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Article

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International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2017, 7(6), 119-127.

Renewable Energy Consumption-Economic Growth Nexus in Italy

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ABSTRACT

This study examines the renewable energy consumption-economic growth nexus in Italy over the period 1970–2007. Results of unit root tests show that all variables are non-stationary in their level form, but stationary in first differences. Cointegration analysis reveals that a single long-run relationship emerges. According to the long-run estimations, if renewable energy consumption increases by 1%, real gross domestic product (GDP) decreases by 0.23%. The Toda and Yamamoto approach shows that exists a unidirectional causal flow, running from renewable energy consumption to aggregate income, in line with the "growth hypothesis." Moreover, these results are confirmed by Granger causality tests. Forecast error variance decomposition evidence that the forecast errors in real GDP are mainly due to uncertainty in GDP itself and renewable energy consumption, while the errors in predicting the renewable energy consumption are sensitive to disturbances only in energy equation.

Keywords: Renewable Energy Consumption, Economic Growth, Causality, Italy
JEL Classifications: B22, C32, N54, Q43

1. INTRODUCTION

Unlike the enormous literature on the energy consumption-economic growth nexus for a lot of countries (i.e. Ozturk, 2010; Payne, 2010; Bo, 2011; Magazzino 2017, 2015, 2014; Magazzino and Giolli 2014, among others, for an exhaustive literature survey) few studies on this topic concern the Italian case. In a panel context, some studies have investigated G-7 or OECD countries (Soytas and Sari, 2006; Lee et al., 2008; Narayan and Prasad, 2008; Narayan and Smyth, 2008; Sadorsky, 2009; Apergis and Payne, 2010; Tugcu et al., 2012; Kula, 2014; Bhattacharya et al., 2016; Jebli et al., 2016; Rafindadi and Ozturk, 2017; Benavides et al., 2017; Taher, 2017; Hassine and Harrathi, 2017; Dogan and Ozturk, 2017).

Nevertheless, the acceptance of any hypothesis depends on its credible explanation of the economic reality across countries with different economic and institutional framework (Cheng, 1997).

The "growth hypothesis" states that energy consumption plays a relevant role in economic growth, both directly and indirectly, in the production process as a complement to labor and capital. The "conservation hypothesis" implies that conservation policies-aiming at reducing greenhouse emissions, improving energy efficiency and curtailing energy consumption and waste-boost real gross domestic product (GDP) by enhancing the efficiency of energy use. According to the "neutrality" hypothesis, energy consumption is not correlated with income. Finally, the "feedback" hypothesis suggests that more (less) energy consumption results in increases (decreases) in real GDP, and vice versa (Magnani and Vaona, 2013).

As stressed also by Vaona (2012) and Bastianelli (2006), adopting an Italian dataset is interesting because it can well represent the challenges facing countries that considerably depend on energy imports. In the specific case of Italy, Southern regions-traditionally characterized by development problems-received significant economic transfers within the framework of the structural funds (Colangelo, 2011).

The remainder of the paper is organized as follows. We first present an essential survey of previous results for the Italian case in Section 2. Section 3 illustrates the methodology, model and data, and follow with a discussion of the empirical findings in Section 4. Concluding remarks and policy implications are in Section 5.

2. A BRIEF SURVEY OF THE EMPIRICAL FINDINGS FOR ITALY

The directions of the causality relationship between energy production and aggregate income can be categorized into four types, each of which may have important implications for energy policy (Apergis and Payne, 2009; Magazzino, 2012).

As summarized by 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.
- Conservation hypothesis: A unidirectional causality running from GDP to energy consumption.
- Growth hypothesis: A unidirectional causality running from energy consumption to GDP.
- Feedback hypothesis: When there exists a bi-directional causality flow between GDP and energy consumption.

