Energy consumption and aggregate income in Italy: cointegration and causality analysis

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ENERGY CONSUMPTION AND AGGREGATE INCOME IN ITALY: COINTEGRATION AND CAUSALITY ANALYSIS

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ABSTRACT: The aim of this article is to assess the empirical evidence of the nexus between aggregate income and energy consumption for Italy during the period 1970-2009, using a time-series approach. After a brief introduction, a survey of the economic literature on this issue is shown, before discussing the data and introducing some econometric techniques. Stationarity tests reveal that both series are non-stationary, or I(1). Moreover, we found a cointegration relationship between the two variables. The short-run dynamics of the variables show that the flow of causality runs from energy use to GDP, and there is a long-run bi-directional causal relationship (or feedback effect) between the two series. Consequently, we conclude that energy is a limiting factor to GDP growth in Italy.

SUMMARY: 1. Introduction; 2. The nexus between energy consumption and GDP; 3. Econometric methodology and data; 4. Discussion of empirical results; 5. Concluding remarks and policy implications; 6. Suggestions for future researches.

KEYWORDS: Energy policies; energy consumption; GDP; stationarity; cointegration; causality; Italy.

JEL Codes: B22; C22; N54; Q43.

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1. – Introduction

The causal relation between energy consumption and economic growth has been a well-studied topic. Energy is one of essential factors for any country's economic development and therefore plays an important role in economy activities. Energy demand, supply and pricing impact on the socio-economic development, the living standards and the overall quality of life of the people (Iwayemi, 1998). On the other hand, higher level of economic development could induce more energy consumption.

Over the past three decades, a lot of studies – using the concepts of cointegration and Granger causality – focused on several countries and time periods. Since the pioneering study by Kraft and Kraft (1978), empirical findings are mixed and, for some countries, controversial (Ozturk, 2010). The results differ even on the direction of causality and the short-term versus long-term effects on energy policies. Depending upon what kind of causal relationship exists, its policy implications may be significant.

Moreover, multiple causality studies have been done for many countries in the world; however, few studies have been devoted to the analysis of this nexus for the Italian case: Soytas and Sari (2003, 2006), Zachariadis (2007), Lee and Chang (2007b), and Narayan and Smyth (2008).

So, this paper examines the nexus between real per capita GDP and per capita energy consumption in Italy for the period 1970-2009, using time series methodologies on stationarity, cointegration and causality. The results might help to define and implement the appropriate energy development policies in Italy. The data used are obtained by Total Economy Database (TED) and International Energy Agency (IEA).

The outline of this paper is as follows. Section 2 provides a survey of the economic literature on the nexus between energy consumption and GDP. Section 3 contains an overview of the applied empirical methodology and a brief discussion of the data used. Section 4 discusses our empirical results. Section 5 presents some concluding remarks and, finally, Section 6 gives suggestions for future researches.

2. – The nexus between energy consumption and GDP

The directions of the causality relationship between energy consumption and aggregate income could be categorized into four types, each of which has important implications for energy policy (Apergis and Payne, 2009a; Chen *et al.*, 2007; Payne, 2009).

As explained in Ozturk (2010), we can have:

- *Neutrality hypothesis:* if no causality exists between GDP and energy consumption. It implies that energy consumption is not correlated with GDP. The absence of Granger-causality supports the neutrality hypothesis as documented by Akarca and Long (1980), Yu and Hwang (1984), Yu and Choi (1985), Erol and Yu (1987), Yu *et al.* (1988), Yu and Jin (1992), Cheng (1996), Masih and Masih (1996), Glasure and Lee (1997), Fatai *et al.* (2002), Soytas and Sari (2003), Altinay and Karagol (2004), Chontanawat *et al.* (2006), Jobert and Karanfil (2007), Lee (2006), Soytas *et al.* (2007), Zachariadis (2007), Chiou-Wei *et al.* (2008), Karanfil (2008), Yuan *et al.* (2008), Chontanawat *et al.* (2009), Halicioglu (2009), Payne (2009), Soytas and Sari (2009), and Wolde-Rufael (2009).

- *Conservation hypothesis:* the unidirectional causality running from GDP to energy consumption. This hypothesis had empirical supports in Kraft and Kraft (1978), Abosedra and Baghestani (1989), Masih and Masih (1996), Cheng and Lai (1997), Cheng (1998, 1999), Soytas *et al.* (2001), Aqeel and Butt (2001), Soytas and Sari (2003), Soytas and Sari (2006), Lee (2006), Zachariadis (2007), Zamani (2007), Mehrara (2007), Lise and Van Montfort (2007), Lee and Chang (2007b), Chiou-Wei *et al.* (2008), Ang (2008), Zhang and Cheng (2009), and Wolde-Rufael (2009).

- *Growth hypothesis:* the unidirectional causality running from energy consumption to GDP. This hypothesis is in line with empirical findings in Stern (1993), Masih and Masih (1996), Glasure and Lee (1997), Stern (2000), Asafu-Adjaye (2000), Soytas and Sari (2003), Wolde-Rufael (2004), Thoma (2004), Lee (2005), Lee and Chang (2005), Soytas and Sari (2006), Lee (2006), Lee and Chang (2007b), Ho and Siu (2007), Climent and Pardo (2007), Ang (2007), Narayan and Smyth (2008), Chiou-Wei *et al.* (2008), Wolde-Rufael (2009), Odhiambo (2009), Tsani (2010), and Pereira and Pereira (2010).

- *Feedback hypothesis:* if there exists a bi-directional causality flow between GDP and energy consumption. The feedback hypothesis is documented by Hwang and Gum (1991), Masih and Masih (1996, 1997), Asafu-Adjaye (2000), Yang (2000), Hondroyiannis *et al.* (2000), Glasure (2002), Soytas and Sari (2003), Paul and Bhattacharya (2004), Oh and Lee (2004a, 2004b), Ghali and El Sakka (2004), Soytas and Sari (2006), Lee (2006), Zachariadis (2007), Mahadevan and Asafu-Adjaye (2007), Erdal *et al.* (2008), Belloumi (2009), Mishra *et al.* (2009), and Wolde-Rufael (2009).

