Economic growth, electricity consumption and foreign dependence in Italy between 1963 and 2007

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Abstract

The energy sector is assuming an increasing importance in the global economy. As a consequence, there is a vast literature on the causal relation between energy use and others economic variables. In this paper, I investigate the relationship between electricity consumption and economic growth for Italy using yearly data covering the period 1963–2007. Unlike previous works, this paper specifically concerns the causal link between the dynamics of GDP and the different sources of electricity production. Regarding the dependence from foreign suppliers, the paper tests the hypothesis of a causal relationship between economic growth and electricity imports. The results show a unidirectional causality from economic activity to other variables. More specifically, economic growth Granger cause total electricity consumption, industrial consumption and electricity import. For the others source of generation, any specific causal relationship has been found.

Keywords: Energy and Growth, Italy, Vector Error Correction Model, Granger Causality

JEL classifications: Q4, C3.

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Introduction

The interest in the relationship between energy and economic growth dates back at least to the two oil crises in the 1970s, when the sharp increase of energy prices heavily affected economic activity (Zachariadis, 2007). Nowadays, the energy-growth issue is assuming an increase importance in debate for at least three reasons. First, understanding the relationship among energy consumption, regulation and economic growth might allow the policymaker to have a better understanding in planning strategic energy investment. This aspect is crucial, for example, for the electricity transmission grids operators. Long run investments should be planned forecasting industrial and residential electricity consumption and their connection with economic growth.

Second, both high income countries and emerging economies are placing an increasing interest into green policies. Almost every government are promoting new innovation strategies anchored to "green technology" (Economist, 2010). The effect on the economy of this new wave of investment remains an unexplored issue. Despite all, it is still to show if the "green push" is a real economic subject or just a political agenda issue.

Third, environmental concern and particularly the problem of global warming is gaining increasing attention urging a need to decrease greenhouse gas emissions by reducing energy consumption (Chontanawat et al., 2008). Assuming that electricity consumption (ECONS) can favour economic growth (RGDP), emission ceiling might likely have a negative impact on energy consumption and consequently on economic growth.

Considering the relevance of this topic, it is not surprising that several studies have sought to establish and quantify the causal relationship between ECONS and RGDP. In general, it may assume three particular forms: i) unidirectional, from energy to economic growth; ii) unidirectional, from economic growth to energy; and iii) bidirectional, if there is a mutual causal relationship. The first systematic study on this topic was by Kraft and Kraft (1978), who found causality from GDP to energy consumption in the US. After this work, several authors performed empirical studies in other industrialised regions (i.e. Yu and Choi, 1985; Erol and Yu, 1988; Yuan et al., 2007, for Europe, Japan and China). Zachariadis (2007) investigated the causal relationship between ECONS and RGDP considering the G-7 countries. Recently, Payne (2010) has reviewed the literature on this topic with reference to several countries in the period 1996–2010, pointing out that the causal relationship can vary depending on variables selected, model specifications, time periods and econometric approaches. The Italian case confirms this state of ambiguity: both Zachariadis (2007) and Chontanawat et al. (2008), covering respectively the time spans 1970–2004 and 1960–2000, found bidirectional causality[2]. Conversely, Erol and Yu (1988), Soytas and Sari (2003) and Lee (2006) found unidirectional causality for the period 1950–1982, 1950–1992 and 1960–2001 respectively[3]. Finally, with reference to the period 1960–2002, Narayan et al. (2008) found unidirectional causality from ECONS to RGDP. Table 1 provides a chronological list of the literature on the causal relationship for Italy.

Table 1 Summary of Granger causality tests for Italy between RGDP (Y) and ECONS (E)

Study	**Method**	**Period**	**Causality**
Erol and Yu (1988)	Granger test	1950–1982	E←Y
Soytas and Sari (2003)	VEC	1950–1992	E←Y
Chontanawat et al. (2008)	Hsiao	1960–2002	E↔Y
Lee (2006)	Toda–Yamamoto	1960–2001	E←Y
Zachariadis (2007)	VEC and ARDL*	1970–2004	E↔Y
	Toda–Yamamoto		E—Y
Narayan and Prasad (2008)	Boot. Granger test	1960–2002	E→Y

Note: * ARDL = autoregressive distributed lag.