As regards study on the Italian case, Lee and Chien (2010) studied the dynamic linkages among energy consumption, capital stock, and real income in G-7 counties. A unidirectional relationship running from energy consumption to real income was observed. Chontanawat et al. (2008) tested for causality between energy and GDP using a dataset of 30 OECD and 78 non-OECD countries. In the case of Italy, they showed evidence of causality from energy to GDP. Zachariadis (2007) applied bivariate energy use-economic growth causality tests for G-7 countries. Bidirectional Granger-causality emerges for most sectors. Lee (2006) explored the causality relationship between energy consumption and GDP in G-11 countries. The results indicate that unidirectional causality running from GDP to energy consumption exists in Italy. Soytas and Sari (2006) analyzed the relationship between energy consumption and income in G-7 countries. For Italy, they found that causality seems to run both ways.

3. METHODOLOGY, MODEL AND DATA

The empirical strategy starts from the analysis of stationarity for time series variables. A linear combination of two non-stationary series can be stationary, and if such a stationarity exists, the series are considered to be cointegrated (Engle and Granger, 1987). Yet, this requires that the series have the same order of integration. Therefore, the Augmented Dickey and Fuller (ADF) (1979), the Elliott, Rothenberg, and Stock (ERS) (1996), the Phillips and Perron (PP) (1988), and the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) (1992) tests are performed to test whether the data are difference stationary or trend stationary, as well as to determine the number of unit roots at their levels. Moreover, we also check if any of the variables have structural breaks or estimate the long memory (fractional integration) parameter of a time-series in order to check results robustness. To this extent, the Zivot and Andrews (ZA) (1992), the Clemente, Montañés and Reyes (CMR) (1998), the Geweke and Porter-Hudak (GPH) (1983), the Lo (1991), and Robinson (1995) tests are performed.

If the variables are non-stationary at their levels and are in the same order of the integration, we can apply the Johansen and Juselius (1990) cointegration test.

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

However, due to the small sample size (38 annual observations) used in this study, the Johansen test statistics may be biased (Cheung and Lai, 1993). Therefore, we follow the approach by Reinsel and Ahn (1992), who suggest multiplying the Johansen trace statistics with the scale factor N/(N-pk), where N is the number of observation, k is the number of variables and p is the lag parameter in the estimated vector autoregression (VAR) system. Such a procedure corrects for small sample bias and allows more appropriate statistical interferences to be made with small samples. If the cointegrating relationship is found then in order to account for non-stationary variables vector error correction model has to be estimated.

In this study, two causality tests are considered. First, we applied Toda and Yamamoto tests (TD) (1995) test, which is available whether the series is I(0), I(1), or I(2), non-cointegrated, or cointegrated of any arbitrary order. To take on the Toda and Yamamoto non-causality test, for VAR (3), (k=2 and d_{max}=1), we estimate the next system equations, as in Ocal and Aslan (2013), Apergis and Danuletiu (2012), and Apergis and Payne (2014):

$$\begin{bmatrix} \ln Y_t \\ \ln RE_t \\ \ln K_t \\ \ln L_t \end{bmatrix} = A_0 + A_1 \begin{bmatrix} \ln Y_{t-1} \\ \ln RE_{t-1} \\ \ln K_{t-1} \\ \ln L_{t-1} \end{bmatrix} + A_2 \begin{bmatrix} \ln Y_{t-2} \\ \ln RE_{t-2} \\ \ln K_{t-2} \\ \ln L_{t-2} \end{bmatrix} + A_3 \begin{bmatrix} \ln Y_{t-3} \\ \ln RE_{t-3} \\ \ln K_{t-3} \\ \ln L_{t-3} \end{bmatrix} + \begin{bmatrix} \varepsilon \ln Y_t \\ \varepsilon \ln RE_t \\ \varepsilon \ln K_t \\ \varepsilon \ln L_t \end{bmatrix} \quad (1)$$

Furthermore, a "standard" Granger causality analysis has been developed. A time series X_t is said to Granger-cause another time series Y_t if the prediction error of current y declines by using past values of X in addition to past values of Y (Granger, 1969).

In addition to causality analyses, we present and discuss the forecast error variance decomposition (FEVD), determining how much of the forecast error variance of each of the variables can be explained by exogenous shocks to the other variables.

