regression models of the dependent variable are estimated, as the dependent variable is regressed on the same variable with a lag. Then, the regression is fitted by using two lags of the dependent variable and it continues as this. In this step, in fact, m number of regressions are estimated as follows:

$$d(x_t) = \alpha + \sum_{i=1}^{m} \beta_i \, d(X_{t-i}) + \varepsilon_{it} (7)$$

In this equation, *i* contains figures from 1 to m which indicate the lag length. Selection of the lags length depends on sample size and economic structure of the variable. For a proper estimation with (i= 1, 2, ..., m), the value of FPE is calculated for each of the regressions as follows:

$$F = \frac{T+m+1}{T-m-1} ESS(m) / T (8)$$

Where T, FPE, and ESS denote number of samples, final prediction error, and error sum squares, respectively. The optimal value of m (m*) is the lag length which provides the minimum FPE. Therefore, m* should be calculated. In the second step of Hsiao Causality Test, the regression proportional to the selected certain m* is calculated. However, this time, another variables is added and estimation repetition for the new variable is done by considering the fixed value of m* and repeating the lag (n).

In other words, the process of selection of the optimal lag for the new variable is repeated like the first step. Thus, the repeated regressions will be as follows:

$$d(x_t) = \alpha + \sum_{i=1}^{m^*} \beta_i d(X_{t-i}) + \sum_{j=1}^{n} \delta_i d(y_{t-j}) + \varepsilon_{2t} (9)$$

Where, j varies between 0 and 1 indicates lag length for the variable Y_t. Therefore, the length of optimal lag (n*) occurs when FPE is below the minimum:

$$FPE(m^*,n) = \frac{T+m^*+1}{T-m^*-1} ESS(m^*,n)/\,T(10)$$

In above equation, m*, n, and T, respectively, represent the optimal lag length, for variable X_t, lag length for variable Y_t, and number of samples. As explained, when the numerical value of Equation (11) reaches the minimum, the optima lag length (n*) will be determined. By determining the optima lag length (n*), the following regression will be finally fitted.

$$d(x_t) = \alpha + \sum_{i=1}^{m^*} \beta_i d(X_{t-i}) + \sum_{j=1}^{n^*} \delta_i d(y_{t-j}) + \varepsilon_{2t}(11)$$

Finally, by eliminating one of the variables and comparing it by the SPE proportional to m* and n*, which also involves the eliminated variable, the result of Hsiao Causality Test between X_t and Y_t will be determined. If hypothetically the variable Y is eliminated, the FPE related to the regression proportional to m* is obtained, the regression (12) is regressed, and the FPE proportional to it (m* and n*) is compared with the prior one, the direction of causality between X_t and Y_t can be easily determined. The criterion for determining the direction of causality is as follows:
If FPE m*<FPE (m* and n*), then Y is not the cause of X.
If FPE m*>FPE (m* and n*), then Y is the cause of X.

III. RESULTS AND DISCUSSION

3.1. Estimation of causality between variables

In this study, the causality relationship between electricity consumption and human development was analyzed using the Panel Data Analysis in the selected developing countries. The selected countries included Iran, Jordan, Yemen, the United Arab Emirates, Morocco, Tunis, Armenia, Azerbaijan, Sudan, Turkey, Russia, India, Brazil, Thailand, Peru, Malaysia, Mexico, Philippines, Argentina, Uruguay, Bolivia, Senegal, Benin, Columbia, Paraguay, Ecuador, Croatia, Indonesia, and Kazakhstan. Data Panel Estimation in data panel was used for estimation of research models. Thus, Hsiao Causality Method was evaluated. Since the integrated data for the period 1985-2011 in 30 countries were used in this study, it was not possible to perform Hsiao Causality Test as usual, and, therefore, the causality between per capita electricity consumption and components of human development index.

3.2. Estimation of causality between per capita electricity consumption and per capita GDP

Firstly, Akaike's information criterion was used for determining the optimal lag length for per capita electricity consumption and per capita GDP. The results indicated that 6 was the optimal lag length for both of them. The best results of econometric estimations are obtained by seemingly unrelated regressions (SUR). The results of this method are shown in Table 1. Then, Wald test was used for determining the direction of causality between per capita electricity consumption and per capita GDP.