All mentioned studies consider final or primary consumption as the electricity variable and ECONS for the residential, industry and services sectors separately (Zachariadis, 2007). A peculiar feature of this paper is that it aims at testing the causal relationship between economic growth and the different sources of generation in electricity production: thermoelectric, hydroelectric and geothermal[4]. In addition, concerning the dependency problem, the paper tests the hypothesis of the causal relationship between economic growth and electricity imports. The main finding is that Granger causality is unidirectional from economic activity to: i) total and industrial ECONS and ii) foreign imports.

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2 Zachariadis (2007) found bidirectional causality studying primary and final electricity consumption with the VEC model and the ARDL approaches. Using the Toda–Yamamoto approach he found no evidence of any relationship. In addition, the study considered the final energy consumption in four sectors (residential, industrial, services and transport) with contrasting results.

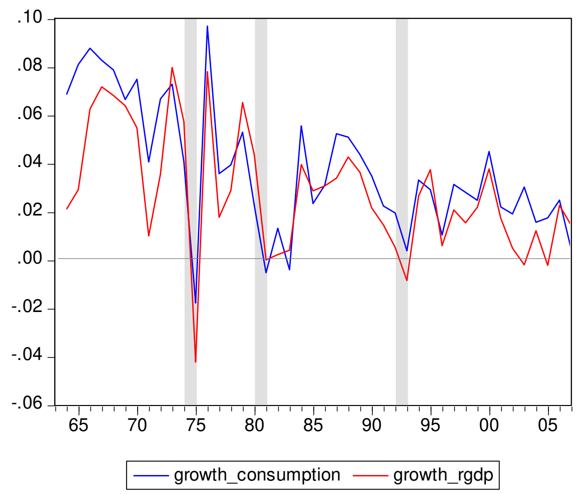
3 They used the standard Granger test, VEC model and Toda–Yamamoto approaches respectively.

4 Because of the incompleteness of the series I will not consider nuclear and wind sources of generation.

Energy and Growth in Italy

Figure 1 shows RGDP and ECONS growth in Italy for the period 1963–2007. From 1963 to 1974, Italy grew at an average rate of 5%. After the 1975 crisis[5] and until 1990, Italy's growth was assessed around 2.7%; after the 1992 currency crisis and until 2007 the average growth rate was 1.4%. In the same three periods, ECONS grew at average rates of 6.9% (1963–1974), 3.3% (1975–1989) and 2.2% (1990–2007). The growth rate series show a clear tendency to move together, even if ECONS has a small positive gap compared with the RGDP series in almost all the considered periods. It is worthwhile to notice that the ECONS growth rate series tends to be stationary starting from the end of 1980.

Figure 1 RGDP and ECONS growth 1963–2007 (Source: Terna 2007)



The power electricity industry in Italy was liberalised in 1999. The market was divided into three sections: generation, transmission and distribution. A peculiarity of the Italian electricity industry is the lack of the nuclear energy source. The policy decision to renounce nuclear energy, made after the public referendum held in 1987[6], shaped the market's structure. Even though Italy had been a pioneer country in civil nuclear power, nuclear energy production stopped in 1987, thereby compelling Italy to a heavy dependence from foreign energy suppliers[7].

[5] During the 1975 crisis, the real GDP loss was about 3%. The crisis exploded because of oil shocks in the international markets, high inflation (17%) and strong devaluation of Lira (the Italian currency before Euro).

[6] The public referendum was taken in November 1987, eighteen months after the Chernobyl nuclear disaster had occurred.

[7] Consider that the average nuclear production in Europe (EU-27) is 29%. France produces 78% of energy with nuclear sources (Source: Terna, 2010).

As shown in Figure 2a, in recent years, the Italian energy production has been dominated by the thermoelectric source (85% of total electricity supply), while other sources have been less important (hydroelectric 12%, geothermic 2% and wind energy 1%). The total supply has been far less than demand, involving substantial imports of energy from abroad and a heavy dependence on foreign suppliers (Figure 2b). In particular, after excluding nuclear energy production, the electricity dependence on foreign countries has increased 3% in 30 years: from 11.5% in 1987 to 14.8% in 2007.