Table 1 – A comparison of studies about causality analysis between energy consumption and GDP.

Authors	Countries	Study period	Causality
Kebede, Kagochi, Jolly (2010)	20 Sub-Saharan Africa countries	1980-2004	-
Pereira, Pereira (2010)	Portugal	1977-2003	EC → Y
Tsani (2010)	Greece	1960-2006	EC → Y
Belloumi (2009)	Tunisia	1971-2004	Y ⇆ EC
Halicioglu (2009)	Turkey	1960-2005	Neutral
Mishra, Smyth, Sharma (2009)	Pacific Island countries	1980-2005	Y ⇆ EC
Odhiambo (2009)	Tanzania	1971-2006	EC → Y
Payne (2009)	USA	1949-2006	Neutral
Soytas, Sari (2009)	Turkey	1960-2000	Neutral
Wolde-Rufael (2009)	17 African countries	1971-2004	Cameroon, Kenya: Neutral Gabon, Ghana, Togo, Zimbabwe: Y ⇆ EC Algeria, Benin, South Africa: EC → Y Egypt, Ivory Coast, Morocco, Nigeria, Senegal, Sudan, Tunisia, Zambia: Y → EC
Zhang, Cheng (2009)	China	1960-2007	Y → EC
Ang (2008)	Malaysia	1971-1999	Y → EC
Chiou-Wei, Chen, Zhu (2008)	Asian newly industrialized countries and USA	1970-2000	South Korea, Thailand, USA: Neutral Hong Kong, Indonesia, Malaysia, Taiwan: EC → Y Philippines, Singapore: Y → EC
Erdal* et al. *(2008)	Turkey	1970-2006	Y ⇆ EC
Karanfil (2008)	Turkey	1970-2005	Neutral
Narayan, Smyth (2008)	G7 countries	1972-2002	EC → Y
Yuan* et al. *(2008)	China	1963-2005	Neutral
Ang (2007)	France	1960-2000	EC → Y
Climent, Pardo (2007)	Spain	1984-2003	EC → Y
Ho, Siu (2007)	Hong Kong	1966-2002	EC → Y

Jobert, Karanfil (2007)	Turkey	1960-2003	Neutral
Lee, Chang (2007b)	18 developing countries, 22 developed countries	1971-2002 1965-2002	18 developing countries: Y → EC 22 developed countries: EC → Y
Lise, Van Montfort (2007)	Turkey	1970-2003	Y → EC
Mahadevan, Asafu-Adjaye (2007)	20 countries	1971-2002	Energy importers (developed countries): Y ⇆ EC
Mehrara (2007)	Oil exporting countries	1971-2002	Y → EC
Zamani (2007)	Iran	1967-2003	Y → EC
Zachariadis (2007)	G-7 countries	1960-2004	USA: Neutral France, Germany, Italy, Japan: Y ⇆ EC Canada, UK: Y → EC
Lee (2006)	11 developed countries	1960-2001	Germany, UK: Neutral Sweden, USA: Y ⇆ EC Belgium, Canada, Netherlands, Switzerland: EC → Y France, Italy, Japan: Y → EC
Soytas, Sari (2006)	G-7 countries	1960-2004	France: Neutral Canada, Italy, Japan, UK: Y ⇆ EC USA: EC → Y Germany: Y → EC
Lee (2005)	18 developing countries	1975-2001	EC → Y
Lee, Chang (2005)	Taiwan	1955-2003	EC → Y
Altinay, Karagol (2004)	Turkey	1950-2000	Neutral
Ghali, El Sakka (2004)	Canada	1961-1997	Y ⇆ EC
Oh, Lee (2004a, 2004b)	South Korea	1970-1999	Y ⇆ EC
Paul, Bhattacharya (2004)	India	1950-1996	Y ⇆ EC
Thoma (2004)	USA	1973-2000	EC → Y
Wolde-Rufael (2004)	Shanghai	1952-1999	EC → Y
Soytas, Sari (2003)	G-7 countries	1950-1992	Brazil, Canada, India, Indonesia, Mexico, Poland, South

	10 emerging markets		Africa, UK, USA: Neutral Argentina: Y ⇆ EC France, Germany, Japan, Turkey: EC → Y Italy, South Korea: Y → EC
Fatai* et al. *(2002)	New Zealand	1960-1999	Neutral
Glasure (2002)	South Korea	1961-1990	Y ⇆ EC
Hondroyiannis* et al. *(2002)	Greece	1960-1996	Y ⇆ EC
Aqeel, Butt (2001)	Pakistan	1955-1996	Y → EC
Asafu-Adjaye (2000)	4 developing countries	1971-1995	Philippines, Thailand: Y ⇆ EC India, Indonesia: EC → Y
Soytas* et al. *(2001)	Turkey	1960-1995	Y → EC
Stern (2000)	USA	1947-1994	EC → Y
Yang (2000)	Taiwan	1954-1997	Y ⇆ EC
Cheng (1999)	India	1952-1995	Y → EC
Cheng (1998)	Japan	1952-1995	Y → EC
Cheng, Lai (1997)	Taiwan	1955-1993	Y → EC
Glasure, Lee (1997)	Singapore and South Korea	1961-1990	South Korea: Neutral Singapore: EC → Y
Masih, Masih (1997)	Taiwan, South Korea	1955-1992	Y ⇆ EC
Masih, Masih (1996)	6 Asian countries	1955-1990	Malaysia, Philippines, Singapore: Neutral Pakistan: Y ⇆ EC India: EC → Y Indonesia: Y → EC
Cheng (1995)	USA	1947-1990	Neutral
Stern (1993)	USA	1947-1990	EC → Y
Yu, Jin (1992)	USA	1974-1990	Neutral

Hwang, Gum (1991)	Taiwan	1961-1990	Y ⇆ EC
Abosedra, Baghestani (1989)	USA	1947-1987	Y → EC
Erol, Yu (1987)	Japan	1950-1982	Neutral
Yu, Choi (1985)	South Korea	1954-1976	Neutral
Yu, Hwang (1984)	USA	1947-1979	Neutral
Akarca, Long (1980)	USA	1950-1970	Neutral
Kraft, Kraft (1978)	USA	1947-1974	Y → EC

Sources: our elaborations.

