Price and Income Elasticities of Residential Demand for Electricity in Jordan: An ARDL Bounds Testing Approach to Cointegration

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ABSTRACT

This paper seeks to provide short- and long-run estimates of price and income elasticities of demand for electricity by the residential sector in Jordan using the ARDL (bounds testing) approach to cointegration over the period 1980-2013. The long run estimates were highly significant and had the expected signs. In the short-run all estimates had the correct signs and were highly significant except for the price elasticity. As expected, the short run elasticities were smaller, in absolute terms, than their counterparts in the long run. Whether in the short run or the long run, the demand is more responsive to income than it is to price. Therefore, price policies are not highly effective in changing the consumption behaviour of the households. The demand for electricity is affected by changes in weather conditions. However, in the long-run the demand for electricity for cooling is more elastic than is the demand for heating purposes.

Keywords: Electricity, ARDL, Heating and Cooling Degree Days, Elasticity.

INTRODUCTION

Electricity consumption has become a hotly discussed topic in Jordan and addressing it has become a national priority. On one hand, increased demand for electricity driven by the influx of Syrian refugees to Jordan together with the disruptions in the natural gas -the major fuel used in producing electricity in Jordan- supplies from Egypt, have forced the generators to increase reliance on more costly fuels - fuel oil and diesel- causing an increase in the cost of producing electricity by several folds since 2011. As a result, the National Electricity Power Company (NEPCO), the Jordanian public transmission company has incurred massive losses. To deal with this financial crisis, the government had the option of raising the tariffs as one of the remedial measures. Among the other measures is designing and implementing media plans to raise awareness about energy saving and consumption rationing (see footnote 13). On the other hand, the pace of the restructuring process of the electricity sector which started in the early 1990s is still ongoing and one key element of that process is reforming the prevailing tariff structure including the elimination of cross subsidies. Taken together, these challenges create the need for designing proper energy polices. However, without knowledge of the impact of price and income changes on electricity consumption, the outcomes of such policies might not be as efficient as anticipated. Unfortunately, except for Verme (2011), no recent studies within this context are available. Therefore this study tries to fill some of the void in this strand of literature by providing policy makers and officials in the sector with reliable estimates of the short- and long-run response of residential electricity consumption to changes in price and income through the estimation of price and income elasticities. These estimates are invaluable tools for apprising the impact of changing electricity rate structures (Filippini, 1995c), as well as, designing better income and price policies including the tariff reform mentioned above (Narayan and Smyth, 2005). From another perspective, these estimates enable more efficient forecasts of demand, as well as, better planning and management of supply and demand of electricity. The choice of studying the residential sector is justified on two grounds. First, this sector is the largest consumer of electricity in Jordan (in 2013, residential demand comprised nearly 43% of total demand compared with

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24% as industrial demand, 17% as commercial demand, 14% the demand for water pumping and 2% for street lighting purposes). Second, as shown later, studies of this sector are either limited or outdated. The remainder of the paper is structured as follows. Section 2 discusses the structure of the Jordanian electricity market. Section 3 contains the theoretical background and literature review. Section 4 describes model specification and empirical strategy. Section 5 describes the data used in the model. Empirical findings are reported in Section 6. Section 7 summarizes and concludes the paper and provides some policy implications.

Electricity Market Structure: A Historical Overview

The electricity industry in Jordan dates from 1938 with the establishment of a privately owned company, which was named the Jordanian Electric Power Company limited (JEPCO) in 1947. In the same year JEPCO was awarded the first concession to generate and distribute electricity in Amman and its suburbs. In 1962 the concession was renewed for fifty years. In 1961, Irbid District Electricity Company (IDECO), another privately owned company, was established to generate and distribute electricity in the northern part of Jordan. In 1967, the Jordan Electricity Authority (JEA) was established as an independent government utility and was entrusted, among other things, with the generation and transmission of electricity in addition to the distribution of electricity to areas outside the concession of JEPCO and IDECO. Over the period 1967-1994 the market structure of electricity consisted of a vertically-integrated power utility, owned by the government, with a monopoly over generation and transmission activities and a tiny portion of the distribution activities and two distributors; JEPCO and IDECO. In 1994, the government took the decision to restructure JEA before moving onwards to the privatization of the electricity sector as a whole. In September, 1996, JEA became a share-holding company named the National Electricity Power Company (NEPCO), wholly owned by the government. In 1997, the government decided to proceed further with the restructuring process by unbundling the activities of power generation, transmission and distribution. To that end, new businesses were established to operate in only one of these areas. Consequently, in 1999 NEPCO was split into three businesses. The Central Electricity Generation Company (CEGCO) to be in charge of all the public generating capacity. The Electricity Distribution Company (EDCO), to take over JEA/NEPCO’s distribution activities. A third company, which inherited NEPCO’s name, remains a state owned monopoly. This company owns and operates the system, offers transmission and acts as a single buyer for power (monopsonist) from all generators and a single bulk seller of electric power to the distributors. In 2002, Samra Electric Power Generation Company (SEPGCO), a state-owned company, was established to increase the generation capacity of Jordan. With the establishment of SEPGCO, monopoly over generation came to an end. In 2007 and 2009, two Independent Power Producers (IPP) entered the market. The first IPP is the Amman east power plant (AES-Al Manakher) while the second is the Qatrana Electric Power Company (QEPCO). In brief, the sector is currently comprised of eight utilities and a regulatory commission. These utilities are distributed as: (i) Four power generators; CEGCO, SEPGCO, (AES-Al-Manakher) and QEPCO. (ii) A single transmission company (NEPCO) and (iii) Three distribution companies; JEPCO, EDCO and IDECO.