Figure 2a: Italian Electricity Production

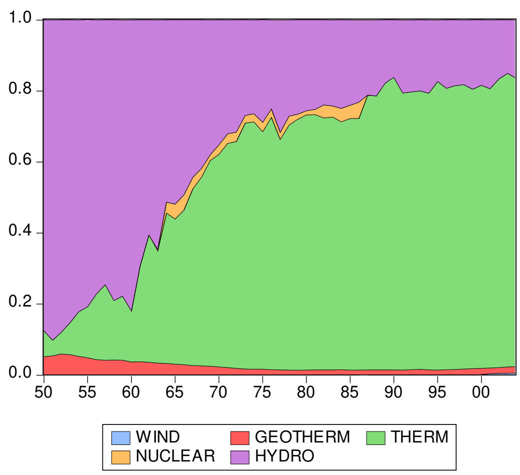
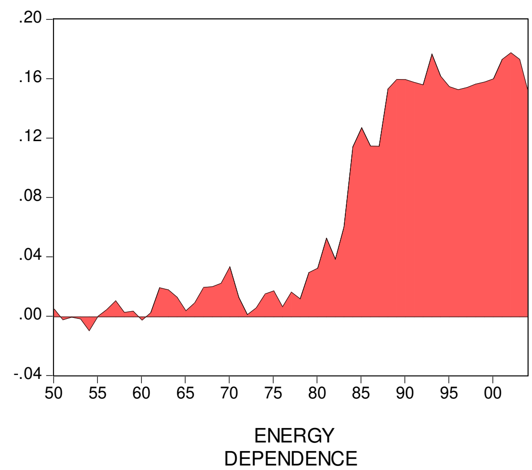


Figure 2b Energy dependence (% on total production)

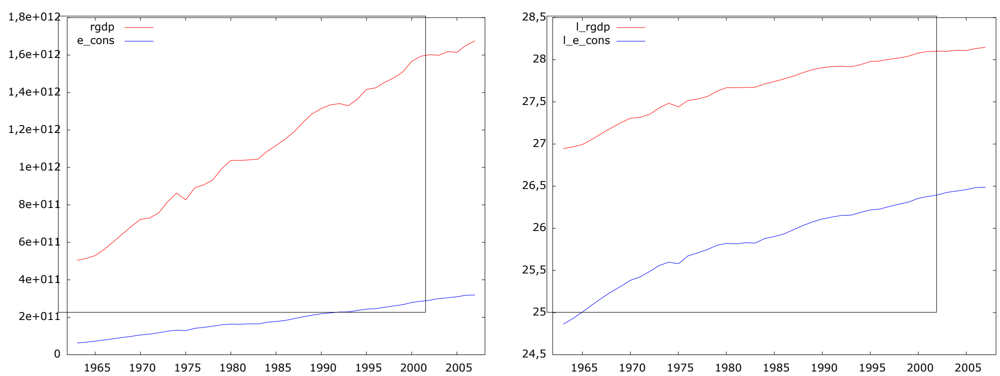


In the rest of the paper I will try to give an answer to a number of questions connected to the relationship between economic activity on one side and overall electricity consumption, imported electricity from foreign (FOR) countries and electricity production from different sources on the other, by using Granger causality in a vector error correction model (VEC) environment.

Data

In the following investigation, (natural logarithms of) Italian RGDP and ECONS for the 1963–2007 period (yearly data) are used. RGDP (expressed in dollars; base year=2000) is obtained from the Penn World Table (2010). ECONS are measured in kilowatt hours (KWh). Data for the different components of ECONS (residential and commercial services) and the different sources of electricity production (thermoelectric, hydroelectric, geothermal and foreign production) are expressed in KWh as well. The source of data on ECONS is the public dataset of *Terna – Rete Elettrica Nazionale SpA*[8], a large-scale operator in the industry of electricity transmission grids. Finally, the variable *tdd*, i.e. total degree days[9] has been calculated from data supplied by *Aeronautica Militare – C.N.M.C.A* [10]. Figure 3 plots RGDP and ECONS in levels and logs.

Figure 3 RGDP and ECONS in level and log form



As it is well known, a series is said to be stationary if it has mean, variance and autocovariance constant over time. From Granger and Newbold (1974), we know that if we use a linear regression model on non-stationary variables, we risk generating a spurious regression. In this work, I use the augmented Dickey–Fuller (ADF) statistic for testing series stationarity. Owing to the small sample size (45 observations) I choose Akaike's information criterion (AIC) over Schwartz's Bayesian criterion to select the appropriate number of lags.