Table 1 above presents a concise overview on causality between aggregate income and energy consumption discussed in several studies on this topic.

3. – Econometric methodology and data

In this research we use time-series econometric analysis. So, the VAR (*Vector AutoRegressive*) and VEC (*Vector Error Correction*) models were used[2].

Most of time series have unit root as many studies indicated, including Nelson and Plosser (1982), and as proved by Stock and Watson (1988) and Campbell and Perron (1991) among others, that most of the time series are non-stationary. The presence of a unit root in any time series means that the mean and variance are not independent of time. Conventional regression techniques based on non-stationary time series produce spurious regression and statistics may simply indicate only correlated trends rather than a true relationship (Granger and Newbold, 1974). Spurious regression can be detected in regression model by low Durbin-Watson statistics and relatively moderate R^2.

One of the most widely used unit root test is the ADF unit root test (Dickey and Fuller, 1979, 1981). Alternatively, Phillips (1987) and Phillips and Perron (1988) proposed a nonparametric method to correct a wide variety of serial correlation and heteroskedasticity (PP). Perron (1989, 1990) demonstrates that if a time series exhibits stationary fluctuations around a trend or a level containing a structural break, then unit root tests will erroneously conclude that there is a unit root. PP and ADF tests have the same asymptotic distributions.

Elliott, Rothenberg, and Stock (DF-GLS, 1996) proposed a modified Dickey-Fuller t test (known as the DF-GLS test). Essentially, the test is an augmented Dickey-Fuller test, except that the time series is transformed via a generalized least squares (GLS) regression before performing the test. The augmented Dickey–Fuller test involves fitting a regression of the form

$$\Delta y_t = \alpha + \beta y_{t-1} + \delta t + \xi_1 \Delta y_{t-1} + \xi_2 \Delta y_{t-2} + \ldots + \xi_k \Delta y_{t-k} + \varepsilon_t \qquad [1]$$

and then testing the null hypothesis H_0: $\beta=0$. The DF-GLS test is performed analogously but on GLS-detrended data. The null hypothesis of the test is that y_t is a random walk, possibly with drift.

[2] For a detailed analysis of the time-series modelling used see, among others: Lütkepohl, H., (2005), *New Introduction to Multiple Time Series Analysis*, Milan: Springer-Verlag; Enders, W., (2003), *Applied Econometric Time Series*, Chichester: Wiley; Dagum, E.B., (2002), *Analisi delle serie storiche: modellistica, previsione e scomposizione*, Milan: Springer-Verlag; Franses, P.H., (2002), *Time series models for business and economic forecasting*, Cambridge: Cambridge University Press; Hamilton, J.D., (1994), *Time Series Analysis*, Princeton: Princeton University Press.

Finally, the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS, 1992) test differs from those unit root tests in common use (such as ADF, PP, and DF-GLS) by having a null hypothesis of stationarity. The test may be conducted under the null of either trend stationarity (the default) or level stationarity. Inference from this test is complementary to that derived from those based on the Dickey-Fuller distribution.

Then we examine the unit root (or stationarity) properties of the variables, accounting for structural breaks. The present paper employs Zivot and Andrews (ZA, 1992) test to address this issue. The Zivot and Andrews test is performed by running the following regressions:

$$x_t = \mu + \beta t + \alpha x_{t-1} + \sum_{i=1}^{k} \delta_i \, \Delta x_{t-i} + \varepsilon_t \qquad [2]$$

for $t=1,\dots,T$, where x_t is a potentially non-stationary time-series, and the terms Δx_{t-i}, $i=1,\dots,k$ are included to purge any serial correlation among residuals.

Furthermore, Clemente, Montañés and Reyes (CMR, 1998) have developed a procedure allowing for a gradual shift in the mean to test more than one break point.

The non-stationary series with the same order of integration may be cointegrated if there exist some linear combination of the series that can be tested for stationarity. The Johansen and Juselius procedure (Johansen, 1988; Johansen and Juselius, 1990) is preferable to test for cointegration for more than two series.

Moreover, Johansen and Juselius procedure is considered better than Engle-Granger even in two time series case and has better small sample properties since it allows feedback effects among the variables under investigation where it is assumed in the Engle and Granger procedure that there are no feedback effects between the variables. The procedure is based on likelihood ratio (LR) test to determine the number of cointegration vectors in the regression. Johansen technique enables to test for the existence of non-unique Cointegration relationships.

Three tests statistics are suggested to determine the number of cointegration vectors: the first is Johansen's "trace" statistic method, the second is his "maximum eigenvalue" statistic method, and the third method chooses r to minimize an information criterion.

Having established the long-run equilibrium relationship between government expenditure and revenues, the short-run adjustments are estimated using the error correction model (ECM). The error correction model is based on the two following equations:

$$\Delta X_t = \alpha_0 + \alpha_1 e_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta X_{t-i} + \sum_{i=1}^{n} \alpha_j \Delta Y_{t-i} + \varepsilon_t \qquad [3]$$

$$\Delta Y_t = \beta_0 + \beta_1 u_{t-1} + \sum_{i=1}^{m} \beta_i \Delta Y_{t-i} + \sum_{i=1}^{n} \beta_j \Delta X_{t-i} + \eta_t \qquad [4]$$

where e_{t-1} and u_{t-1} represent the error-correction terms which are the lagged residuals from the cointegration relations. The error correction terms will capture the speed of the short-run adjustments toward the long-run equilibrium. Furthermore, the error correction model equations (3) and (4) allow to test for short-run as well the long-run causality between government expenditure and aggregate income.