Electricity Tariff Structure of the Residential Sector

This section briefly discusses the tariff structure applied in Jordan for the residential sector. The purpose of this discussion is twofold. First to provide a historical overview of the progress of the price reform over time. Second, as illustrated below, the nonlinear pricing of electricity has interesting implications both from theoretical and empirical perspectives. Prior to 1984, the residential tariff was flat with some sort of price discrimination on geographical basis. In areas under the concession of JEPCO and EDCO the price was (37Fils/ kWh), while it was (52Fils/ kWh) in areas under the concession of IDECO. In 13/12/1984, the first tariff reform took place; flat tariff was converted into non-linear tariff. More specifically it became an increasing block pricing schedule in the sense that the marginal price facing the consumer increases as consumption increases. This tariff consisted of two parts; a fixed fee (a minimum charge of JD1) plus an increasing marginal price. As shown in Figure 1, both the tariff and the number of blocks were subject to change over time. Contrary to the first block (1-160 kWh) which has experienced some cuts during certain periods, the rest of the blocks witnessed persistent upward movements all over the time. In 1990 and 1993 the schedule increased by one more block per
each year. In 2011, two more blocks were introduced. Finally, in mid-2012, the schedule was modified by the inclusion of an extra block. Accordingly the schedule has become a seven-block schedule; this structure will continue to prevail until the end of 2017. (12) As noted earlier, in response to escalating losses incurred by NEPCO, the government has decided, in addition to other measures, to raise the tariffs on certain types of consumers within predetermined threshold levels of consumption. (13)

Figure 1. Residential electricity tariff (Fils/kWh/month), 1984-2014. Source: JEA’s and NEPCO’s annual reports, different issues

Theoretical Background and Literature Review
In his literature survey of the demand for electricity, Taylor (1975) asserted that electricity does not generate direct utility by itself, rather it is used as an input for producing other commodities that generate utility, therefore the demand for electricity is a derived demand from the demand for inter alia lighting, heating, hot water and cooked food. More formally, the demand for electricity can be modelled according to the household production theory. (14) According to this theory, a household uses some of the goods bought from the market as inputs to produce commodities that appear as arguments in the utility function. When this theory is applied to the special case of electricity, it implies that a household combines electricity and capital stock of appliances to produce a composite energy commodity. (15) In order to empirically estimate the demand function for electricity, a functional form needs to be selected. However, before discussing this, some theoretical aspects need to be highlighted.

Some Theoretical Issues
Taylor (1975) argued that studies of residential demand for electricity are characterized by a number of challenges posed by the fact that electricity is priced according to nonlinear (multistep block) pricing structure. Closely related to this issue, is determining what electricity price -marginal or average- should be included in the demand function. The distinction between short-run and long-run demand is another crucial issue that has its own implications. Finally the choice of the functional form of the demand function also has its own theoretical and empirical consequences. Accordingly, this section discusses briefly the implications of each of these issues in turn.

Implications of Block Tariff on the Demand Function
As noted by Taylor (1975), in the normal situation when each good has a single price, the budget constraint is linear. But when faced with a price schedule -nonlinear pricing- the consumer’s budget constraint becomes nonlinear (piecewise-linear) and consumer may not respond in accordance with the expectations of the economic theory. More specifically, the demand function derived from nonlinear budget constraint is discontinuous with jumps from one segment on the budget line to another segment. Despite this, Taylor contended that these implications are more important for theoretical rather than practical considerations.
Average Price versus Marginal Price

Houthakker (1951) and Taylor (1975), in line with the axioms of the economic theory where consumers equate marginal benefit with marginal cost, assumed that consumers respond to marginal price. From another perspective, Shin (1985) and Ito (2012) postulated that the consumer responds to average price. Apart from this debate, the major problem associated with the price is the endogeneity problem caused by the correlation between average price and the quantity of electricity consumed by the household (Houthakker, 1951 and Taylor, 1975). However, as discussed in Shin (1985), when aggregated data is used, the endogeneity problem may not be severe. Alberini et al. (2011) and Paul et al. (2009) treated the average price as exogenous since it is determined by the regulatory body rather than the interaction of supply and demand. From another side, Pesaran and Shin (1999) maintained that an appropriate selection of the orders of the Autoregressive Distributed Lag (ARDL) model is sufficient to correct the problems associated with endogenous variables. In light of the above arguments the average price can be used confidently in our study without worrying about the simultaneity problem for three reasons: (1) the tariff is exogenously determined (2) the data used in the analysis is aggregated and (3) the study uses the ARDL methodology.

Functional Form

Historically, the empirical literature on the residential demand for electricity started with Houthakker (1951). He employed a linear logarithmic (log-linear) demand function in which electricity consumption is a function of income, price of electricity, price of gas as a substitute good and holdings of appliances to represent prices of complementary goods. Xiao et al. (2007) showed that the log-linear model performs better than the linear model and it has the advantage of interpreting the coefficients as elasticities.

Short-run and Long-run Demand for Electricity

Taylor (1975) distinguished explicitly between short- and long-run demand for electricity. In the short-run, the stock of electric appliances is fixed, whereas in the long-run the capital stock is variable. Therefore the demand for electricity in the short-run reflects the level of the utilization rate of the existing capital stock of appliances. However, in the long-run, the demand for electricity is equivalent to the demand for the capital stock itself. Blázquez et al. (2013) suggested that it is important to distinguish between short- and long-run demand because each of them has different determinants. In the long-run, the household can minimize the consumption of electricity by choosing the optimal level of capital stock. However, long-term equilibrium is not always attained because the stock of electrical appliances does not adjust instantaneously to its long-term equilibrium. Therefore, policies designed in the short-run might not be optimal in the long-run.

