Consumption of Electricity and Oil in Jordan: A non-parametric analysis using B-splines

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Consumption of Electricity and Oil in Jordan: A non-parametric analysis using B-splines

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ABSTRACT

This research is needed to provide scientific evidence that the consumption of electricity in Jordan substituted consumption of petroleum products. The study addresses changes of growth in both consumptions to analyze the impact of changes in electricity consumption on changes in the demand for oil in Jordan, both as annual growth percentages during 1971-2007. The method of B-spline is utilised to analyse and examine the shift from petroleum products to electricity. B-spline curves are also employed to determine the extent of this shift and when it did happen. To do that, the study employs a non-linear optimization model for the determination of B-spline order and function estimates. After that, it calculates the speed and acceleration of growth of both electricity and petroleum products. The study concludes that electricity has substituted petroleum products during several periods but major substitutions occurred during 1971-1976 and 2004-2007.

Keywords: Non-Parametric Analysis, Econometric Models, Economics of Energy.

1. INTRODUCTION

Jordan energy relies heavily on imported oil. This makes Jordan extremely vulnerable to exogenous supply shocks. The oil price shocks in 1973, 1979, and 2008 made this all too obvious. Steadily rising energy demand, more expensive crude oil, and the devaluation of the Jordanian Dinar in 1988 years have made it necessary for Jordan to seek alternatives to imported oil for its energy use. Electricity consumption has been growing at a higher pace compared to economic growth due to increasing urbanization, industrialisation, and rural electrification. High prices of oil and the capacity in electric generation with low operating costs have also led to high electricity usage level. Between 1970 and 2007, there was a very fast increase in both electricity and oil use in Jordan. The annual growth in electricity consumption was more than double that of petroleum products; i.e. 13.3% for electricity and 6.4% for petroleum products. From 1970 to 1974, the electricity consumption increased by 15.5% annually while that of petroleum products increased 13.9%. From 1975 to 1979, the average of annual growth of electricity consumption was 32.2% compared to 17.3% for petroleum products, (Central Bank of Jordan, 2004). This pattern continued even at higher rates during the 80's and 90's. Figures that are more recent reveal that during 2005-2007 the average annual growth in electricity consumption was almost seven times of that in petroleum products, as shown in Table 1.

The growth of electricity shows several trend changes during the study period with major changes in 1976, 1979, 1987, 1992, 1999, 2004, and 2007. The growth of consumption of petroleum products was very much lower. Out of 37 growth rates during 1971-2007, only in nine years was the annual growth of petroleum products higher than that of electricity growth, as depicted in Table 1 and illustrated in Fig. 1.

2. LITERATURE REVIEW AND THEORETICAL BACKGROUND

Over the past few years, several studies have constructed econometric models to explain the relationship between energy consumption and economic growth. The major part of empirical research was devoted to examining the relationship between electricity or petroleum consumption and other economic activities. These models could be divided into three categories. The first category includes a group of theoretical models that addressed the links between

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economic growth and electricity on one hand and petroleum consumption on the other, using mainly a parametric approach, (see for example: Abdel-Aal, 2008; Bernard et al., 2007; Berndt and Wood, 1975; Conrad, 2000; and Ferguson et al., 2000).

The second category of models could be considered as single-country models. Kraft and Kraft (1978) were the first to discuss the relationship between energy consumption and economic growth with the United States data from 1947 to 1974. They found that the causality runs from economic growth to energy consumption. Other applied models for the US economy include Mukherjee, 2008; Sanders et al., 2008; Stern, 1993 and Stern, 2000. Other most recent single-country models were applied to China (Adams and Shachmurove, 2008; Shiu and Lam, 2004 and Yuan et al., 2008), India (Ghosh, 2002), Iran (Zamani, 2007), Canada (Ghali and El-Sakka, 2004), Fiji Islands (Narayan and Singh, 2007), South Africa (Nkomo, 2005), Korea (Oh and Lee, 2004), and Malaysia (Tang, 2008).

The third category of recent models could be classified as more-than-one country models. In a study of over more than hundred countries, Chontanawat et al. (2008) found that the causal relationship between energy consumption and economic growth was more pronounced in developed than in developing countries. Other studies found bi-directional causality for some countries while for others they found unidirectional causality running from energy consumption to economic growth, (see Mahadeven and Asafu-Adjaye, 2007 and Yu and Chio, 1985). Another group of models was applied to Africa such as Akinlo, 2008 and Chiou-Wei et al., 2008. Models for Organisation of Petroleum Exporting Countries include Mehrara, 2007 and Squalli, 2007 and Wolde-Rafael, 2005. These models showed that the negative impact of energy consumption on real GDP could be attributed to either excessive energy consumption in unproductive sectors of the economy, capacity constraints, or an inefficient energy supply. The conservation hypothesis asserts that energy conservation policies designed to reduce energy consumption and waste will not adversely affect real GDP. The conservation hypothesis is supported if an increase in real GDP causes an increase in energy consumption. However, it is possible that a growing economy constrained by political, infrastructural, or mismanagement of resources could generate inefficiencies and the reduction in the demand for goods and services, including energy consumption. Al-Iriani (2006) studied a group of six Gulf Cooperation countries and found a unidirectional causality running from economic growth to energy consumption.