The short-run causality is based on a standard F-test statistics to test jointly the significance of the coefficients of the explanatory variable in their first differences. The long-run causality is based on a standard t-test. Negative and statistically significant values of the coefficients of the error correction terms indicate the existence of long-run causality.

For the purpose of this paper, all the variables analyzed have been expressed in a logarithmic scale. Our empirical study uses the time-series data of real per capita GDP and per capita energy consumption for the 1970-2009 period in Italy. Data are obtained from the Total Economy Database (2010) maintained and updated by the Conference Board of the Groningen Growth and Development Centre, and from International Energy Agency (IEA)[3]. In this paper, per capita energy consumption is expressed in terms of kg oil equivalent while per capita GDP is expressed in constant 1990 US$. The choice of the starting period was constrained by the availability of data on energy consumption.

In Table 2 variables of the model are summed up. All series contains yearly data for real value of the variables.

Table 2 – List of variables.

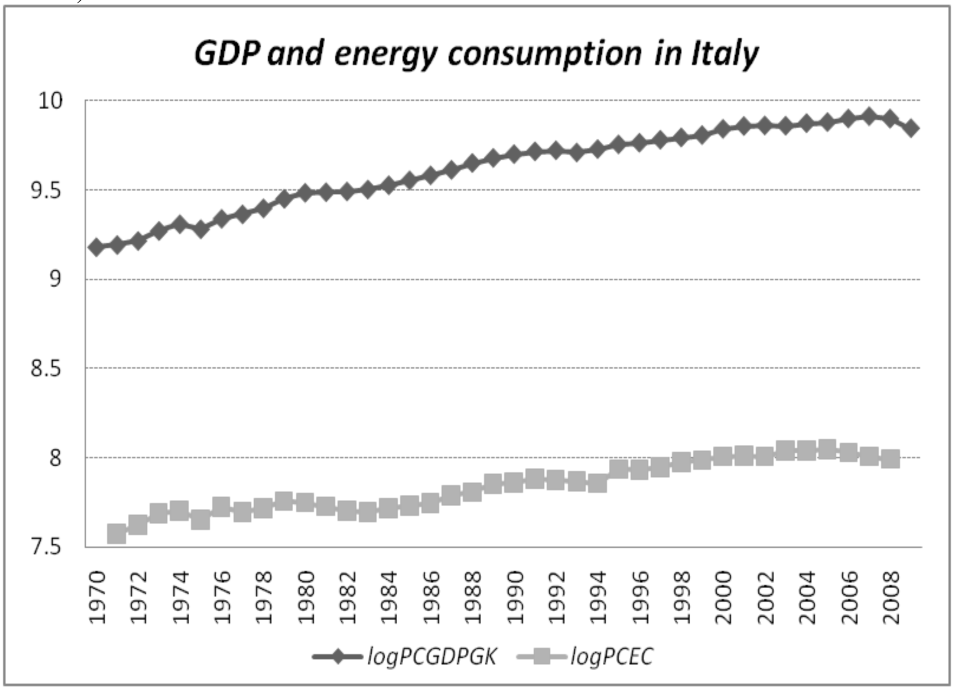
Variable	***Explanation***
PCGDPGK	Per capita GDP in 1990 US $, converted at Geary-Khamis PPPs thousand million LIT
PCEC	Per capita energy consumption, kg of oil equivalent

Sources: TED and IEA data.

Figure 1 shows the historical trends of real per capita GDP and per capita energy consumption for Italy in a log-scale.

[3] See, for more information: http://www.ggdc.net/databases/ted.htm and http://www.iea.org/.

Figure 1 – Real per capita GDP and energy consumption in Italy (1970-2009, log-scale).



Sources: our elaborations on TED and IEA data.

As a preliminary analysis, some descriptive statistics are presented in the following Table 3.

Table 3 – Exploratory data analysis.

Variable	*Mean*	*Median*	*Standard Deviation*	*Skew-ness*	*Kurtosis*	*Range*
PCGDPGK	9.6188	9.6891	0.2255	-0.4702	1.9620	0.7286
PCEC	7.8408	7.8536	0.1391	0.0076	1.6646	0.4700

Sources: our calculations on TED and IEA data.

The two series are strongly correlated. In fact, the correlation coefficient (*r*) is equal to 0.9494.

4. – Discussion of empirical results

Above all, we obtained log-transformations of the time-series. As a preliminary analysis, Inter-Quartile Range show the absence of outliers in our samples. Then, we applied time-series techniques on stationarity and unit root processes, in order to check some stationarity properties. Table 4 contains results of common unit root tests, for our variables.

Table 4 – Results for stationarity tests.

Variable	***Stationarity tests***				
	Deterministic component	**ADF**	**ERS**	**PP**	**KPSS**
PCGDPGK	intercept, trend	NS: -3.018	NS: -0.081	NS: -2.935	NS: 2.010
PCEC	intercept, trend	NS: -2.233	NS: -2.104	NS: -2.307	NS: 0.134
ΔPCGDPGK	intercept, trend	DS: -4.897	DS: -3.751	DS: -4.897	DS: 0.066
ΔPCEC	intercept	DS: -6.366	DS: -2.797	DS: -6.391	NS: 0.172

Notes: NS: Non Stationary; DS: Difference Stationary.
Source: our calculations on TED and IEA data.