Review of Similar Studies on Residential Demand for Electricity

Broadly speaking, studies on residential demand for electricity differ according to the type of data and the econometric method(s) used in the analysis. Some studies used cross-sectional data such as Filippini (1995a) and Filippini and Pachauri (2004). A number of studies analyzed pool/panel data including Filippini (1995b, 1999 and 2011), Bose and Shukla (1999), Narayan et al. (2007), Alberini et al. (2011), Alberini and Filippini (2011) and Blázquez et al. (2013). Other studies utilized time series data, among these are Al-Faris (2002), Bentzen and Engsted (2001), Halicioglu (2007), Hondroyiannis (2004), Kamerschen and Porter (2004), Narayan and Smyth (2005), De Vita et al. (2006), Zachariadis and Pashourtidou (2007), Dergiades and Tsoulfidis (2008 and 2011), Neeland (2009), Athukorala and Clevo (2010) and Jamil and Ahmad (2011). Table A1 in the Appendix summarizes some major findings of these studies. In the context of Jordan, studies of residential demand for electricity are scarce and some are outdated. Four studies were found in this field. The first is Verme (2011); in this study income and price elasticities of residential demand for electricity were estimated using a cross sectional data provided by the Household Income and Expenditure Survey (2010). Verme (2011) estimated a log-linear static model and reported long-run marginal price and income elasticities of -0.550 and 0.006, respectively. In a second study, Al-Majali (2004) estimated price and income elasticities of demand for the residential sector using yearly data over the period (1975-2002), income and price elasticities were -0.166 and -7.11, respectively. El-Nader and Al-Raimony (1998) used annual time series data (1970-1994) to estimate a log-linear static demand model, with regard to the residential sector, the long-run price and income elasticities were -0.49 and 0.85, respectively. Finally, Al-Zu’bi and Hamed (1995) analyzed the demand for electricity in 1991 using a
sample of 250 households located in greater Amman -the capital city of Jordan- area. They used a combination of a discrete choice model-multinomial logit model- to capture the households’ choice of having electric appliances and a continuous model to represent demand for electricity. They found a positive impact of the number of appliances owned by the household, the income of the household and the household size on electricity consumption.

Model Specification and Empirical Strategy

In addition to the explanatory variables identified by Houthakker (1951), temperature is a key determinant of residential demand for electricity. To capture the effect of this variable on electricity consumption, two measures are widely used in the literature; the heating degree days (HDD) and the cooling degree days (CDD). As defined in Moral-Carcedo and Vicéns-Otero (2005) and Blázquez et al. (2013), HDD and CDD measure the number of days during which the temperature is below and above certain levels (thresholds) of cooling and heating, respectively, and by how many degrees, i.e., HDD and CDD, indirectly, reflect the demand for heating and cooling services, respectively. These measures are defined as follows (Blázquez et al., 2013):

\[ HDD = \sum_{t=1}^{nd} \max(0; T^* - T_t) \]
\[ CDD = \sum_{t=1}^{nd} \max(0; T_t - T^*) \]

where \( nd \) is the number of days of a particular year, \( T^* \) is the threshold temperature of cold or heat, and \( T_t \) is the observed temperature on day \( t \). Accordingly, residential demand for electricity can be generally modeled as:

\[ EC = f(EP, Y, HDD, CDD) \]  

where \( EC \) is electricity consumption, \( EP \) is real average price of electricity and \( Y \) is real income. Following the authors cited above (refer to footnote 17); the following log-linear specification is applied to equation (1).

\[ \ln EC_t = \beta_0 + \beta_1 \ln EP_t + \beta_2 \ln Y_t + \beta_3 \ln HDD_t + \beta_4 \ln CDD_t + u_t \]  

(2)

Where \( \ln \) stands for the natural logarithm, \( \beta_i, i = 0,1,2,3 \) and 4 are the parameters to be estimated (in this case, the parameters are interpreted as elasticities except for \( \beta_0 \) which represents the drift) and \( u_t \) is an error term which is assumed to be white noise and normally identically distributed. The subscript \( t \) represents the years of the study (\( t = 1980-2013 \)). According to the economic theory, the price elasticity of demand is expected to be negative, while the income elasticity of demand is expected to be positive and the elasticities of both heating and cooling degree days are expected to be positive because positive and negative deviations from the threshold temperature create the need for cooling and heating and respectively (Dergiades and Tsoulfidis, 2008). Equation (2) expresses a long-run relationship that can be explored using cointegration techniques. Bentzen and Engsted (2001) noted that, in the context of time series analysis, the autoregressive distributed lag (ARDL) model is the most widely used model in estimating energy demand functions. The reason beyond this is that energy consumption does not promptly respond to changes in its determinants, therefore the inclusion of the lagged values of the dependent variable makes the ARDL an attractive option. In addition to its ability to compromise the endogeneity problem cited above, the ARDL has a number of desirable properties including its ability to separate short-run and long-run effects. Moreover, the ARDL has the advantage of testing cointegration relationships irrespective of whether the underlying variables are \( I(0), I(1) \) or a combination of both. These reasons put together make the ARDL approach to cointegration a proper choice in this study. To estimate equation (2) via ARDL, two steps are needed (Naryan and Smyth, 2005; Dergiades and Tsoulfidis, 2008 and 2011). First to establish the existence of a long run relationship given by equation (2). Second to estimate the long run and short run coefficients of equation (2). To establish the long run relationship, an ARDL representation of equation (2) given by the following unrestricted error correction (conditional error correction) model has to be estimated using OLS method:

\[ \Delta \ln EC_t = \alpha_0 + \alpha_1 \Delta \ln EC_{t-1} + \alpha_2 \Delta \ln EP_{t-1} + \alpha_3 \ln Y_{t-1} + \alpha_4 \ln HDD_{t-1} + \alpha_5 \ln CDD_{t-1} + \sum_{i=1}^{P_1} \alpha_i \Delta \ln EC_{t-i} + \sum_{j=0}^{P_2} \beta_j \Delta \ln EP_{t-j} + \sum_{k=0}^{P_3} \gamma_k \Delta \ln Y_{t-k} + \sum_{l=0}^{P_4} \delta_l \Delta \ln HDD_{t-l} + \sum_{m=0}^{P_5} \epsilon_m \Delta \ln CDD_{t-m} + \varepsilon_t \]  