According to Engle and Granger (1987), a linear combination of two stationary series with the same order of integration $X \sim I(1)$ and $Y \sim I(1)$ generates a series $Z \sim I(0)$. The $Z \sim I(0)$ series assures that a long-run relationship between the two endogenous variables

[8] The Terna website supplies production time series on ECONS from 1883 to 2007. See: http://www.terna.it/default/Home/SISTEMA_ELETTRICO/statistiche/dati_storici/tabid/421/Default.asp.

[9] The variable is the average of the heating degree day (HDD) and cooling degree day (CDD) expressed in logarithm for three Italian weather stations: Piacenza, Roma and Messina. I selected 18°C and 22°C as realistic reference temperatures for calculating HDD and CDD respectively.

[10] The author is grateful to *Aeronautica Militare – C.N.M.C.A. Centro Nazionale di Meteorologia e Climatologia Aeronautica* for making data available for this study.

exists. To test if $RGDP \sim I(1)$ and $ECONS \sim I(1)$, I first analyse the variables' trend (Figure 10 in Appendix), then I perform an ADF test by adding an intercept and a trend for each variable. The ADF test shows that the considered variables are stationary at the 1% confidence level. Table 2 summarises the results for all variables used in the model.

Table 2 ADF test results

		Level			Logarithm		
	Variables	I~(0)	I~(1)	I~(2)	I~(0)	I~(1)	I~(2)
	RGDP		X			X	
	ECONS		X			X	
Sector	Residential		X			X	
	Industrial		X			X	
	Services			X		X	
Source	Geothermal			X		X	
	Hydroelectric	X				X	
	Thermoelectric		X		X		
	Foreign import		X			X	

Vector Error Correction Model

Causality can be tested by three different approaches: i) VEC; ii) ARDL and iii) the Toda–Yamamoto method. In this work, causality is tested by using the VEC method because of its good properties in small samples (Zachariadis, 2007).

The variables of interest integrated in order one are tested two-by-two to check if a linear combination exists by using the Engle–Granger methodology. If the series are cointegrated, thanks to the Granger representation theorem, it is possible to incorporate the error correction (EC) part in a vector autoregressive model. Afterward, I detect the Granger relationship between RGDP and ECONS and between RGDP and each of the other selected variables. Finally, the impulse response function (IRF) is used to study the shock effect of a variable on the other and the variance decomposition method (VDC) is used to make out-of-sample analysis. Figures 4 and 5 show the long-run relationship between RGDP and ECONS suggesting that these variables might be cointegrated. Following Engle and

Granger (1987), the augmented form of the Dickey–Fuller can be used to test the residual's stationarity:

$$\Delta \hat{u}_t = \alpha_1 \hat{u}_{t-1} + \sum_{i=1}^{n} \Delta \hat{u}_{t-i} + \varepsilon_t$$

Since the null hypothesis $H_0 : \alpha_1 = 0$ is rejected at the 1% level, the residual sequence can be considered stationary and the two variables cointegrated (Enders, 2004).

Figure 4 RGDP vs. ECONS plot

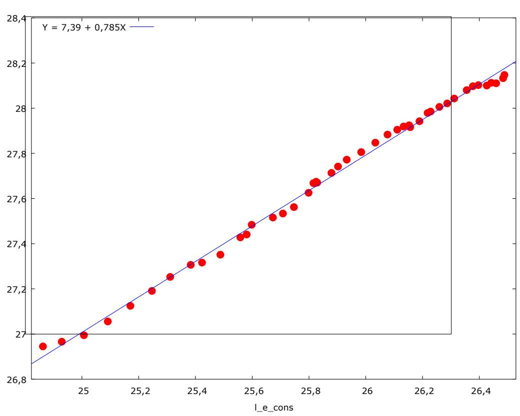
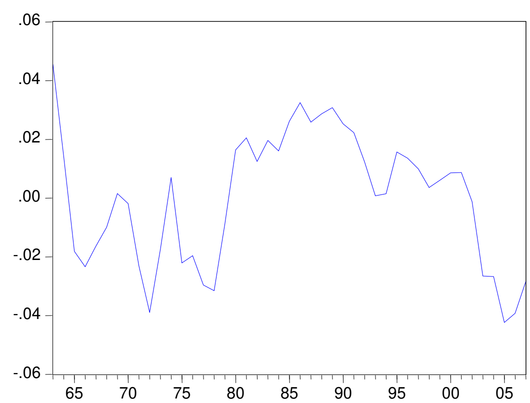