The third column presents results for Augmented Dickey and Fuller (1979) test; the fourth one for Elliott, Rothenberg and Stock (1992) test; the fifth column contains results for Phillips and Perron (1988) test; in the last column there are results for Kwiatkowski, Phillips, Schmidt and Shin (1992) test. Here, results indicate that the two series are nonstationary according to their levels, but stationary in first differences. This indicates that the *PCGDPGK* and *PCEC* variables of Italy are individually *I(1)*. Given that integration of the two series is of the same order, we continue to test whether the two series are cointegrated over the sample period.

Table 5 – Results for unit root tests with structural breaks.

Variable	***TB***	***k***	***t-stat***	***1% Critical Value***	***5% Critical Value***
PCGDPGK	1992	1	-1.805	-5.57	-5.08
PCEC	1981	1	-3.229	-5.57	-5.08
ΔPCGDPGK		0	-5.337	-5.57	-5.08
ΔPCEC		0	-7.562	-5.57	-5.08

Sources: our calculations on TED and IEA data.

The results of the Zivot and Andrews unit root test are summarized in Table 5. An examination of these results indicate that the null hypothesis of a unit root cannot be rejected in levels for the two series. When these are examined in first differences, it is found that we can reject the null hypothesis at a 1% level of significance for energy consumption, and at a 5% level for the real per capita GDP. Therefore, each of these series can be characterized as an *I(1)* process.

Table 6 – Results for additive outlier unit root tests.

Variable	***SB***	***k***	***t-stat***	***5% Critical Value***
PCGDPGK	1993	1	-2.432	-3.560
PCEC	1982	1	-3.344	-3.560
ΔPCGDPGK		0	-5.130	-3.560
ΔPCEC		0	-7.025	-3.560

Sources: our calculations on TED and IEA data.

From the Table 6 above, we note that the break detected by the Clemente *at al.* test roughly corresponds to the timing of the signing of the Maastricht Treaty for *PCGDPGK*, and to the second oil shock for *PCEC*. Here, results are in line with those found with the Zivot and Andrews test. Despite the structural break, we are unable to reject the null hypothesis of a unit root in this series; yet, if we perform the test at the first differences, our series become stationary: so, we can conclude again that GDP and energy consumption are *I(1)* processes.

Since the series examined have the same order of integration, this paper is able to perform the Johansen and Juselius cointegration procedure. Cointegration tests have been subsequently applied, in order to find the long-run relationship between real per capita GDP (*PCGDPGK*) and energy consumption (*PCEC*). Therefore, to carry out the test, we need to make an assumption regarding the trend underlying our data. We assume here that the level data have no deterministic trends and the cointegrating equations have intercepts. The choice of this specification is based on the investigation of the graphs of the two series and the unit root tests, which indicate that the two series do not have a common deterministic trend.

The lag-order selection has been chosen according to the final prediction error (FPE), Akaike's information criterion (AIC), Schwarz's Bayesian information criterion (SBIC), and the Hannan and Quinn information criterion (HQIC): two lag intervals in first differences, for both series.

Starting with the null hypothesis of no cointegration among the variables, H_0: $r_0=0$, the trace test as shown in Table 7, the null hypothesis of no cointegration is rejected at the 5% level of significance. Hence, results of both tests imply that we reject the hypothesis of no cointegrating equation at the 5% significance level. Turning to the maximal eigenvalue statistic is 26.7013, which is above the 5% critical value of 19.96. Hence, the null hypothesis of $r_0=0$ is rejected at the 5% level of significance. However, under H_0: $r_0=1$, the trace and maximum eigenvalue statistics are equal to 2.7037, which are below the 5% critical value of 9.42 and 9.24, respectively. Hence, the null hypothesis is accepted at the 5% significance level. These results imply that the two *PCEC* and *PCGDPGK* series have one cointegrating equation; in other words, there is a long-run relationship between real per capita GDP and per capita energy consumption for Italy. Cointegration implies the existence of Granger causality; however, it does not indicate the direction of the causality relationship.

Table 7 – Results for cointegration tests between real per capita GDP growth and energy consumption.

Johansen and Juselius procedure		
Rank = 1	Rank = 1	Rank = 1
Trace statistic: 2.7037	Maximum-eigenvalue statistic: 2.7037	SBIC: -9.7784
5% Critical Value: 9.42	5% Critical Value: 9.24	HQIC: -10.0074
Log-Likelihood: 190.3446	Log-Likelihood: 190.3446	AIC: -10.1303

Notes: 5% Critical Values in parenthesis.
Source: our calculations on TED and IEA data.

Since the two series are cointegrated, a VECM is set up for investigating short- and long-run causality. The lag of the system is decided by the HQIC criterion to be 2. Estimation of the VECM gives the cointegrating vector as (1, -5.96, -0.51). We have normalized the cointegrating equation with respect to the *PCEC* coefficient. The coefficient of the ECT is found to be statistically significant and negative in the two equations at the 1% level. This result implies that the *PCGDPGK* and *PCEC* variables are not weakly exogenous, suggesting bi-directional long-run causality (feedback effect) between real per capita GDP and energy consumption.

Table 8 shows the results of the causality test based on the VECM. Granger causality tests suggest a bi-directional flow, at 1% significance level, for real per capita GDP and energy consumption in the Italian case, in the short-run; and a unidirectional flow, in the direction from *PCEC* to *PCGDPGK* in the short-run (at 10% level). Additionally, by using a joint F-test, we confirm the bi-directional long-run causality between energy consumption and GDP because we reject, at the 5% level, the null hypotheses that the coefficients on the ECTs and the interaction terms are jointly zero in both *PCGDPGK* and *PCEC* equation.

Table 8 – Results for short and long-run causality tests.

Lags	*Log-likelihood*	*SBIC*	*Causality in the long-run*	*Causality in the short-run*
2	189.4949	-9.7312	PCEC ⇆ PCGDPGK	PCEC → PCGDPGK

Source: our calculations on TED and IEA data.