(3)
Where $\Delta$ denotes the first difference operator, $a_0$ is the intercept, the coefficients $a_1, a_2, a_3, a_4$ and $a_5$ are the long-run coefficients. While $a_6, a_7, a_8, a_9$ and $a_{10}$ are the short-run coefficients, $\epsilon_t$ represents a white noise error term. Finally, $p_1, p_2, p_3, p_4$ and $p_5$ correspond to the lag lengths.\(^{23}\) Next, the F-test (Wald test) should be applied to determine the presence of a long-run relationship by restricting the coefficients of the lagged level variables to zero, i.e., by excluding $\ln EC_{t-1}$, $\ln EP_{t-1}, \ln Y_{t-1}$, $\ln HDD_{t-1}$ and $\ln CDD_{t-1}$ from equation (3). In other words, the following null hypothesis of no cointegration:

$$H_0: a_1 = a_2 = a_3 = a_4 = a_5 = 0$$

is tested against the alternative hypothesis:

$$H_1: a_1 \neq a_2 \neq a_3 \neq a_4 \neq a_5 \neq 0.$$  

Testing these hypotheses entails the comparison of the calculated F-statistic with the lower critical bound (LCB) and the upper critical bound (UCB) values reported in Pesaran et al. (2001). If the calculated F-value is greater than the UCB then the null of no cointegration is rejected, however, if the calculated F-statistic is smaller than the LCB then the null of no cointegration is not rejected and the dependent variable is replaced each time by one of the independent variables, i.e., “the demand function is normalized with respect to each of the independent variables”. For example when the demand function is normalized with respect to $EP$, equation (4) changes to $F_{PE}(PE/EC, Y, HDD, CDD)$ and so on. If the statistical evidence supports the alternative hypothesis of a valid long-run relationship between the variables, then the long-run relationship of equation (2) can be estimated using the following conditional (restricted) ARDL 

\(p,q,r,s,t\) specification.\(^{24}\) $\ln EC_t = a_0 + \sum_{i=0}^{q} a_i \ln EC_{t-i} + \sum_{j=0}^{r} a_j \ln EP_{t-j} + \sum_{k=0}^{s} a_k \ln Y_{t-k} + \sum_{l=0}^{t} a_l \ln HDD_{t-l} + \sum_{m=0}^{t} a_m \ln CDD_{t-m} + \epsilon_t$ \(5\)

Where $p,q,r,s$ and $t$ are the lag lengths. The estimates of the above equation are used to calculate the long run elasticities using the delta method.\(^{25}\) Finally, the following error correction model (ECM) representation of the above ARDL representation is estimated to capture the dynamics of the model:

$$\Delta \ln EC_t = \rho_0 + \sum_{i=0}^{p} \gamma_i \Delta \ln EC_{t-i} + \sum_{j=0}^{q} \gamma_j \Delta \ln EP_{t-j} + \sum_{k=0}^{r} \gamma_k \Delta \ln Y_{t-k} + \sum_{l=0}^{s} \gamma_l \Delta \ln HDD_{t-l} + \sum_{m=0}^{t} \gamma_m \Delta \ln CDD_{t-m} + \gamma_{11} ECT_{t-1} + u_t$$

Where $ECT_{t-1}$ stands for a one period lagged error correction term and $\gamma_{11}$ represents the speed of adjustment towards equilibrium after a shock. $ECT_{t-1}$ is derived form the cointegration equation (5).

**Description of the Data**

The study covered the period 1980-2013. Data on aggregate electricity consumption by the residential sector measured in Gigawatt hours (GWh) was collected from NEPCO. Real income was proxied by real GDP (1994=100) figures compiled with the Central Bank of Jordan (CBJ). Due to the lack of information on marginal prices and following Alberini et al. (2011), Alberini and Filippini (2011) Blázquez et al. (2013) and Shin (1985), the average price of electricity was used (see section 3.1.2). The average selling price -measured in Fils/kWh/month- was calculated by dividing total revenue from the residential sector by the aggregate consumption of electricity of this sector (measured in kWh) for each of the three distribution companies. To get one figure, these prices were weighted by the number of subscribers and they were adjusted by consumer price index (CPI). Unpublished data on the mean temperature (\(2^\text{min max}\)) was provided by the Department of Meteorology of Jordan for 13 weather stations distributed all over the country. Following Alberini et al. (2011), Dergiades and Tsoulfidis (2008 and 2011), Kamerschen and Porter (2004), the HDD and CDD were calculated using a threshold of 18 degree Celsius (approximately equals to 65 degree Fahrenheit). Then HDD and CDD were averaged across the weather stations distributed over the country to get a national figure (Zachariadis and Pashourtidou, 2007 and Narayan and Smyth, 2005).

**Empirical Findings**

This section presents the estimation results of the econometric model including stationarity test, bounds test for cointegration, short-run and long-run elasticities and the dynamics of the model.
Stationarity Tests
To make sure that none of the series is \( I(2) \), stationarity of the underlying variables was tested using the Augmented Dickey and Fuller (ADF) and Phillips-Perron (PP) unit root tests. The results (see Table 1) show that under the ADF test, only the heating degree days series (expressed in natural logarithm) was stationary at the level. However, the rest of the variables became stationary at the first difference. Under the PP test, only heating degree and cooling degree days series were stationary at the level, while the other series became stationary at the first difference. Since none of the series is \( I(2) \), the ARDL technique can be employed.