Developing countries were also studied by Lee, 2005 and Sari and Soytas, 2007 who studied six developing countries and found that energy was an important factor of production. Similar studies were extended to other economic or regional blocs such as those for G11[a] (Lee, 2006), G7[b] (Narayan and Smyth, 2008 and Soytas and Sari, 2006), Central America (Sprout, 1977) and Asia, other than the above, (Chen et al., 2007 and Yoo, 2006). Using regression analysis, Boyd and Pang (2000) measured productivity at the plant level in the flat glass industry and the container glass industry. They estimated how the difference in energy intensities was attributed to differences in plant level productivity and other economic variables. Their results show that there is an important linkage between energy intensity and plant level productivity. Similarly, Huang et al. (2008) found no causality between energy consumption and economic growth in low-income groups while in middle-income and high-income countries they found that economic growth leads energy consumption. Lee (2005) in a panel co integration and causality study for a group of 18 developing countries found causality running from energy consumption to economic growth but not vice versa. Similarly, in a panel causality study of sixteen Asian countries, Lee and Chiang (2008) found a long-run causality running from energy consumption to economic growth. In a panel of G7 countries, Narayan and Smyth (2008) found that capital formation, energy consumption Granger cause real GDP positively in the long run.

Many studies, and particularly studies for the Middle East, suffer from omitted variable bias. A common view in the literature is that studies which focus on two-variable models may be biased due to the omission of relevant variables (Stern, 2000). Some recent studies have included, in addition to energy and output, one variable or more such as employment (Narayan and Smyth, 2005). None of the existing studies, however, has measured the substitution from within a B-spline theory framework.

The problem of the present study is how to provide scientific evidence that electricity substituted petroleum during several periods and how to measure the speed and acceleration of this substitution. In other words, this study fills the gap of measurement of speed and acceleration and substitution changes using B-spline theory.

3. METHODOLOGY

The analysis of growth of electricity and petroleum products, which depends on descriptive study of data and depicted in Table 1 and Fig. 1, provides only a *prima face* evidence of substitution. However, to demonstrate that the substitution actually took place, the study employs a scientific approach to calculate precisely the extent and duration of this substitution. To design an energy-system model for optimization, it is important to notice that electricity and oil demands are not always linear functions. On production level, very often non-linear relations appear which means that the model must represent non-linear relationships. This is done by applying a non-parametric analysis which employs the B-splines.

The choice of B-spline approach is made because of the dynamic nature of changes in consumption of electricity and petroleum products and the ability of this approach to measure the speed and acceleration of these changes while traditional non-linear parametric, or regression, methods do not provide such measurement. B-spline dynamic analysis depends on the optimization with a time division reflecting the variations. The length of each time step and the number of time steps are flexible since these systems may go under major changes from time to time.

Consider the following equation:

$$Y_t = f(t) + e$$

Where Y_t is the observed phenomenon at time *t*, $f(t)$ represents the value of phenomenon which we want to estimate with B-splines and *e* is the error term. Let $G(t)$ be the B-spline estimator of $f(t)$ such as:

$$G(t) = \sum_{s=1}^{r} \alpha_s \, B_{s,k}(t)$$

,

where *k* is the vector of knots associated with the studied phenomena and α_s , s=1, 2,..., r are the B-splines coefficients. Following De Boor (1978), let $B_{s,k}(t)$ be the a normalized B-spline blending function which is described by the order *k* and by a non decreasing sequence of real numbers $\{t_s : s=1, 2, \ldots, r+k\}$ normally called "knot sequence", The $B_{s,k}(t)$ function is defined as follows:

$$B_{s,0}(t) = \begin{cases} 1, if\ t_s \le t < t_{s+1} \\ 0, otherwise \end{cases}$$

$$B_{s,k}(t) = \frac{t - t_s}{t_{s+k} - t_s} B_{s,k-1}(t) + \frac{t_{s+k+1} - t}{t_{s+k+1} - t_{s+1}} B_{s+1,k-1}(t)$$