Annual data from 1970 to 2007 were obtained from the World Data Bank Development Indicators for Italy[1]. The end period has been selected in order to avoid the economic-financial crisis effects, which greatly influenced our variables. The econometric framework includes GDP (Y) in billions of constant 2000 US $, combustible renewables and waste % of total energy (RE) defined in thousands of metric tons, gross fixed capital formation (K) in billions of constant 2000 US $,and total labor force (L) in millions. This sample is dictated by data availability of RE variable (Table 1). Moreover, the current economic-financial crisis might represent a break in the data. For our purpose, the log transformation of the variables have been derived.

Figure 1 shows the dynamic of our series, where the two vertical bars correspond to the oils shocks occurred in the Seventies. In the right-side panel, the first-differences series are graphed. A visual inspection of the log-transformed series shows an upward trend for our variables, which are summed up in Table 1.

As a preliminary analysis, some descriptive statistics are summarized in Table 2. Mean value of all variables except renewable energy consumption is positive. Aggregate income, renewable energy consumption and labor have negative value of skewness, indicating that the distribution is skewed to the left, with more observations on the right. The kurtosis values are not so far from 3.

As shown in the last column, we cannot reject the null hypothesis of normal distribution for our series at 1% significance level. Moreover, the Doornik and Hansen (2008) multivariate normality test produces a χ^2=15.241 with a P=0.0546, confirming our previous findings.

The correlation analysis show that these series are strongly correlated: In fact, all the correlation coefficients (r) exceed 0.81 (Table 3).

In addition, these results are broadly confirmed by cross correlations analysis.

4. EMPIRICAL RESULTS

The inter-quartile range shows the absence of any severe outliers in the sample. After that, in order to check the stationarity properties, time series techniques on stationarity and unit root processes have been applied. As shown in Table 4, all the data series under consideration do not seem to fulfill these stationary properties in their level form (by ocular inspection), contrarily to the relative first differences. Nevertheless, for capital level series some contrasting findings emerge.

Thus, all series are non-stationary in their level form, but after taking the first difference we reject null hypothesis of non-stationary at the 5% level of significance. We conclude that the four series are integrated of order one, or I(1).

1 See, for more details: http://www.econstats.com/wdi/wdic_ITA.htm and http://www.iea.org/.

Table 1: List of the variables

Variable	Explanation	Source
Y	GDP (constant 2000 US$)	WDI
RE	Combustible renewables and waste (% of total energy)S	WDI
K	Gross fixed capital formation (constant 2000 US$)	WDI
L	Total labor force (Labor force statistics)	WDI

GDP: Gross domestic product

The results of ZA's unit root test are summarized in Table 5. The null hypothesis of a unit root cannot be rejected in levels. Yet, taking their first differences, it is found that we can reject everywhere the null hypothesis at 5% level of significance. Therefore, these results broadly confirm the previous ones of I(1).

As robustness checks, we also perform three additional tests on fractional integration parameter. The GPH test, the Lo test, and the Robinson test indicate that the series are not I(0) (Table 6).

From Table 7 we note that the breaks detected by the CMR tests roughly correspond to the turbulent first nineties years. Despite the structural break, we are unable to reject the null of unit root; notwithstanding, if we perform the tests at the first differences, the series are stationary: So, we can conclude that are I(1) processes. Moreover, results for CMR tests for two breaks confirm previous findings (Table 8).

Since the series examined have the same order of integration, we might perform the Johansen and Juselius cointegration test, in order to find a (potential) long-run relationship among real GDP, renewable energy consumption, capital formation, and labor force.

The lag-order selection has been chosen based on final prediction error, Akaike's information criterion, Schwarz's Bayesian information criterion (SBIC), and the Hannan and Quinn information criterion (HQIC): We present the results in Table 9.