<table>
<thead>
<tr>
<th>Variable</th>
<th>ADF</th>
<th>PP</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \ln EC_t )</td>
<td>-2.144617</td>
<td>-3.500810**</td>
</tr>
<tr>
<td>( \ln EP_t )</td>
<td>-2.462254</td>
<td>-3.288518**</td>
</tr>
<tr>
<td>( \ln Y_t )</td>
<td>0.386469</td>
<td>-3.123568**</td>
</tr>
<tr>
<td>( \ln HDD_t )</td>
<td>-4.185465***</td>
<td>-4.266069***</td>
</tr>
<tr>
<td>( \ln CDD_t )</td>
<td>-1.590329</td>
<td>-12.46558***</td>
</tr>
</tbody>
</table>

Table (1)
Unit root tests

Table 1 shows the results of the ADF and PP unit root tests. The variables under the ADF test became stationary at the first difference, except for \( \ln EC_t \) which was stationary at the level. Under the PP test, only \( \ln HDD_t \) and \( \ln CDD_t \) were stationary at the level, while the rest became stationary at the first difference.

Bounds Test for Cointegration
To undertake the bounds test for cointegration, the unrestricted error correction model given in equation (3) was estimated using OLS, the calculated F-value was 11.7381 which is greater than the 1 percent UCB (5.06). Thus the null hypothesis of no cointegration is rejected, confirming the existence of equilibrium relationship. This process was repeated for the models normalized on each one of the independent variables. As reported in Table 2, long-run cointegration relationships are established among all the variables except when the equation is normalized on \( EP \).

<table>
<thead>
<tr>
<th>Equation</th>
<th>F-Statistic (Calculated)</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>( F_{EC}(EC/EP,Y,HDD,CDD) )</td>
<td>11.7381***</td>
<td>Cointegration</td>
</tr>
<tr>
<td>( F_{EP}(EP/EC,Y,HDD,CDD) )</td>
<td>2.3594</td>
<td>No cointegration</td>
</tr>
<tr>
<td>( F_Y({Y/EC,EP,HDD,CDD}) )</td>
<td>6.1358***</td>
<td>Cointegration</td>
</tr>
<tr>
<td>( F_{HDD}(HDD/EC,EP,Y,CDD) )</td>
<td>8.6732***</td>
<td>Cointegration</td>
</tr>
<tr>
<td>( F_{CDD}(CDD/EC,EP,Y,HDD) )</td>
<td>8.0431***</td>
<td>Cointegration</td>
</tr>
</tbody>
</table>

At 1%: Lower bound critical value = 3.74 and Upper bound critical value = 5.06
At 5%: Lower bound critical value = 2.86 and Upper bound critical value = 4.01
At 10%: Lower bound critical value = 2.45 and Upper bound critical value = 3.52

Note: these value are taken from Pesaran et al. (2001): Table CI(iii) Case III: Unrestricted intercept and no trend.

Note: the asterisks*; ** and *** denote the significance at the 10, 5 and 1 percent level, respectively.
Estimation of Long- and Short-run Elasticities

The existence of cointegration relationship implies the existence of a long run relationship between the variables. Thus, equation (2) was estimated using the ARDL specification given by equation (5). Based on these estimates, long-run elasticities are calculated and reported in Table 3. All the estimates are statistically significant at the 1 percent level and have the expected signs. In particular, the long-run price elasticity of demand is -0.56, reflecting an inelastic demand; this is normal since there are no close substitutes to electricity except for LPG, diesel and kerosene which can replace electricity only for heating purposes. It is worthy to note that this value is very close to the value reported by Verme (2011) based on cross sectional data and using marginal price of electricity (Verme reported an elasticity of -0.55), however it is a little bit higher, in absolute terms, than (-0.49) as reported by El-Nader and Al-Raimony (1998). The long-run income elasticity of demand is 1.49, indicating that electricity is a normal good and is highly responsive to income changes. Moreover, as expected by Blázquez et al. (2013), increase in income might further increase electricity consumption through the increase in the purchase of electric appliances. The demand for electricity is affected by changes in weather conditions, however in the long-run demand for electricity for cooling is more elastic (0.67) than is the demand for heating purposes (0.51), this differential can be justified by the absence of close substitutes for electricity for cooling, which contrasts the availability of substitutes for heating. Similar reasoning is found in Blázquez et al. (2013) concerning the increased dependency of Spanish households on gas heating rather than electric heating. Since the weather variables are almost completely exogenous (Dergiades and Tsoulfidis, 2008), the remaining variables that have influence on demand are the income and the average price of electricity. However, since long run demand is more responsive to income than it is to price, then raising tariffs will not substantially reduce electricity consumption although it might increase the tax revenues of the government, therefore the government needs to resort to other measured including regulations and awareness campaigns (see footnote 13) to promote the use of energy-saving appliances (Dergiades and Tsoulfidis, 2011 and Blázquez et al., 2013).

Dynamics of the Model

The short run dynamics were estimated using the error correction model (equation 6) and are reported in Table 4. As expected the short run-elasticities are smaller, in absolute value, than the long run elasticities, meaning that the impact of income and price policies increases over time (Al-Faris, 2002). These estimates held the expected signs and all were significant at one percent level except for the price elasticity of demand which does not differ statistically from zero, i.e., short run demand is independent of the price (Hondroyiannis, 2004). This result complies with the sluggish adjustment of the capital stock of appliances expected to take place in response to increase in the price of electricity. As noted earlier, in the short run, households can only adjust their rate of utilization of appliances. Therefore the impact of the price changes in the short run is almost negligible. Our short-run price elasticity (-0.06) complies with Al-Faris (2002) result for Saudi Arabia; he reported a price elasticity of (-0.04) which was insignificant. Ahmad and Jamil (2011) displayed a short run estimate of price elasticity of (-0.07) which was insignificant too. In the same context, Zachariadis and Pashourtidou (2007) found that the short run price elasticity is insignificant but did not reveal its value. As shown in Table 4, the short-run income elasticity was 0.4. This value falls within the range of the estimates of Al-Faris (2002) that varied from 0.02 for UAE, Oman, and Bahrain to 0.70 for Kuwait. It is also close to 0.44 as reported by Bentzen and Engsted (2001). Finally the lagged error correction term has the
correct negative sign and is highly significant. More specifically, about 27% of disequilibrium from the past year will be corrected in the next year, put it another way, adjustment following a shock towards long-run equilibrium takes around 3.7 years.