$B_{s,k}(t)$ is also called "degree *k* polynomial function in knot *t*". Here, for all *s*, *k* and *t*, $B_{s,k}(t)$ is a non-zero polynomial on $[t_s, t_{s+k+1})$. On any span $[t_s, t_{s+1})$, at most k+1 degree *k* basis functions are non-zero, namely: $B_{s-k,k}(t)$, $B_{s-k+1,k}(t)$, $B_{s-k+2,k}(t)$, …, and $B_{s,k}(t)$. The partition-of-unity property makes the sum of all non-zero degree *k* basis functions on span $[t_s, t_{s+1})$ equal to 1. This property also shows that $B_{s-k,k}(t)$, $B_{s-k+1,k}(t)$, $B_{s-k+2,k}(t)$, …, and $B_{s,k}(t)$ are non-zero on $[t_s, t_{s+1})$, or the sum of these k+1 basis functions is 1. Since $B_{r,k}(t)$ is the last basis function, it is not difficult to see that the degree *k* basis functions are $B_{0,k}(t)$, $B_{1,k}(t)$, $B_{2,k}(t)$, …, and $B_{r,k}(t)$. It can also be shown that at a knot of multiplicity *m*, basis function $B_{s,k}(t)$ is C^{k-m} continuous. Therefore, increasing multiplicity decreases the level of continuity, and increasing degree increases continuity. In the B-spline curve, there are many control points, and therefore, a restricted number of the degree of the polynomial segments, (Joy, 1997).

Since $G(t)$ is the estimator of Y_t which is a function of time, the speed $G'(t)$ and the acceleration $G''(t)$ of the phenomena are obtained as the first and second derivatives of the B-spline function with respect to time, respectively. Since our phenomenon is a function of time and following Lafrance and Perron (1993), it can be shown that the speed, which is the first derivative by time, is:

$$G'(t) = \sum_{s=2}^{r} (k-1) \frac{\alpha_s - \alpha_{s-1}}{w_{s+k+1} - w_s} B_{s,k-1}(t)$$

While the acceleration of the phenomena, which is the second derivative by time, is:

$$G''(t) = \sum_{s=3}^{r} (k-2) \frac{\alpha_s - 2\alpha_{s-1} + \alpha_{s-2}}{(w_{s+k-1} - w_s)(w_{s+k-2} - w_s)} B_{s,k-2}(t)$$

The vector of knots is chosen arbitrarily but should satisfy the form:

$$w_1 = \cdots = w_k < w_{k+1} < \cdots < w_r < w_{r+1} = \cdots = w_{r+k}$$

4. ESTIMATION AND TIME SERIES DATA

The non-parametric approach which is based on B-splines explained above is applied to fit the annual growth of electricity and petroleum products as closely as possible to the observed data. It also allows us, after estimating the coefficients of the splines, to calculate the speed of growth *G'(t)* and the acceleration of growth *G"(t)* of the annual growth of both phenomena. Applying B-spline approach to Jordan's data, over a period of 38 years shown in Table 1, indicates that the vector of knots associated with the studied phenomena does not include more than nine knots. The basis function $B_{s,k}(t)$ is a composite curve of degree k polynomials with joining points at knots in $[t_s, t_{s+k+1})$. The selection of r and k, although arbitrarily from theoretical point of view since B-spline approach gives optimal knot distribution, is limited to nine in each case. This leaves us with only four options, as follows:

Option 1: k=1, r=8, leading to:

$$w_1 < w_2 < w_3 < w_4 < w_5 < w_6 < w_7 < w_8 < w_9$$

Where the assumed knot vector is {0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0}

$$and\ G(t) = \sum_{s=1}^{8} \alpha_s B_{s,1}(t)$$

Option 2: k=2, r=7, which make:

$$w_1 = w_2 < w_3 < w_4 < w_5 < w_6 < w_7 < w_8 = w_9$$

Where the assumed knot vector is
{0.0, 0.0, 0.2, 0.4, 0.5, 0.6, 0.8, 1.0, 1.0}

$$and\ G(t) = \sum_{s=1}^{7} \alpha_s B_{s,2}(t)$$

Option 3: k=3, r=6, that is:

$$w_1 = w_2 = w_3 < w_4 < w_5 < w_6 < w_7 = w_8 = w_9$$

Where the assumed knot vector is
{0.0, 0.0, 0.0, 0.25, 0.50, 0.75, 1.0, 1.0, 1.0}

$$and\ G(t) = \sum_{s=1}^{6} \alpha_s B_{s,3}(t)$$

Option 4: k=4, r=5, leading to:

$$w_1 = w_2 = w_3 = w_4 < w_5 < w_6 = w_7 = w_8 = w_9$$

Where the assumed knot vector is
{0.0, 0.0, 0.0, 0.0, 0.5, 1.0, 1.0, 1.0, 1.0}

$$and\ G(t) = \sum_{s=1}^{5} \alpha_s B_{s,4}(t)$$

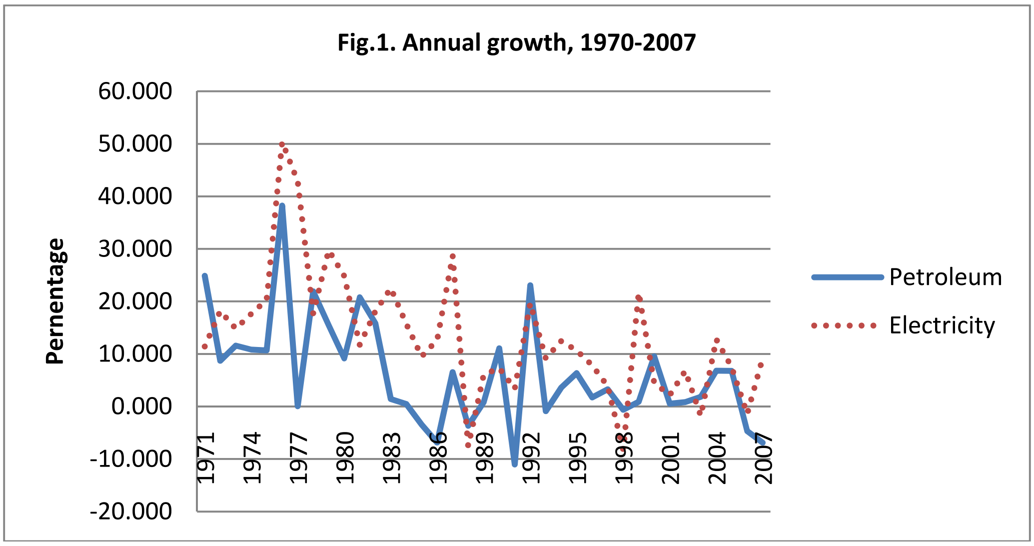
As can be seen, from substituting k and r values in the B-spline function, *G(t),* other values of k and r are irrelevant for our data. However, for estimating the speed of growth *G'(t)* and the acceleration of growth *G"(t)* only the last three options (2, 3 and 4) and the last two options (3 and 4) are relevant, respectively. The results of estimating the B-spline functions for both electricity and petroleum products, presented in Tables 3-6, support that option 3 and 4 are the most appropriate options.

Table 1. Production of electricity and petroleum products, 1970-2007

Year	Electricity (Million KWh)	Petroleum products (1000 ton)	Annual growth of electricity %	Annual growth of petroleum products %
1970	120.0	445.8	---	---
1971	133.7	556.7	11.417	24.877
1972	158.0	605.1	18.175	8.694
1973	181.4	675.3	14.810	11.601
1974	213.4	748.4	17.641	10.825
1975	256.7	828.2	20.291	10.663
1976	386.0	1145.0	50.370	38.252
1977	551.4	1145.5	42.850	0.044
1978	649.1	1396.6	17.719	21.921
1979	842.1	1612.4	29.733	15.452
1980	1051.4	1760.0	24.855	9.154
1981	1174.9	2126.0	11.746	20.795
1982	1387.2	2463.9	18.070	15.894

Year	Electricity (Million KWh)	Petroleum products (1000 ton)	Annual growth of electricity %	Annual growth of petroleum products %
1983	1699.9	2499.0	22.542	1.425
1984	1967.0	2510.9	15.713	0.476
1985	2154.0	2423.9	9.507	-3.465
1986	2426.8	2257.1	12.665	-6.881
1987	3123.8	2404.5	28.721	6.531
1988	2887.1	2316.0	-7.577	-3.681
1989	3061.5	2335.1	6.041	0.825
1990	3284.8	2593.8	7.294	11.079
1991	3395.0	2307.2	3.355	-11.049
1992	4062.8	2839.6	19.670	23.076
1993	4435.2	2814.5	9.166	-0.884
1994	4988.6	2915.8	12.477	3.599
1995	5519.5	3100.8	10.642	6.345
1996	5951.7	3154.2	7.830	1.722
1997	6180.2	3257.3	3.839	3.269
1998	5670.0	3236.9	-8.255	-0.626
1999	6900.2	3266.0	21.697	0.899
2000	7208.2	3578.2	4.464	9.559
2001	7365.7	3596.8	2.185	0.520
2002	7864.9	3627.2	6.777	0.845
2003	7721.4	3694.6	-1.825	1.858
2004	8708.9	3946.5	12.789	6.818
2005	9359.3	4213.7	7.468	6.771
2006	9227.1	4017.2	-1.412	-4.663
2007	10078.0	3740.4	9.222	-6.890

For 1970-2003, Central Bank of Jordan, 2004, Yearly Statistical Series 1964-2003, Central Bank of Jordan, Table 41, p. 62, Amman. For 2004-2007, Central Bank of Jordan, 2007, Annual Report, No. 44, Central Bank of Jordan, Table 5, p. 83, Amman. Data for 2006 and 2007 are preliminary. The last two columns are calculated by the author.