As regard the robustness of the VECM, for all our equations, a Lagrange-multiplier (LM) test for autocorrelation in the residuals of Vector Error-Correction Model (VECM) clarifies as at the 5% significance level we cannot reject the null hypothesis that there is no serial correlation in the residuals for the orders 1,…,5 tested. Using the Portmanteau autocorrelation test, the Box-Pierce and Ljung-Box Q-statistics are equal to 22.19 and 28.01, respectively. Thus, we accept the null hypothesis of no serial correlation up to lag 12. Checking the eigenvalue stability condition in a VECM, the eigenvalues of the companion matrix lie inside the unit circle, and the real roots are far from 1 (0.86). As regard the Wald lag-exclusion statistics, we strongly reject the hypothesis that the coefficients either on the first lag or on the second lag of the endogenous variables are zero in all two equations jointly. The Jarque and Bera normality test results present statistics for each equation and for all equations jointly against the null hypothesis of normality. For our models, results suggest normality: in fact, the Jarque-Bera statistics are equal to 8.84 in the *PCGDPGK* equation and 4.84 in the *PCEC* equation, which indicate that we accept the null hypothesis of normality of the residuals. The joint test statistics of the White homoskedasticity test with the no cross terms is 18.67, with a P-Value of 0.41, so we accept the null hypothesis of non-heteroskedasticity at a 5% confidence level. Hence, the model passes all the tests successfully and the residuals are Gaussian white noise. Finally, the analysis of ARCH effects shows the absence of this problem for the estimated model.

5. – Conclusions and policy implications

The purpose of this paper is to contribute to the literature on the nexus between GDP and energy consumption, using recent econometric techniques. So, we studied the relationship between real per capita GDP and per capita energy consumption for Italy, using annual data covering the period 1970-2009. The time-series properties of the data were assessed using several unit root tests (ADF, DF-GLS, PP, and KPSS). Furthermore, in order to evaluate the presence of eventual structural breaks, some tests (ZA and CMR) have been conducted. Empirical findings indicate that both series are clearly non-stationary, as a *I(1)* process.

Then, cointegration analysis revealed that there is a long-run relationship between GDP and energy consumption. Based on a VEC model after testing for multivariate cointegration between per capita energy use and per capita GDP, we found that energy enters significantly into the cointegration space. The short-run dynamics of the variables show that the flow of causality runs from energy use to GDP, and there is a long-run bi-directional causal relationship (or feedback effect) between the two series. Yet, if there is a bi-directional causal relationship, then economic growth may demand more energy, whereas more energy consumption may also induce economic growth. So, energy consumption and economic growth complement each other such that radical energy conservation measures may significantly hinder economic growth (Yang, 2000; Belloumi, 2009). Consequently, we conclude that energy is a limiting factor to GDP growth in Italy, and, therefore, shocks to the energy supply will have a negative effect on aggregate income.

6. – Suggestions for future researches

Further analysis may be conducted studying the nexus between different sources of energy and aggregate income in Italy. This could be of help to the debate on Italy's return to nuclear power. Conclusions for Italy may be relevant for a number of countries that have to go through a similar development path of increased pressure on already scarce energy resources.

References

Abosedra, S., Baghestani, H., (1989), New evidence on the causal relationship between United States energy consumption and gross national product, *Journal of*

Energy Development, 14, 285-292.

Akarca, A.T., Long, T.V., (1980), On the relationship between energy and GNP: a reexamination, *Journal of Energy Development*, 5, 326-331.

Akinlo, A.E., (2008), Energy consumption and economic growth: evidence from 11 Sub-Sahara African countries, *Energy Economics*, 30 (5), 2391-2400.

Al-Iriani, M.A., (2006), Energy-GDP relationship revisited: an example from GCC countries using panel causality, *Energy Policy*, 34 (17), 3342-3350.

Altinay, G., Karagol, E., (2004), Structural break, unit root, and the causality between energy consumption and GDP in Turkey, *Energy Economics*, 26 (6), 985-994.

Amirat, A., Bouri, A. (2010), Energy and Economic Growth: The Algerian Case, typewritten.

Ang, J.B., (2007), CO_2 emissions, energy consumption, and output in France, *Energy Policy*, 35,4772-4778.

Ang, J.B., (2008), Economic development, pollutant emissions and energy consumption in Malaysia, *Journal of Policy Modeling*, 30, 271-278.

Aqeel, A., Butt, M.S., (2001), The relationship between energy consumption and economic growth in Pakistan, *Asia Pacific Development Journal*, 8 (2), 101-110.

Apergis, N., Payne, J.E., (2009a), Energy consumption and economic growth in Central America: evidence from a panel cointegration and error correction model, *Energy Economics*, 31, 211-216.

Apergis, N., Payne, J.E., (2009b), Energy consumption and economic growth: evidence from the Commonwealth of Independent States, *Energy Economics*, 31 (5), 641-647.

Apergis, N., Payne, J.E., (2009c), CO_2 emissions, energy usage, and output in Central America, *Energy Policy*, 37(8), 3282-3286.

Asafu-Adjaye, J., (2000), The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries, *Energy Economics*, 22, 615-625.

Belloumi, M., (2009), Energy consumption and GDP in Tunisia: cointegration and causality analysis, *Energy Policy*, 37 (7), 2745-2753.

Bowden, N., Payne, J.E., (2009), The causal relationship between US energy consumption and real output: a disaggregated analysis, *Journal of Policy Modeling*, 31 (2), 180-188.

Cheng, B.S., (1995), An investigation of cointegration and causality between energy consumption and economic growth, *Journal of Energy Development*, 21, 73-84.

Cheng, B.S., (1997), Energy consumption and economic growth in Brazil, Mexico and Venezuela: a time series analysis, *Applied Economics Letters*, 4 (11), 671-674.