Table (4)
Error correction representation for the selected ARDL Model: ARDL (1,1,0,0,0) selected based on Schwarz Bayesian Criterion

<table>
<thead>
<tr>
<th>Regressor</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T-Ratio[Prob]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ ln EP</td>
<td>-0.057475</td>
<td>0.063033</td>
<td>-0.91182[0.370]</td>
</tr>
<tr>
<td>Δ ln Y</td>
<td>0.40230</td>
<td>0.051478</td>
<td>7.8151 [0.000]</td>
</tr>
<tr>
<td>Δ ln HDD</td>
<td>0.13716</td>
<td>0.036872</td>
<td>3.7602 [0.001]</td>
</tr>
<tr>
<td>Δ ln CDD</td>
<td>0.17942</td>
<td>0.062739</td>
<td>2.8597 [0.008]</td>
</tr>
<tr>
<td>Δρ₀</td>
<td>-3.0016</td>
<td>0.70881</td>
<td>-4.2347[0.000]</td>
</tr>
<tr>
<td>ECT₁₋₁</td>
<td>-0.26938</td>
<td>0.036958</td>
<td>-7.2888[0.000]</td>
</tr>
</tbody>
</table>

Table (5)
Diagnostic tests

<table>
<thead>
<tr>
<th>Diagnostic Test</th>
<th>Test Statistic [Prob. values]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial correlation</td>
<td>$F(1,24) = 1.8163[0.190]$</td>
</tr>
<tr>
<td>Ramsey's RESET test</td>
<td>$F(1,24) = 2.9241[0.100]$</td>
</tr>
<tr>
<td>J-B Normality test</td>
<td>$\chi^2 (2) = 0.13602[0.934]$</td>
</tr>
<tr>
<td>Heteroscedasticity test</td>
<td>$F(1,30) = 2.6507[0.114]$</td>
</tr>
</tbody>
</table>

Diagnostic Tests
As shown in Table 5, the model passed successfully the tests of serial correlation, functional form, normality and heteroscedasticity. Empirical evidence shows no serial correlation, the functional form of the model is well specified, the residual term is normally distributed and the null hypothesis of homoscedasticity is not rejected.

Figure 2. Plot of CUSUM
To test for the stability of parameters, cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUMSQ) were used. As shown in Figures 2 and 3, all values lie within critical bounds of 5 percent. This asserts the satiability of short run and long run parameters.
Summary, Conclusion and Policy Implications

This paper has examined the short- and the long-run response of aggregate electricity consumption of the residential sector to changes in the average price of electricity and income in addition to weather conditions represented by the heating and cooling degree days. To that end, an ARDL approach has been applied to time series data that spanned over the period 1980-2013. All the variables were expressed in natural logarithm, which allows the interpretation of the coefficients as elasticities. Long run estimates were significant at one percent level and were in tandem with the expectations of the economic theory and the pervious empirical research. Price elasticity was negative and less than one in absolute terms (0.56), reflecting an inelastic demand, this result is supported by the lack of close substitutes to electricity, except for some fuels like LPG, kerosene and diesel that might replace electricity for heating purposes. Income elasticity of demand was positive and greater than one (1.49), indicating that electricity is a normal good. Response to changes in weather conditions was positive as expected; however demand for electricity for cooling is more elastic (0.67) than the demand for heating purposes (0.51). This result is supported by the fact the households can actually use other resources than electricity for heating including LPG, diesel and kerosene. However, possibilities of fuel switching for cooling do not almost exist. As expected, short run estimates were smaller, in absolute values, than their long run counterparts. These estimates had the expected signs and were all significant at one percent level except for the price elasticity of demand which is considered zero from a statistical point of view (see Table 4). This modest effect of price on residential electricity consumption in the short- run is normal because in the short-run households can only change the rate of utilization of the appliances but cannot instantaneously adjust their capital stock of appliances in response to rise in the price of electricity. Since the consumption of electricity by the residential sector is more responsive to changes in income than to changes in price both in the short- and the long-run, then raising the tariffs is not expected to curtail residential electricity consumption substantially, this is on one hand. On the other hand increase in income will most probably result in more purchase of electric appliances which will in turn increase electricity consumption. Therefore, if the reduction of electricity consumption is among the government’s priorities, then it needs to consider other measures in addition to tariff change including the introduction of higher energy efficiency standards for electrical appliances as well as the implementation of awareness campaigns to encourage households to reduce electricity consumption.

Acknowledgments

The author would like to thank, Dr. Nooh Al-Shyab, Dr. Samer Nawiseh, Dr. Mohammad Momani, and Dr. Khaldoon Qudah from Yarmouk University. Special thanks go for Mr. Mohammad Samawi, the Director General of Jordan Metrological Department, for the provision of temperature data. Thanks are also extended to Mr. Fayez Qawsmeh, Mr. Mazen Al-Mouhasen, Mr. Yousef moheidat, Mr. Esam Othman, Mr. Osama Sabbagh, Mr. Abelmotaleb Al-Nugrush and Eng. Anas
Maabreh for providing data on electricity consumption and prices. The author is highly grateful to Prof. Ahmad Malawi, Prof. Russell Smyth and Prof. Taleb Warrad for their constructive comments on earlier version of the paper.