5. EMPIRICAL RESULTS

To estimate $G(t)$ with B-splines we apply De Boor's algorithm to obtain the proper values of k and r where the values of w's are assumed according to the above four options. However, for each phenomenon only one optimal knot distribution is produced by this algorithm. After estimating the coefficients α's and the values of B's, both $G'(t)$ and $G''(t)$ are calculated. Estimation results for the coefficients of B-splines, α's, are presented in Tables 3-6. As can be seen, estimation results in Tables 3 and 4 are not statistically accepted. The values of t statistics are insignificant for both electricity and petroleum products. For this reason the estimated values of the coefficients are not used to estimate the speed of growth $G'(t)$ or acceleration of growth $G''(t)$. Examining the results in Tables 5 indicates that these results can be used to calculate $G'(t)$ and $G''(t)$ for petroleum products. Moreover, the results in Table 6 are proper for calculating $G'(t)$ and $G''(t)$ for electricity.

Our selection of the appropriate model was not only guided by the significance values of t statistics, at the 5% level, but also by other statistics, such as adjusted coefficient of multiple determination (adjusted R^2), proportion of variance explained, Durbin-Watson statistic, log likelihood ratio, and many other traditional statistics which are normally produced by statistical software applications. However, since there are many models and statistics involved in our analysis, the research presents only the most important ones.

Table 2. Results for electricity, petroleum products, and conversion to electricity

Knots (in years)	Electricity (k=4)	Petroleum products (k=3)	Conversion to electricity (k=2)
w_1	1985	1988	1972
w_2	1986	1998	1979
w_3	1988	2003	1982
w_4	1991	2006	1989
w_5	1993	---	1991
w_6	1998	---	1993
w_7	2006	---	1999
w_8	2007	---	2001
w_9	---	---	2004

Note: Vector knots are not expressed in values of w_i's but in years of incidence.

Table 3. Estimation results for electricity and petroleum products, *k=1, r=8*

Coefficients	Electricity		Petroleum products	
	value	t-ratio	value	t-ratio
α_1	2.123E-08	0.847	1.165E-08	0.520
α_2	-3.455E-06	-0.905	-2.259E-06	-0.662
α_3	2.322E-04	0.970	1.766E-04	0.825
α_4	-8.286E-03	-1.037	-7.219E-03	-1.011
α_5	0.167	1.096	0.165	1.216
α_6	-1.870	-1.119	-2.130	-1.426
α_7	10.301	1.038	14.241	1.606
α_8	-20.233	-0.727	-42.470	-1.709

Note: This option is not selected for electricity or petroleum products.

Table 4. Estimation results for electricity and petroleum products, *k=2, r=7*

Coefficients	Electricity		Petroleum products	
	value	t-ratio	value	t-ratio
α_1	-2.284E-07	-1.012	-4.885E-07	0.642
α_2	3.104E-05	1.032	6.623E-05	-0.640
α_3	-1.656E-03	-1.032	-3.580E-03	0.604
α_4	0.044	0.994	0.098	-0.520
α_5	-0.564	-0.880	-1.413	0.378
α_6	3.005	0.612	10.236	-0.266
α_7	-1.801	-0.104	-32.354	0.642

Note: This option is not selected for electricity or petroleum products.

Table 5. Estimation results for electricity and petroleum products, *k=3, r=6*

Coefficients	Electricity		Petroleum products	
	value	t-ratio	value	t-ratio
α_1	6.647E-07	0.323	1.263E-06	1.553
α_2	-5.004E-05	-0.212	-1.439E-04	-2.442
α_3	4.877E-04	0.047	5.980E-03	2.483
α_4	4.592E-02	0.210	-0.108	-2.517
α_5	-1.396	-0.614	0.823	2.527
α_6	12.086	1.160	-2.653	-2.487

Note: This option is selected for calculating *G'(t)* and *G"(t)* for petroleum products.

Table 6. Estimation results for electricity and petroleum products, *k=4, r=5*

Coefficients	Electricity		Petroleum products	
	value	t-ratio	value	t-ratio
α_1	2.573E-05	2.387	1.283E-07	0.007
α_2	-2.804E-03	-1.583	-2.786E-04	-0.163
α_3	0.113	1.853	1.993E-02	0.337
α_4	-2.063	-2.209	-0.445	-0.496
α_5	14.838	2.506	2.578	0.453

Note: This option is selected for calculating *G'(t)* and *G"(t)* for electricity.