Cheng, B.S., Lai, T.W., (1997), An investigation of co-integration and causality between energy consumption and economic activity in Taiwan, *Energy Economics*, 19 (4), 435-444.

Cheng, B.S., Lai, T.W., (1997), An investigation of co-integration and causality between energy consumption and economic activity in Taiwan, *Energy Economics*, 19 (4), 435-444.

Cheng, B.S., (1999), Causality between energy consumption and economic growth in India: an application of cointegration and error-correction modeling, *Indian Economic Review*, 34, 39-49.

Chiou-Wei, S.Z., Chen, Ching-Fu, Zhu, Z., (2008), Economic growth and energy consumption revisited-evidence from linear and non linear Granger causality, *Energy Economics*, 30(6), 3063-3076.

Chontanawat, J., Hunt, L.C., Pierse, R., (2008), Does energy consumption cause

economic growth? Evidence from a systematic study of over 100 countries, *Journal of Policy Modeling*, 30, 209-220.
Climent, F., Pardo, A., (2007), Decoupling factors on the energy-output linkage: the Spanish case, *Energy Policy*, 35, 522-528.
De Janosi, P.E., Grayson, L.E., (1992), Patterns of energy consumption and economic growth and structure, *Journal of Development Studies*, 8 (2), 241-249.
Erdal, G., Erdal, H., Esengün, K., (2008), The causality between energy consumption and economic growth in Turkey, *EnergyPolicy*, 36(10), 3838-3842.
Erol, U., Yu, E.S.H., (1987), On the causal relationship between energy and income for industrialized countries, *Journal of Energy Development*, 13, 113-122.
Fatai, K., Oxley, L., Scrimgeour, F., (2002), Energy consumption and employment in New Zealand: searching for causality, paper presented at NZAE Conference, Wellington, 26-28 June 2002.
Francis, B.M., Moseley, L., Iyare, S.O., (2007), Energy consumption and projected growth in selected Caribbean countries, *Energy Economics*, 29, 1224-1232.
Ghali, K.H., El-Sakka, M.I.T., (2004), Energy use and output growth in Canada: a multivariate cointegration analysis, *Energy Economics*, 26, 225-238.
Glasure, Y.U., Lee, A., (1997), Cointegration, error correction and the relationship between GDP and energy: the case of South Korea and Singapore, *Resource and Energy Economics*, 20, 17-25.
Glasure, Y.U., (2002), Energy and national income in Korea: further evidence on the role of omitted variables, *Energy Economics*, 24, 355-365.
Halicioglu, F., (2009), An econometric study of CO_2 emissions, energy consumption, income and foreign trade in Turkey, *Energy Policy*, 37,1156-1164.
Hondroyiannis, G., Lolos, S., Papapetrou, E., (2002), Energy consumption and economic growth: assessing the evidence from Greece, *Energy Economics*, 24, 319-336.
Hu, J.L., Lin, C.H., (2008), Disaggregated energy consumption and GDP in Taiwan: a threshold co-integration analysis, *Energy Economics*, 30, 2342-2358.
Huang, B.N., Hwang, M.J., Yang, C.W., (2008), Causal relationship between energy consumption and GDP growth revisited: a dynamic panel data approach, *Ecological Economics*, 67, 41-54.
Hwang, D., Gum, B., (1991), The causal relationship between energy and GNP: the case of Taiwan, *Journal of Energy Development*, 16, 219-226.
Iwayemi, A., (1998), Energy sector development in Africa, African Development Report.
Jobert, T., Karanfil, F., (2007), Sectoral energy consumption by source and economic growth in Turkey, *Energy Policy*, 35, 5447-5456.
Karanfil, F., (2008), Energy consumption and economic growth revisited: does the size of unrecorded economy matter?, *Energy Policy*, 36 (8), 3029-3035.
Karanfil, F., (2009), How many times again will we examine the energy-income nexus using a limited range of traditional econometric tools?, *Energy Policy*, 36, 1191-1194.
Kebede, E., Kagochi, J, Jolly, C.M., (2010), Energy consumption and economic development in Sub-Saharan Africa, *Energy Economics*, 32, 532-537.
Kraft, J., Kraft, A., (1978), On the relationship between energy and GNP, *Journal of Energy and Development*, 3, 401-403.
Lee, C.C., (2005), Energy consumption and GDP in developing countries: a cointegrated panel analysis, *Energy Economics*, 27, 415-427.
Lee, C.C., (2006), The causality relationship between energy consumption and GDP in G-11 countries revisited, *Energy Policy*, 34, 1086-1093.