To determine the appropriate restrictions in the model, we adopt the procedure described in Becketti (2013), starting with the estimation of two alternative models and moving from the nested model-which includes a restricted trend (Model 1), to the encompassing (Model 2), which includes a linear trend. Then we perform a likelihood-ratio (LR) test. It is important to note that in order to account for a small sample bias, the critical values were multiplied scale factor.

As can be seen from Table 10, the null hypothesis of no cointegrating relationship against alternative of at most one cointegrating relationship is rejected in Model 1 at a 5% level of significance, suggesting that one cointegrating relationship exists among variables. Although the 5% critical values were adjusted (lifted up) to account for a small sample bias, similar conclusions are reached. A LR test between Model 1 and 2 suggest that the previous is more adequate to our data.

Accordingly, the estimated coefficients indicate that renewable energy consumption has negative impacts on economic growth

Table 2: Exploratory data analysis

Variable	Mean	Median	SD	Skewness	Kurtosis	10-Trim	IQR	JB test
Y	13.6561	13.7308	0.2550	−0.4934	2.0762	13.68	0.3926	0.0995
RE	−0.1623	−0.2217	0.6074	−0.4895	3.7806	−0.13	0.4801	0.1355
K	12.0803	12.0692	0.2215	0.0825	1.8070	12.08	0.3467	0.0294
L	10.0688	10.0870	0.0829	−0.4253	2.2782	10.07	0.0989	0.2594

For the Jarque and Bera (JB) joint normality test, P values are reported. Sources: Our calculations on WDI data. SD: Standard deviation, IQR: Inter-quartile range

Table 3: Correlation matrix

Variable	Y	RE	K	L
Y	1.0000			
RE	0.8180* (0.0000)	1.0000 (0.0000)		
K	0.9646* (0.0000)	0.8129* (0.0000)	1.0000	
L	0.9817* (0.0000)	0.8247* (0.0000)	0.9616* (0.0000)	1.0000

Bonferroni's correction has been applied, P values are reported. *P<0.05

Table 4: Results for unit roots and stationarity tests

Variable	Unit root and stationarity tests				
	Deterministic component	ADF	ERS	PP	KPSS
Y	Constant, trend	−1.194	−0.417	−1.142	0.447***
		(−3.548)	(−3.273)	(−3.548)	(0.146)
RE	Constant, trendw	−2.978	−3.087*	−2.707	0.154**
		(−3.556)	(−3.283)	(−3.552)	(0.146)
K	Constant, trend	−4.056*	−4.165***	−2.886	0.0602
		(−3.552)	(−3.273)	(−3.548)	(0.146)
L	Constant, trend	−2.372	−1.801	−1.658	0.309***
		(−3.548)	(−3.264)	(−3.544)	(0.146)
ΔY	Constant	−4.960***	−4.547 ***	−4.960***	0.753***
		(−2.966)	(−2.355)	(−2.966)	(0.463)
ΔRE	Constant	−6.705***	−7.797***	−6.705***	0.0554
		(−2.969)	(−2.364)	(−2.969)	(0.463)
ΔK	Constant	−4.316***	−4.678***	−4.316***	0.0372
		(−2.966)	(−2.355)	(−2.966)	(0.463)
ΔL	Constant	−4.056***	−3.195***	−4.056***	0.203
		(−2.964)	(−2.346)	(−2.964)	(0.463)

The tests are performed on the log-levels of the variables. ADF: Augmented Dickey-Fuller, ERS: Elliot, Rothenberg, and Stock, PP: Phillips-Perron, and KPSS: Kwiatkowski, Phillips, Schmidt, and Shin refers respectively to the ADF test, the ERS point optimal test, the PP test, and the KPSS test. When it is required, the lag length is chosen according to the SBIC: Schwarz's Bayesian information criterion. 5% critical values are given in parentheses. ***P<0.01, **P<0.05, *P<0.1

Table 5: Results for unit root tests with structural breaks (both in intercept and in trend)