Evaluating the t-ratios for electricity, shown in Tables 3-6, indicate that the optimal number of knots over polynomial piecewise is obtained when *k*=4 and *r*=5, as shown in Table 6. That is:

$$G(t) = \sum_{s=1}^{5} \alpha_s B_{s,4}(t).$$

Hence,

$$G'(t) = 3[\frac{\alpha_2 - \alpha_1}{(w_7 - w_2)} B_{2,3}(t) + \frac{\alpha_3 - \alpha_2}{(w_8 - w_3)} B_{3,3}(t) + \frac{\alpha_4 - \alpha_3}{(w_9 - w_4)} B_{4,3}(t)],$$

and

$$G''(t) = 2[\frac{\alpha_3 - 2\alpha_2 + \alpha_1}{(w_6 - w_3)(w_5 - w_3)} B_{3,2}(t) + \frac{\alpha_4 - 2\alpha_3 + \alpha_2}{(w_7 - w_4)(w_6 - w_4)} B_{4,2}(t) + \frac{\alpha_5 - 2\alpha_4 + \alpha_3}{(w_8 - w_5)(w_7 - w_5)} B_{5,2}(t)].$$

For petroleum products, the optimal number of knots over polynomial piecewise is obtained when *k=3* and *r=6*, as shown in Table 5. In this case, B-splines give optimal knot distribution. The estimate of the annual growth of the consumption of petroleum products can be better obtained when:

$$G(t) = \sum_{s=1}^{6} \alpha_s B_{s,3}(t).$$

Hence,

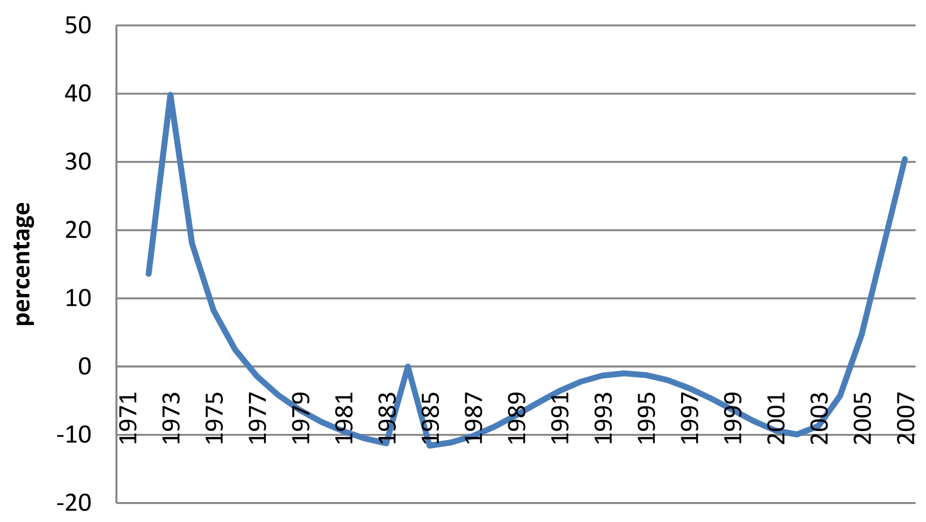
$$G'(t) = 2[\frac{\alpha_2 - \alpha_1}{(w_6 - w_2)} B_{2,2}(t) + \frac{\alpha_3 - \alpha_2}{(w_7 - w_3)} B_{3,2}(t) + \frac{\alpha_4 - \alpha_3}{(w_8 - w_4)} B_{4,2}(t) + \frac{\alpha_5 - \alpha_4}{(w_9 - w_5)} B_{5,2}(t)],$$

and

$$G''(t) = \frac{\alpha_3 - 2\alpha_2 + \alpha_1}{(w_5 - w_3)(w_4 - w_3)} B_{3,1}(t) + \frac{\alpha_4 - 2\alpha_3 + \alpha_2}{(w_6 - w_4)(w_5 - w_4)} B_{4,1}(t) + \frac{\alpha_5 - 2\alpha_4 + \alpha_3}{(w_7 - w_5)(w_6 - w_5)} B_{5,1}(t) + \frac{\alpha_6 - 2\alpha_5 + \alpha_4}{(w_8 - w_6)(w_7 - w_6)} B_{6,1}(t).$$

Applying the above formulas for both electricity and petroleum products produced annual data for both *G'(t)* and *G"(t)*. Table 7 shows that the annual speed of growth of electricity was very much higher than that of petroleum products, during 1971-1976, at the average of 23% and 3%, respectively. After that, the speed was lower but it surged again, during 2005-2007, to reach an average annual growth of about 18% and 0.2%, respectively. Furthermore, the annual rates of growth of acceleration for electricity were always higher than their corresponding rates for petroleum products, at an average of about 20% and -4%, respectively. Comparing Fig. 2 with Fig.4 shows that the patterns of growth of speed of electricity and petroleum product were not linear. As mentioned above, major differences occurred during 1971-1976 and 2005-2007. Fig. 3 and Fig. 5 also show that electricity has substituted petroleum products. The reason for the occurrences of the above-mentioned differences could be attributed to the surge of prices of oil products in comparison to electricity prices. Imports of electrical machinery and the widespread of its use might also help, to a lesser extent, in this substitution.