Table 1: The results of seemingly unrelated regressions (SUR)

-	Coefficient	t-Statistic	Prob.
C(1)	0.96	22.64	0.00
C(2)	0.06	1.08	0.27
C(3)	0.09	1.61	0.10
C(4)	-0.12	-1.98	0.04
C(5)	0.15	2.54	0.01
C(6)	-0.17	-4.50	0.00
C(7)	-0.89	-10.19	0.00
C(8)	0.10	1.21	0.22
C(9)	0.13	1.49	0.13
C(10)	-0.14	-1.67	0.09
C(11)	-0.17	-2.12	0.03
C(12)	0.20	4.33	0.00
C(13)	0.77	14.56	0.00
C(14)	-0.01	-0.53	0.59
C(15)	-0.34	-8.38	0.00
C(16)	-0.06	-1.58	0.11
C(17)	-0.05	-1.20	0.22
C(18)	0.05	1.15	0.24
C(19)	-0.07	-1.70	0.08
C(20)	0.10	3.70	0.00
C(21)	1.22	30.11	0.00
C(22)	-0.15	-2.32	0.02
C(23)	-0.14	-2.19	0.02
C(24)	0.06	1.07	0.28
C(25)	0.11	1.89	0.05
C(26)	-0.12	-3.70	0.00
C(27)	0.40	14.56	0.00
C(28)	0.05	4.23	0.00
Equation: LELC = C(1)*LELC(-1) + C(2)*LELC(-2) + C(3)*LELC(-3) + C(4) *LELC(-4) + C(5)*LELC(-5) + C(6)*LELC(-6) + C(7)*LGDP(-1) + C(8) *LGDP(-2) + C(9)*LGDP(-3) + C(10)*LGDP(-4) + C(11)*LGDP(-5) + C(12)*LGDP(-6) + C(13)*LGDP + C(14)			
Observations: 569			
Adjusted R-squared	0.99	S.D. dependent var	1.10
Durbin-Watson stat		1.95	
Equation: LGDP = C(15)*LELC(-1) + C(16)*LELC(-2) + C(17)*LELC(-3) + C(18)*LELC(-4) + C(19)*LELC(-5) + C(20)*LELC(-6) + C(21)*LGDP(-1) + C(22)*LGDP(-2) + C(23)*LGDP(-3) + C(24)*LGDP(-4) + C(25)*LGDP(-5) + C(26)*LGDP(-6) + C(27)*LELC + C(28)			
Adjusted R-squared	0.99	S.D. dependent var	0.94
Durbin-Watson stat		1.98	

According to the obtained results, in order to make decision about causality test between per capita electricity consumption and per capita GDP, the results of Wald test are shown in Table 2 and Table 3.

Table 2: The results of Wald test for causality relationship from per capita electricity consumption to per capita GDP

Test Statistic	Value	Df	Probability
Chi-square	43.72	1	0.00*
Null Hypothesis Summary:			
Normalized Restriction (= 0)		Value	Std. Err.
C(15) + C(16) + C(17) + C(18) + C(19) + C(20) + C(27)		0.016	0.002

Table 3: The results of Wald test for causality relationship from per capita GDP to per capita electricity consumption

Test Statistic	Value	Df	Probability
Chi-square	21.34	1	*0.00
Null Hypothesis Summary:			
Normalized Restriction (= 0)		Value	Std. Err.
C(7) + C(8) + C(9) + C(10) +C (11)+ C(12) + C(13)		0.019	0.004

According to the results, it can be stated there is a two-way causality relationship between the variables.

3.3. Estimation of causality between per capita electricity consumption and per capita consumption expenditure

Firstly, Akaike's information criterion was used for determining the optimal lag length for per capita electricity consumption and per capita consumption expenditure. The results indicated that 4 was the optimal lag length for both of them. The best results of econometric estimations are obtained by seemingly unrelated regressions (SUR). The results are shown in Table 4.

Table 4: The results of seemingly unrelated regressions (SUR)

-	Coefficient	t-Statistic	Prob.
C(1)	1.22	27.18	0.0
C(2)	-0.24	-3.36	0.00
C(3)	0.04	0.56	0.57
C(4)	-0.02	-0.55	0.57
C(5)	-0.27	-4.81	0.00
C(6)	-0.12	-2.08	0.03
C(7)	-0.06	-1.00	0.31
C(8)	0.08	1.95	0.05
C(9)	0.38	9.69	0.00
C(10)	0.03	1.12	0.25
C(11)	-0.39	-5.87	0.00
C(12)	0.04	0.63	0.52
C(13)	-0.07	-1.08	0.27
C(14)	0.04	1.06	0.28
C(15)	1.00	25.22	0.00
C(16)	0.04	0.74	0.45
C(17)	0.15	2.55	0.01
C(18)	-0.21	-5.30	0.00
C(19)	0.38	9.69	0.00
C(20)	0.00	0.08	0.93
Determinant residual covariance		0.00	