Variable	(a)			(b)		
	T_b	k	t_{min}	T_b	k	t_{min}
Y	1976	1	−2.437 (−4.80)	1988	1	−2.970 (−5.08)
RE	1985	1	−3.267 (−4.80)	1977	1	−3.958 (−5.08)
K	1993	2	−4.681* (−4.80)	1993	2	−4.953* (−5.08)
L	1993	2	−4.535 (−4.80)	1993	2	−4.318 (−5.08)
ΔY	1981	1	−6.783*** (−4.80)	1984	1	−6.747*** (−5.08)
ΔRE	1977	1	−7.493*** (−4.80)	1980	1	−7.019*** (−5.08)
ΔK	1991	2	−4.842** (−4.80)	1997	2	−4.847* (−5.08)
ΔL	1996	1	−4.887** (−4.80)	2002	1	−4.825* (−5.08)

(a) Refers to the model allowing for break in intercept and (b) the model allowing for break also in trend. T_b is the break date endogenously selected. t_{min} is the minimum t-statistic. k denotes the lag length. 5% critical values are given in parentheses. ***P<0.01, **P<0.05, *P<0.1

for Italy, with statistical significance at 1% level. In addition, accordingly with the literature, capital and labor have a positive effect on GDP, but RE is adversely affected. Also, if RE increases by 1%, GDP decreases by 0.23% (Table 11).

Granger causality tests following the Toda and Yamamoto approach requires the estimation of an augmented VAR (k+d) model, where k is the optimal lag length and d is the order of integration of the series. As shown in Table 9, all tests suggest inclusion of one lag in a VAR model and thus k=2; hence, the final model to be estimated is VAR (3). To ensure that the VAR model is well specified and does not suffer from any normality or serial autocorrelation problems, additional tests are carried out. Although the results are not reported to save space, diagnostic tests suggest the general absence of problems in the estimated VAR (3) model, with regard to normality and autocorrelation in

Table 6: Results for the long memory (fractional integration) parameter

Variable	GPH			Lo		Robinson	
	t	P	Standard error	Test statistic	t	P	Standard error
Y	22.4086	0.000***	0.0434	4.14	17.1689	0.000***	0.0441
RE	2.9651	0.041**	0.0713	1.17	4.8350	0.000***	0.1503
K	5.6808	0.005***	0.1751	4.53	12.0788	0.000***	0.0638
L	7.5870	0.002***	0.1302	4.08	16.8299	0.000***	0.0469
ΔY	1.4722	0.215	0.2334	1.35	1.1051	0.279	0.1012
ΔRE	−1.8696	0.135	0.2854	0.896	−1.6664	0.108	0.0874
ΔK	−2.4448	0.071*	0.4589	0.727	0.4106	0.684	0.1792
ΔL	1.6939	0.166	0.3960	0.904	2.9908	0.006***	0.1082

95% critical values for Lo modified R/S test: [0.809, 1.862]. ***P<0.01, **P<0.05, *P<0.1. GPH: Geweke and Porter-Hudak

Table 7: Results for additive outlier unit root tests (single structural break)

Variable	Optimal break point	k	t-stat	5% critical value
Y	1990	1	−2.396	−3.560
RE	2000	1	−2.914	−3.560
K	1991	2	−2.908	−3.560
L	1992	1	−1.984	-3.560
ΔY	1990	0	−6.471 ***	−3.560
ΔRE	1975	3	−7.585 ***	−3.560
ΔK	1991	2	−6.216 ***	−3.560
ΔL	1991	2	−4.680 ***	−3.560

***P<0.01, **P<0.05, *P<0.1

Table 8: Results for additive outlier unit root tests (two structural breaks)

Variable	Optimal break point	k	t-stat	5% critical value
Y	1980, 1991	4	−3.597	−5.490
RE	1996, 2002	5	−0.816	−5.490
K	1985, 1999	0	−3.453	−5.490
L	1981, 2004	2	−3.794	−5.490
ΔY	1981, 1991	5	−2.943	−5.490
ΔRE	1993, 2002	1	−6.620 ***	−5.490
ΔK	1973, 1988	0	−7.370 ***	−5.490
ΔL	1989, 1995	0	−5.514 **	−5.490