Fig. 2: Electricity curve of speed, Jordan 1972-2007



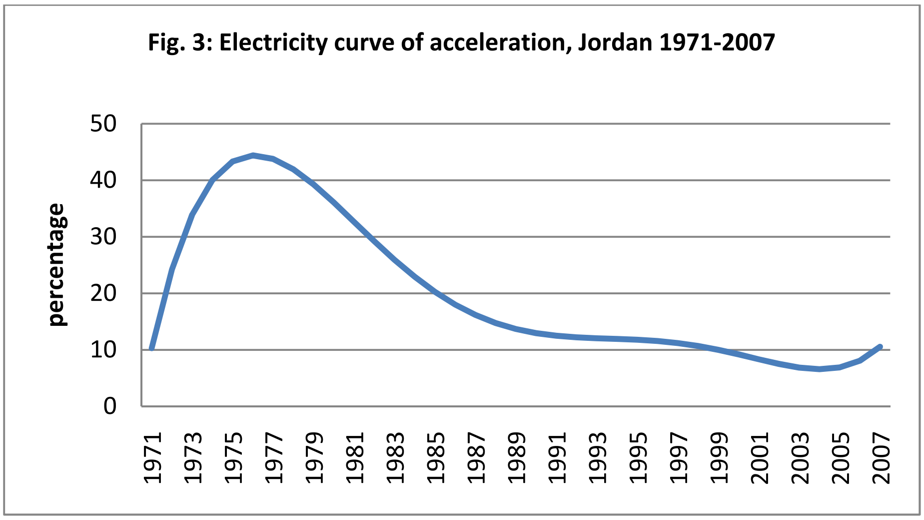


Fig. 3: Electricity curve of acceleration, Jordan 1971-2007
percentage
50
40
30
20
10
0
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007

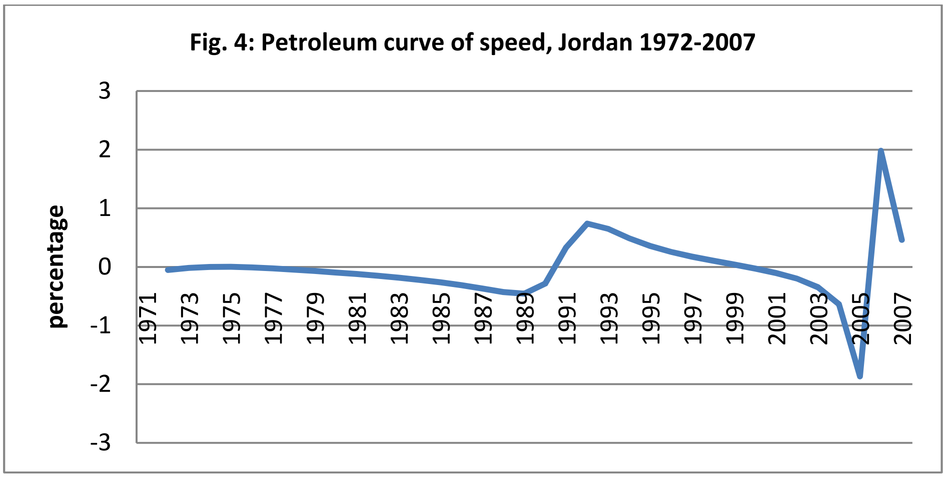


Fig. 4: Petroleum curve of speed, Jordan 1972-2007
percentage
3
2
1
0
-1
-2
-3
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007