NOTES

1) This shock to the supply was a result of the political changes that took place in 2011 and accompanied the Arab Spring in Egypt, among other Arab countries.

2) Verme (2011) could be consulted for a welfare analysis of the financial crisis of NEPCO.

3) As explained later, the decision of successive modification on the tariff until 2017 has already been enacted. The following link contains information about the new tariff structure: http://erc.gov.jo/English/Pages/ElectricityTariff.aspx

4) On one hand, Zachariadis and Pashourtidou (2007) noted that the major focus of a great number of energy analysis studies is to determine the price and income elasticities because these calculations enable the formation of proper forecasts and policy simulations. On the other hand, Reiss and White (2005) maintained that assessing the response of consumers to price changes is important in the course of restructuring electricity markets.

5) Southern Municipalities were responsible for the provision of electricity to the southern part of Jordan through small diesel engines (http://www.nepco.com.jo/en/electricity_improvement_en.aspx).


7) For more details see https://energypedia.info/wiki/Jordan_Energy_Situation#Electricity_Situation.

8) EDCO was established in 1999 and is responsible for distributing electricity in the southern and eastern areas of Jordan.


10) kWh is an abbreviation of kilowatt-hour. The national currency in Jordan is the Jordanian Dinar (JD). JD 1 equals 1000 Fils.

11) The two blocks were (1-160 kWh/Month) and (above 160 kWh/Month) with charges of 38 and 52 Fils/kWh, respectively. See Verme (2011) for a review of the tariff structure in Jordan until the end of 2011. At that time the schedule consisted of six blocks rather than seven blocks as of today.

12) In 1990, the new schedule became: 1-160, 161 – 500 and above 500. In 1993, the new schedule was: 1-160, 161-300, 301 -500 and more than 500. In 2011, the new schedule was: 1-160, 161 - 300, 301 - 500, 501-750, 751-1000 and more than 1000. In 2012, the new schedule was: 1-160, 161 – 300, 301 – 500, 501-600, 601-750, 751-1000 and more than 1000. Note: all figures are measured in (kWh/Month).

13) Other economic sectors are also subject to raising tariffs. For more details and complete mathematical derivations, see Filippini (1995b, 1999 and 2011) and Alberini and Filippini (2011). An accessible textbook discussion on household production theory can be found in Silberberg and Suen (2001).

14) For more details and complete mathematical derivations, see Filippini (1995b, 1999 and 2011) and Alberini and Filippini (2011). An accessible textbook discussion on household production theory can be found in Silberberg and Suen (2001).

15) Examples of composite energy commodities include heated rooms, lighting and hot water, etc. (Blázquez et al., 2013).
16) Although Zarnikau (2003), Xiao et al. (2007), Alberinín and Filippini (2011) and Filippini (2011) argue that such models are ad-hoc. However, Taylor (1975) contended that, the main reason why it is difficult to specify an electricity demand function that is “theoretically plausible” is because the consumer of electricity does not face a single price but a schedule of prices (non-linear prices).


18) The role of price and income elasticities for designing proper energy policies has been widely recognized and addressed by many authors. Bose and Shukla (1999) identified some of the major uses of these elasticities as: providing better understanding of demand behaviour, forecasting and management of demand and designing better prices policies. On top of that, Alberini et al. (2011) remarked that having information about the responsiveness of the residential demand to price changes allow for better planning generation, transmission and distribution activities. From another perspective, Narayan and Smyth (2005) highlighted the importance of elasticities for the restructuring processes where price reform policies are part of these processes. Note that other studies containing similar exposition of the importance of estimating elasticities include Alberini and Filippini (2011), Blázquez et al. (2013), Hondroyiannis (2004) and Zachariadis and Pashourtidou (2007).

19) Astonishingly, the income elasticity of demand was negative. According to the author, this unexpected outcome is a data related issue in the sense that the residential consumption figures do not only represent households’ consumption, rather they include the consumption of other sectors such as the service sector, worship places and hospitals.

20) For a historical review of the foundation of these measures see Psiloglou et al. (2009).

21) Typically, the demand model has to take into account the prices of substitutes and complements. Therefore, we tried to include in the demand function the consumer price index of household electric appliances to take into account the price of complements, and the real prices of liquefied petroleum gas, diesel and kerosene to take into account the price of substitutes. However, they all yield insignificant estimates (the results are not reported to conserve space; however they are available upon request from the author).

Therefore these variables have been confidently dropped out of the model. Dropping out the price of appliances had no significant impact on the estimated coefficients of other variables; this is consistent with Halvorsen (1975), Filippini (1995b, 1999 and 2011) and Filippini and Pachauri (2004). To investigate any substitution possibilities between different types of fuels and electricity, the following fact should be brought up to attention before proceeding further. Except for space and water heating, substitutes for electricity almost don not exist in Jordan. Prior to the unprecedented hike in the world oil prices, kerosene, diesel -mainly used for central heating purposes- and LPG used to be the three major sources of heating in Jordan. Electric heating became a feasible choice only after 2008. Therefore it was not surprising to have insignificant results; this is confirmed by Jamil and Ahmad (2011). Also the findings of De vita et al. (2006) and Filippini and Pachauri (2004) lend support to our results. In the same context, Athukorala and Clevo (2010) dropped the price of LPG from the ECM because it was not significant. An explanation of the insignificant results associated with the inclusion of the prices of substitute fuels is stated in Zachariadis and Pashourtidou (2007): “An explanation for this behaviour can be that electricity uses … are hardly substitutable by another energy form (with space heating being the most important exception).” Al-Faris (2002) attributed the low substitutability between LPG and electricity to the fact that electricity has desirable features including safety and cleanliness which cannot easily be found in other energy sources.