***P<0.01, **P<0.05, *P<0.1

Table 9: Lag order selection criteria (log-levels)

Lag	FPE	AIC	HQIC	SBIC
0	1.6e-09	−8.9036	−8.8424	−8.7240
1	4.9e-13	−17.0101	−16.7039	−16.1123
2	2.3e-13*	−17.7808*	−17.2296*	−16.1646*
3	3.7e-13	−17.4451	−16.6490	−15.1107
4	3.9e-13	−17.6122	−16.5711	−14.5595

*Indicates lag-order selected by each criterion

the residuals, stability condition, and lag-exclusion. Figure A in the Appendix clarifies that the stability of coefficient estimates is supported, since the plots of both CUSUM and CUSUMSQ fall inside the critical bounds of 5% significance. This indicates that the estimated parameters do not suffer from structural instability.

The results of Toda and Yamamoto Granger non-causality tests are presented in Table 12. For the multivariate model, empirical findings show that GDP is driven by renewable energy consumption. In the bargain, the unidirectional causality from energy to economic growth can be explained by the fact that an increase in energy consumption is linked to an increase of input use (Alam et al., 2012). Moreover, a bidirectional causality between capital formation and renewable energy consumption emerges.

However, the empirical evidence remains controversial and ambiguous until now, and there is no consensus in the literature on the economic level at which environmental degradation starts declining (Dinda, 2004). This is particularly important for developing countries where economic growth is still essential to escape from the poverty trap.

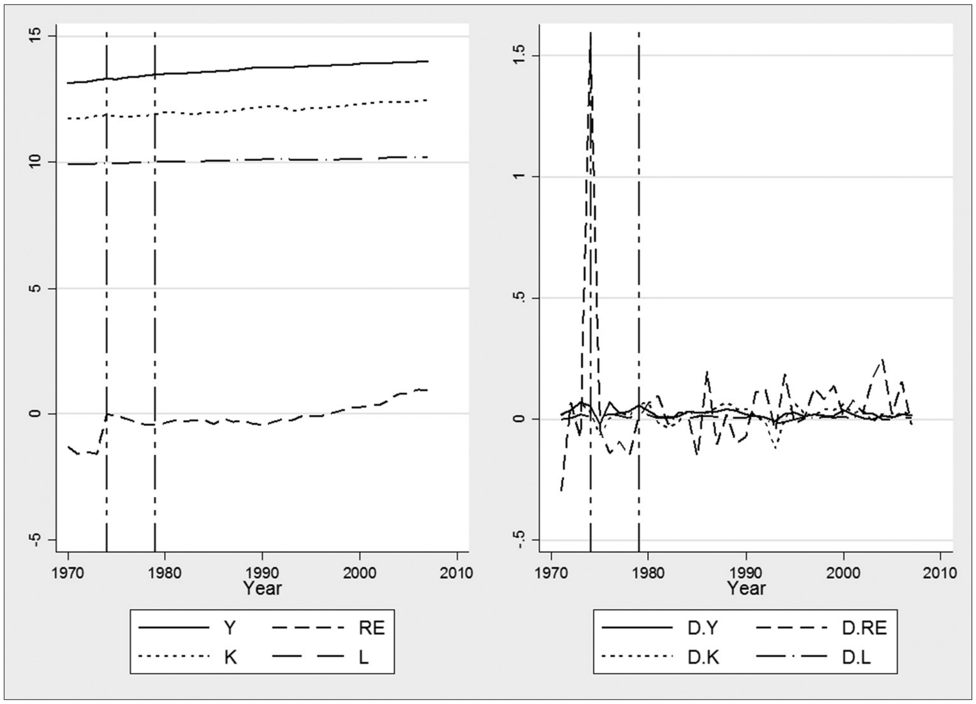
Results of the Granger causality tests indicate that the null hypothesis can be rejected only for a relationship between Y and RE as well as between K and RE-implying that renewable energy consumption Granger causes real aggregate income (RE→Y) but also capital formation (RE→K). Therefore, previous causality findings due to the Toda and Yamamoto approach are reinforced. These results are in line with estimates in Chontanawat et al. (2008), Narayan and Prasad (2008), Narayan and Smyth (2008), Ciarreta and Zarraga (2010), and Magazzino (2014b, 2016). Magazzino (2014a) found a bidirectional Granger causality flow between real per capita GDP and electricity demand; while labor force does not Granger-cause neither real per capita GDP nor electricity demand (Table 13).