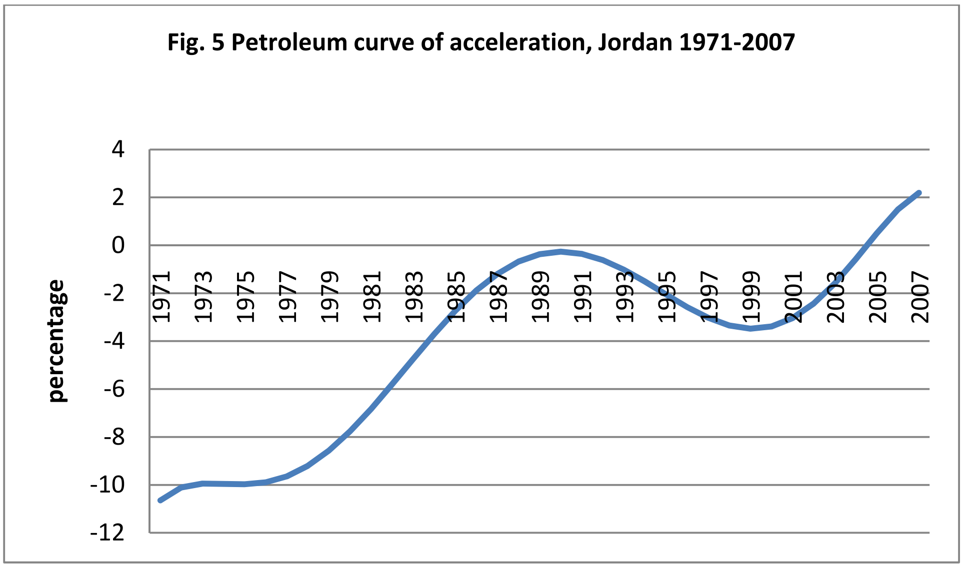


Fig. 5 Petroleum curve of acceleration, Jordan 1971-2007
percentage
4
2
0
-2
-4
-6
-8
-10
-12
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007

Table 7. Speed and acceleration of growth for electricity and petroleum products, 1971-2007

Year	Speed of growth *G'(t)*		Acceleration of growth *G''(t)*	
	electricity	petroleum products	electricity	petroleum products
1971	---	---	10.181	-10.646
1972	135.880	-0.051	24.016	-10.103
1973	39.846	-0.015	33.586	-9.946
1974	18.090	0.001	39.661	-9.957
1975	8.238	0.002	42.929	-9.974
1976	2.479	-0.008	43.993	-9.892
1977	-1.387	-0.025	43.382	-9.645
1978	-4.213	-0.046	41.555	-9.205
1979	-6.391	-0.069	38.899	-8.572
1980	-8.115	-0.094	35.742	-7.766
1981	-9.481	-0.121	32.353	-6.826
1982	-10.526	-0.150	28.948	-5.799
1983	-11.249	-0.183	25.691	-4.738
1984	-11.619	-0.220	22.706	-3.698
1985	-11.592	-0.262	20.074	-2.730
1986	-11.123	-0.311	17.841	-1.880
1987	-10.190	-0.369	16.023	-1.187
1988	-8.826	-0.429	14.609	-0.679
1989	-7.138	-0.455	13.566	-0.370
1990	-5.317	-0.284	12.845	-0.265
1991	-3.600	0.337	12.382	-0.354
1992	-2.214	0.739	12.108	-0.616
1993	-1.323	0.651	11.948	-1.016
1994	-1.001	0.488	11.829	-1.512
1995	-1.241	0.357	11.682	-2.051
1996	-1.984	0.256	11.450	-2.577
1997	-3.144	0.175	11.090	-3.028
1998	-4.621	0.105	10.578	-3.347
1999	-6.289	0.040	9.912	-3.481
2000	-7.973	-0.027	9.122	-3.387
2001	-9.372	-0.103	8.267	-3.039
2002	-9.938	-0.199	7.445	-2.433
2003	-8.713	-0.345	6.797	-1.593
2004	-4.263	-0.636	6.507	-0.580
2005	4.706	-1.867	6.813	0.503
2006	17.533	1.982	8.008	1.500
2007	30.413	0.463	10.443	2.194
Average	2.065	-0.019	19.594	-4.019

6. CONCLUSIONS

The nonparametric study of electricity substitution to petroleum products in Jordan during 1971-2007 has enabled us to test whether substitution took place or not. We can conclude that electricity has substituted petroleum products during several periods but major substitutions occurred during 1971-1976 and 2004-2007. This conclusion is based on using the B-spline technique which allowed us to provide evidence about the growth, speed, and acceleration of the substitution process. Finally, there is clear evidence that B-splines are a useful tool in analyzing the substitution. They allow precise calculation of speed and acceleration of a phenomenon, thereby facilitating the link between its evolution and historical events.

NOTES

(a) The members of G11 block consist of, Croatia, Ecuador, El Salvador, Georgia, Honduras, Indonesia, Jordan, Morocco, Pakistan, Paraguay, and Sri Lanka.

(b) The G7 block is a group of seven industrialised countries which consist of Canada, France, Germany, Italy, Japan, United Kingdom, and United States.

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* [illegible] 2009/1/4 [illegible] .2009/6/3