Equation: LCON = C(1)*LCON(-1) + C(2)*LCON(-2) + C(3)*LCON(-3) + C(4)*LCON(-4) + C(5)*LELC(-1) + C(6)*LELC(-2) + C(7)*LELC(-3) + C(8) *LELC(-4) + C(9)*LELC + C(10)			
Adjusted R-squared	0.99	S.D. dependent var	1.49
Durbin-Watson stat		1.89	
Equation: LELC = C(11)*LCON(-1) + C(12)*LCON(-2) + C(13)*LCON(-3) + C(14)*LCON(-4) + C(15)*LELC(-1) + C(16)*LELC(-2) + C(17)*LELC(-3) + C(18)*LELC(-4) + C(19)*LCON + C(20)			
Observations: 587			
Adjusted R-squared	0.99	S.D. dependent var	1.06
Durbin-Watson stat		2.08	

Then, Wald test was used for determining the direction of causality between per capita electricity consumption and per capita consumption expenditure. According to the obtained results, in order to make decision about causality test between per capita electricity consumption and per capita consumption expenditure, the results of Wald test are shown in Table 5 and Table 6.

Table 5: The results of Wald test for causality relationship from per capita electricity consumption to per capita consumption expenditure

Test Statistic	Value	Df	Probability
Chi-square	8.286	1	*0.004
Null Hypothesis Summary:			
Normalized Restriction (= 0)		Value	Std. Err.
C(5) + C(6) + C(7) + C(8) + C(9)		0.006	0.002

Table 6: The results of Wald test for causality relationship from per capita consumption expenditure to per capita electricity consumption

Test Statistic	Value	Df	Probability
Chi-square	2.843	1	*0.091
N Null Hypothesis Summary:			
Normalized Restriction (= 0)		Value	Std. Err.
C(11) + C(12) + C(13) + C(14) + C(19)		0.002	0.001

According to these results, it can be concluded that there is a two-way causality relationship between logarithm of per capita electricity consumption and per capita consumption expenditure.

3.4. Estimation of causality between per capita electricity consumption and life expectancy at birth

Firstly, Akaike's information criterion was used for determining the optimal lag length for per capita electricity consumption and life expectancy at birth. The results indicated that 6 was the optimal lag length for both of them. The best results of econometric estimations are obtained by seemingly unrelated regressions (SUR).

The results indicate that there is a two-way causality relationship between logarithm of per capita electricity consumption and life expectancy at birth.

3.5. Interpretation of the results of Hsiao Causality Test

Analysis of coefficients and the results of Wald test for the causality relationship between per capita electricity consumption and per capita GDP shows that, at a significance level of 5%, is the cause of per capita GDP and vice versa. Therefore, it can be concluded that there is a two-way causality relationship between per capita electricity consumption and per capita GDP.

The results of Hsiao Causality Test between per capita electricity consumption and per capita consumption expenditure also indicate that, at a significance level of 5%, there is a causality relationship from per capita electricity consumption to per capita consumption expenditure. On the other hand, according to the results of.... test, it can be stated that per capita consumption expenditure is the cause of per capita electricity consumption, at significance level of 10%. Thus, there is a two-way causality relationship between these two variables.

The results of causality test between per capita electricity consumption and life expectancy at birth indicate the existence of a two-way causality relationship between these two variables at a significance level of 5%. Therefore, per capita electricity consumption is the cause of life expectancy at birth and vice versa.

The results of testing the causality relationship between per capita electricity consumption and urbanization rate show there is no causality relationship between these variables. Also, no causality relationship was found between per capita electricity consumption and adult literacy rate.

CONCLUSIONS

The results show that per capita electricity consumption has a causality relationship with GDP, per capita consumption expenditure, and life expectancy at birth. By contrast, urbanization rate and adult literacy rate have no causality relationship with per capita electricity consumption. Therefore, in order to improve the level of welfare of society and human development, per capita electricity consumption should be increased, a special attention should be paid to electricity generation, accessibility of different walks of life to electricity should be facilitated, and supportive policies should be taken in electricity generation sector of developing countries. In fact, the results of Hsiao Causality Test indicate the importance of electricity consumption in societies. Thus, it can be concluded that:

1. Increased per capita electricity consumption not only increases GDP but also it is the cause of GDP. Therefore, in order to increase production in countries, electricity consumption should be increased in various sectors, especially industrial ones.
2. This requires increasing the production and reducing the cost of electricity consumed in manufacturing sectors. On the other hand, per capita GDP is the cause of electricity consumption. As a result, increased production in the studied countries requires increasing the electricity consumption.
3. Per capita electricity consumption is the cause of life expectancy at birth. This indicates that accessibility to electricity increases the use of devices facilitating life and this increases the lifespan of people. On the other hand, life expectancy at birth is the cause of per capita electricity consumption.
4. According to the results of causality test and as per capita electricity consumption is the cause of GDP, consumption expenditure, and life expectancy at birth, the government should pay a special attention to increased electricity generation in the country.

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