22) Narayan and Smyth (2005), De Vita et al. (2006), Halicioglu (2007) and Dergiades and Tsoulfidis (2008 and 2011) among others, used the ARDL approach to cointegration.

23) Since our data is annual time series, the Wald test is performed using two lags (Dergiades and Tsoulfidis, 2008 and 2011; Halicioglu, 2004 and Narayan and Smyth, 2005).

24) The appropriate lag length is usually determined with the assistance of the Akaike Information Criterion and/or the Schwarz Bayesian Criterion. In this study the latter one was used.

25) See Bentzen and Engsted (2001), Baranzini et al. (2013) and Dergiades and Tsoulfidis (2008) for details about these calculations.

26) If any of the series is I(2), the ARDL approach collapses (see Dergiades and Tsoulfidis, 2008 and 2011).

27) As noted by Dergiades and Tsoulfidis (2008 and 2011) and Halicioglu (2007), the critical values developed by Narayan (2005) are more appropriate when the sample is small (30 to 80 observations). However, using these values did not change results.

28) A maximum lag length of two was chosen in line with
29) Also comparing our result with the results of others reveals the following. It is very close to -0.54 as in Narayan and Smyth (2005) and within the range of Alberini and Filippini (2011) (between -0.45 and -0.75) and Halicioglu (2007) (between -0.52 and -0.63) and less than Dergiades and Tsoulfidis (2011) (approximately -0.61).

30) This value is close to (1.56) as reported by Hondroyiannis (2004), and it falls in the range of 0.33 and 5.39 of the GCC countries as estimated by Al-Faris (2002).

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المرونات السعرية والداخلية لطلب القطاع المنزلي من الطاقة الكهربائية في الأردن باستخدام نموذج الانحدار الذاتي للإ للغاية الزمنية الموزعة للمتكابل المشترك

سامح العلوبي

ملخص

هدفت هذه الدراسة إلى تقييم المرونات السعرية والداخلية وقياسها عبر الأدوات لطلب القطاع المنزلي على الطاقة الكهربائية في الأردن والذي يعد القطاع الأكبر استهلاكاً كهرباءً. ويعتبر هذه المرونات بأنها تمثل أدوات فعالة لقياس التغير في سعرية وداخلية فعالة مبنية على أداة فعالة رفيعة، فضلاً عن توجيه السياسات المعمول بها حالياً نحو وجهة أفضل، كما أن هذه المرونات تدعم هذا في تحقيق كل من إدارة وتخطيط الطاقة والاقتصاد بالطلب المستقبلي. وتحقيق هدف تقم تقييم طلب القطاع المنزلي على الطاقة الكهربائية باستخدامه في كل من الدخلي ومتوضئ سعر القطاع الكهربائي السنوي للمتشارك لتمكينه من إضافة إلى درجات الحرارة الحالية عند التحكم والمزيد. ومع ذلك، استخدم بيانات سنوية تجميعية خلال الفترة 1980-2013. وقد تم تقييم نموذج الطاقة العملي من خلال نموذج استجابة النموذج عند اختيار التكامل المشترك. كما كان موثقاً أن المرونات طولة الأجل كانت جيدة بعد من نشرها قدرة صريرة الأجل وذلك عند إعمال الإستراتيجية العالية (أي القطرة المطلقة).

وقد أسفرت النتائج عن تكرار المرونات طولة الأجل ذات معنى احصائي موثوق بأنها مثيرة للاهتمام في الدراسة. وقد انتظرت إشارات المرونة السعرية الأجل مع التوافرات لل источادات والتأثيرات، وتحذير الإشارة إلى أن هذه التأثيرات لم تكن مفيدة، ونسبة في ذلك أن استجابة الأداء في الأداء العشري تقدر على تقييم طاقة الكهربائية موثقة بما تستطيع القيام به من عمليات استبالة للأجهزة الحالية بأوجه أكبر كفاءة وأقل استهلاكاً للطاقة الكهربائية وذلك في المدة الأطول، وبالتالي فإن الإستراتيجية لتكبير المساحات السعرية في المدى القصير تكاد لا تذكر. كما يتبّع النتائج أن التغير في درجات الحرارة باعتبارها الوفقية لها تأثير على الطاقة المنزلي على الطاقة الكهربائية في الخضوع إلى أن استجابة الطبق الفعلي أن الطبق لأي طبق البيئة في الأداء الطويل كان أكثر من الفاعلية في الأداء الدقيق، وبالتالي فإن زيادة التعرفة الكهربائية وذلك انتهت الحكومة مؤخراً، والتي قد تساهل في قطاع محترف شركات الكهرباء الوطنية من جهة كما أنه قد ساهم في زيادة حسب نسبة الحكومات من الإدارات الضريبية من جهة أخرى إلا أن تأتي على تقييم استهلاك الطاقة الكهربائية من قبل القطاع المنزلي سيدي. وبالتالي فإن حل النموذج في بعض الاستراتيجيات الأخرى والتي فشل فيها ترحيل استهلاك الطاقة الكهربائية على النحو الذي تشمل الأنظمة، والتشريعات المتعلقة بقوانين البنية على سبيل بديل ووضع معيار عالي المستوى. استخدام نظام مستمر لإضافة على تلافية التعديل الطويل المدى للنفيك مع كافة الجهات المختلطة في المجتمع مثل مؤسسات المجتمع المدني والمؤسسات الدينية والمدارس والمدارس، حيث تساهم هذه الجهود في تغيير الأنماط الاستهلاكية السائدة وتمكين الارتقاء بها الخصوص بجهد التوقيع الاجتماعي.

الكلمات الدالة: الكهرباء، نموذج الانحدار الذاتي للإ للغاية الزمنية الموزعة، المرونة، طابق التبريد والتدفئة