Lee, C.C., Chang, C.P., (2005), Structural breaks, energy consumption, and economic growth revisited: evidence from Taiwan, *Energy Economics*, 27, 857-872.
Lee, C.C., Chang, C.P., (2007a), The impact of energy consumption on economic growth: evidence from linear and nonlinear models in Taiwan, *Energy*, 32 (12), 2282-2294.
Lee, C.C., Chang, C.P., (2007b), Energy consumption and GDP revisited: a panel analysis of developed and developing countries, *Energy Economics*, 29, 1206-1223.
Lee, C.C., Chang, C.P., (2008), Energy consumption and economic growth in Asian economies: a more comprehensive analysis using panel data, *Resource and Energy Economics*, 30 (1), 50-65.
Lee, C.C., Chang, C.P., Chen, P.F., (2008), Energy-income causality in OECD countries revisited: the key role of capital stock, *Energy Economics*, 30, 2359-2373.
Lise,W., Van Montfort, K., (2007), Energy consumption and GDP in Turkey: is there a co-integration relationship?, *Energy Economics*, 29, 1166-1178.
Mahadevan, R., Asafu-Adjaye, J., (2007), Energy consumption, economic growth and prices: a reassessment using panel VECM for developed and developing countries, *Energy Policy*, 35 (4), 2481-2490.
Masih, A., Masih, R., (1996), Energy consumption and real income temporal causality, results for a multi-country study based on cointegration and error-correction techniques, *Energy Economics*, 18, 165-183.
Masih, A.M.M., Masih, R., (1997), On temporal causal relationship between energy consumption, real income and prices; some new evidence from Asian energy dependent NICs based on a multivariate cointegration/vector error correction approach, *Journal of Policy Modeling*, 19 (4), 417-440.
Mehrara, M., (2007), Energy consumption and economic growth: the case of oil exporting countries, *Energy Policy*, 35 (5), 2939-2945.
Mishra, V., Smyth, R., Sharma, S., (2009), The energy-GDP nexus: evidence from a panel of Pacific Island countries, *Resource and Energy Economics*, 31 (3), 210-220.
Nachane, D.M., Nadkarni, R.M., Karnik, A.V., (1988), Cointegration and causality testing of the energy–GDP relationship: a cross-country study, *Applied Economics*, 20 (11), 1511-1531.
Narayan, P.K., Smyth, R., (2008), Energy consumption and real GDP in G7 countries: new evidence from panel cointegration with structural breaks, *Energy Economics*, 30, 2331-2341.
Odhiambo, N.M., (2009), Energy consumption and economic growth nexus in Tanzania: an ARDL bounds testing approach, *Energy Policy*, 37 (2), 617-622.
Oh, W., Lee, K., (2004a), Causal relationship between energy consumption and GDP: the case of Korea 1970-1999, *Energy Economics*, 26 (1), 51-59.
Oh, W., Lee, K., (2004b), Energy consumption and economic growth in Korea: testing the causality relation, *Journal of Policy Modeling*, 26, 973-981.
Omotor, D.G., (2008), Causality Between Energy Consumption and Economic Growth in Nigeria, *Pakistan Journal of Social Sciences*, 5 (8), 827-835.
Ozturk, I., (2010), A literature survey on energy-growth nexus, *Energy Policy*, 38, 340-349.
Paul, S., Bhattacharya, R.N., (2004), Causality between energy consumption and economic growth in India: a note on conflicting results, *Energy Economics*, 26 (6), 977-983.
Payne, J.E., (2009), On the dynamics of energy consumption and output in the US, *Applied Energy*, 86 (4), 575-577.
Pereira A.M., Pereira, R.M.M., (2010), Is fuel-switching a no-regrets environmental

policy? VAR evidence on carbon dioxide emissions, energy consumption and economic performance in Portugal, *Energy Economics*, 32, 227-242.
Sari, R., Soytas, U., (2007), The growth of income and energy consumption in six developing countries, *Energy Policy*, 35, 889-898.
Shrestha, R.M., (2000), Estimation of international output-energy relation: effects of alternative output measures, *Energy Economics*, 22, 297-308.
Soytas, U., Sarı, R., Özdemir, O., (2001), Energy consumption and GDP relation in Turkey: a cointegration and vector error correction analysis, *Economies and Business in Transition*.
Soytas, U., Sari, R., (2003), Energy consumption and GDP: causality relationship in G-7 countries and emerging markets, *Energy Economics*, 25, 33-37.
Soytas, U., Sari, R., (2006), Energy consumption and income in G7 countries, *Journal of Policy Modeling*, 28, 739-750.
Soytas, U., Sari, R., (2009). Energy consumption, economic growth, and carbon emissions: challenges faced by an EU candidate member, *Ecological Economics*, 68 (6), 1667-1675.
Stern, D.I., (1993), Energy and economic growth in the USA. A multivariate approach, *Energy Economics*, 15, 137-150.
Stern, D.I., (2000), A multivariate cointegration analysis of the role of energy in the US macroeconomy, *Energy Economics*, 22, 267-283.
Tsani, S.Z., (2010), Energy consumption and economic growth: A causality analysis for Greece, *Energy Economics*, 32, 582-590.
Wolde-Rufael, Y., (2004), Disaggregated industrial energy consumption and GDP: the case of Shanghai, 1952-1999, *Energy Economics*, 26, 69-75.
Wolde-Rufael, Y., (2005), Energy demand and economic growth: the African experience, *Journal of Policy Modeling*, 27 (8), 891-903.
Wolde-Rufael, Y., (2009), Energy consumption and economic growth: the experience of African countries revisited, *Energy Economics*, 31 (2), 217-224.
Yang, H.Y., (2000), A note on the causal relationship between energy and GDP in Taiwan, *Energy Economics*, 22 (3), 309-317.
Yu, E.S.H., Hwang, B.K., (1984), The relationship between energy and GNP: further results, *Energy Economics*, 6, 186-190.
Yu, E.S.H., Choi, J.Y., (1985), The causal relationship between energy and GNP: an international comparison, *Journal of Energy and Development*, 10, 249-272.
Yu, E.S.H., Jin, J.C., (1992), Cointegration tests of energy consumption, income, and employment, *Resources and Energy*, 14, 259-266.
Yuan, J.-H., Kang, J.-G., Zhao, C.-H., Hu, Z.-G., (2008), Energy consumption and economic growth: Evidence from China at both aggregated and disaggregated levels, *Energy Economics*, 30, 3077-3094.
Zachariadis, T., (2007), Exploring the relationship between energy use and economic growth with bivariate models: New evidence from G-7 countries, *Energy Economics*, 29, 1233-1253.
Zamani, M., (2007), Energy consumption and economic activities in Iran, *Energy Economics*, 29, 1135-1140.
Zhang, X.-P., Cheng, X.-M., (2009), Energy consumption, carbon emissions, and economic growth in China, *Ecological Economics*, 68, 2706-2712.
Ziramba, E., (2009), Disaggregate energy consumption and industrial production in South Africa, *Energy Policy*, 37, 2214-2220.