It is also noteworthy to mention that there is no evidence of Granger causality in any direction between GDP and capital formation, as well as labor force and GDP.

Notwithstanding, in their review of literature on the energy consumption and economic growth nexus Mozumder and Marathe (2007) conclude that the findings not only vary across countries but also across econometric methodologies.

The long-run impact results are illustrated by the FEVDs for the four variables based on a VAR (2) model in Table 14. The first (left-hand side) panel shows that the forecast errors in real GDP are mainly due to uncertainty in GDP itself and renewable energy consumption (at least in this variables' ordering). Ten steps ahead, 64% of the variance is still attributed to the error in the real GDP equation, 27% is attributed to the error in the renewable energy consumption equation, 7% to the capital disturbances, and only 3% to the labor force errors. These results are in line with those in Magazzino (2016). The remaining panels depict a different picture.

Figure 1: Gross domestic product, combustible renewables, capital and labor for Italy (1970-2007, log-scale)



Sources: WDI data

Table 10: Results for cointegration tests

H^0	H^1	Model 1			Model 2		
		Trace	Eig. Stat.	SBIC HQIC	Trace	Eig. Stat.	SBIC HQIC
None	At most 1	78.9066 (62.99)	36.3524 (31.46)	−15.0023−15.5750	53.4086* (54.64)	21.3266* (30.33)	−15.3124* −15.9996
At most 1	At most 2	42.5542 (42.44)	17.6489* (25.54)	−15.2157* −16.0175	32.0820 (34.55)	16.3105 (23.78)	−15.2080−16.0957
At most 2	At most 3	24.9053* (25.32)	15.1165 (18.96)	−15.1087−16.0823*	15.7715 (18.17)	12.4696 (16.87)	−15.1634−16.1942*
LR test		χ^2=10.47, P=0.0150					

5% critical values in parentheses. Model 1 includes a restricted trend in the model, Model 2 includes a linear trend in the cointegrating equations and a quadratic trend in the undifferenced data

In fact, the errors in predicting the renewable energy consumption are sensitive to disturbances only in energy equation: After 10 steps, almost 84% of the error variance in energy consumption forecasts is due to contributions from its own shocks. The third panel shows that forecast errors in gross fixed capital formation are mainly due to aggregate income and to capital, but in a decreasing way; whilst the effect of a shock in renewable energy consumption is increasing. Finally, the last panel shows how the forecast errors in labor force should be connected to GDP as well as labor force itself. After 5 years, nearby 27% of the variance in labor force is related to real income equation.

5. CONCLUDING REMARKS AND POLICY IMPLICATIONS

This study has extended the research on the relationship between renewable energy consumption and economic growth for Italy over the period 1970-2007. The results for unit roots and stationarity tests reveal that all variables are integrated of order one, I(1), being stationary in their first differences. Cointegration tests show the existence of one long-run relationship among the four variables. In particular, the estimated coefficients indicate that renewable energy consumption exerts, in the long-run, a negative impact on economic growth for Italy. In addition, accordingly with the literature, capital and labor have a positive effect on real GDP. Moreover, if renewable energy consumption increases by 1%, GDP decreases by 0.23%. The results of multivariate Toda and Yamamoto approach show that real GDP is driven by renewable energy consumption. This unidirectional causal link from energy to aggregate income is confirmed by Granger causality tests. Therefore, we can conclude that empirical findings confirm the "growth hypothesis" in the Italian case. Finally, FEVDs analyses underline that the error variance in real aggregate income forecasts is due to contributions from its own shocks as well as from shocks in renewable energy consumption; on the contrary, the errors in predicting the renewable energy consumption are mainly due to uncertainty in energy itself.

Table 11: Results for long-run coefficients

Dependent variable: Y	
Constant	0.3997*** (0.000)
Trend	0.0368*** (0.000)
RE	−0.2305*** (0.000)
K	0.4977*** (0.005)
L	0.2450*** (0.000)

P-values in parentheses, ***P<0.01, **P<0.05, *P<0.1

Table 12: Results of multivariate Granger non-causality tests (Toda-Yamamoto approach)

Dependent variable	Independent variables			
	Y	RE	K	L
Y	-	19.722*** (0.000)	4.0553 (0.256)	2.777 (0.427)
RE	5.7743 (0.123)	-	10.747** (0.013)	3.7649 (0.288)
K	1.9132 (0.591)	6.9203* (0.074)	-	3.0828 (0.379)
L	1.1704 (0.760)	14.385*** (0.002)	10.199** (0.017)	-

Wald tests (P-values in parentheses), ***P<0.01, **P<0.05, *P<0.1

Table 13: Results of multivariate Granger causality tests

Dependent variable	Independent variables			
	Y	RE	K	L
Y	-	20.89*** (0.000)	1.438 (0.487)	0.4072 (0.816)
RE	3.5639 (0.168)	-	3.1395 (0.208)	1.9721 (0.373)
K	0.5474 (0.761)	6.1659** (0.046)	-	0.9702 (0.616)
L	1.6613 (0.436)	4.0879 (0.130)	1.0311 (0.597)	-

Wald tests (P-values in parentheses), ***P<0.01, **P<0.05, *P<0.1

Table 14: Results for FEVD

Step	Y				RE			
	Y	RE	K	L	Y	RE	K	L
1	1.0000	0.0000	0.0000	0.0000	0.0007	0.9993	0.0000	0.0000
3	0.6762	0.2794	0.0263	0.0181	0.0751	0.8576	0.0239	0.0434
5	0.6417	0.2652	0.0657	0.0274	0.0790	0.8458	0.0294	0.0458
7	0.6420	0.2668	0.0646	0.0266	0.0809	0.8427	0.0295	0.0469
10	0.6405	0.2663	0.0658	0.0274	0.0813	0.8420	0.0297	0.0470
Step	**K**				**L**			
	Y	RE	K	L	Y	RE	K	L
1	0.4716	0.0107	0.5177	0.0000	0.1537	0.0765	0.1110	0.6588
3	0.4353	0.1321	0.4021	0.0305	0.2692	0.1080	0.1078	0.5150
5	0.4448	0.1337	0.3864	0.0351	0.2695	0.1056	0.1183	0.5066
7	0.4439	0.1332	0.3873	0.0356	0.2681	0.1080	0.1198	0.5041
10	0.4434	0.1337	0.3867	0.0362	0.2694	0.1079	0.1197	0.5030

FEVD: Forecast error variance decomposition

To conclude, an increase in energy consumption has a negative impact on Italian economic growth, since its growing economy requires a decreasing amount of energy consumption as production shifts toward less energy intensive service sectors.

The results presented in this paper should be connected with the analyses of the impact of different sources of energy on economic growth, since the use of aggregate energy data does not capture the degree or extent to which countries depend on various energy resources (Yang, 2000; Sari et al., 2008; Ziramba, 2009; Magazzino, 2012).

From a policy perspective, the results in this study are consistent with the energy-dependent hypothesis, suggesting that energy consumption is a major factor influencing economic growth. This invokes more studies on the effects of CO_2 emissions on GDP, in the light of Kyoto Protocol's rules.

6. SUGGESTIONS FOR FUTURE RESEARCHES

Given our conclusions, further analysis may be conducted in order to estimate the Environmental Kuznets Curve (EKC) (Kuznets, 1955) for Italy, both at a national and sub-national (regions, provinces) level.

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APPENDIX

Figure A: Plot of cumulative sum (CUSUM) of squares of recursive residuals