Figure 5 Residual



Once detected the cointegration relationship, the following step consists of estimating a VEC model including the long-run relationship as an EC term in the system. AIC for lag length selection is applied indicating a lag length of 2. The VEC model takes therefore the form:

$$\Delta r_t = \alpha_r (r_{t-1} - \hat{\beta}_1 e_{t-1} - \hat{\beta}_0) + \alpha_{11} \Delta r_{t-1} + \alpha_{12} \Delta r_{t-2} + \alpha_{13} \Delta e_{t-1} + \alpha_{14} \Delta e_{t-2} + \gamma tdd_t + \varepsilon_{Rt}$$

$$\Delta e_t = \alpha_e (r_{t-1} - \hat{\beta}_1 e_{t-1} - \hat{\beta}_0) + \alpha_{21} \Delta e_{t-1} + \alpha_{22} \Delta e_{t-2} + \alpha_{23} \Delta r_{t-1} + \alpha_{24} \Delta r_{t-2} + \gamma tdd_t + \varepsilon_{Et}$$

where r_t and e_t are the natural logarithms of RGDP and ECONS respectively; $(r_{t-1} - \hat{\beta}_1 e_{t-1} - \hat{\beta}_0)$ is the EC term representing the estimated error from the long-run cointegrating relationship and ε_t the serially uncorrelated error term. Following Zachariadis and Pashourtidou (2007), tdd (total degree days) is included among the explanatory variables to catch the possible effect of weather conditions on the endogenous variables.

Finally, an intercept is included in the cointegration relationship because of the long-run relationship between the analyzed variables. Table 3 reports the results for two bivariate VEC models. Model 1 for RGDP and ECONS, model 2 for RGDP and FOR. In these models, the overall change of dependent variables is composed by a part connected to changes of independent variables (short-run movement) and by another part due to deviations from the equilibrium (long-run movement). This latter is the EC, reflecting the current "error" in achieving long-run equilibrium (Kennedy, 2008). α_r and α_e have the interpretation of speed of adjustment: the larger α_r, the greater the response of short-run deviations of RGDP to the previous period's deviation from the long-run equilibrium (Enders, 2004). For example (Model 1, equation 2), short-run deviations in ECONS might be explained by:

i) short-run deviations in ECONS at $t-1$ and $t-2$;

ii) short-run deviations in RGDP at $t-1$ and $t-2$;

iii) deviations from the long-run relationship between ECONS and RGDP;

iv) temporary shocks in ε at t.

The speeds of the adjustment parameters α_r and α_e are strongly significant in both equations, pointing out the existence of a cointegration relationship and a Granger causality relationship among the variables. Since in Equation 1 the only significant coefficient is α_{12}, the short-run variation of RGDP is partially explained by the short-run RGDP variation at $t-2$, plus the deviation from the equilibrium captured by the EC term. These results indicate that the short-run variations of ECONS are negatively affected by the short-run variation of RGDP at $t-1$ (–74%) and positively affected by the short-run variation of ECONS at $t-1$ and $t-2$ (54% and 45% respectively). The variable tdd is significant in both equations presenting a negative sign.

Model 2 presents results for the bivariate VEC model built with RGDP and FOR variables.

Granger causality

A time series X is said to Granger-cause Y if the prediction error of the current Y decreases by using past values of X and past values of Y (Payne, 2010). In a VEC environment, Zachariadis (2007) argues that Granger causality can be examined by observing: i) the significance of the lagged differences of the variables of the VEC model with a joint Wald or F-test (short-run or weak Granger causality); ii) the significance of the EC term as a measure of long-run causality by using the *t* statistic; or iii) the joint significance of the EC and the lagged variables with a joint Wald or F-test (strong Granger causality). Table 4 shows the Granger causality test between RGDP and each of the electricity consumption and production variables (as mentioned before, I have not considered nuclear and wind power because of the incompleteness of the time series).

Table 4 Summary of Granger causality tests

	Variables	**RGDP (Y) Causality**
Sector	ECONS	E ← Y
	Residential	E ~Y
	Industrial	E ← Y
	Services	E ~Y
Source	Geothermal	E ~Y
	Hydroelectric	E ~Y
	Thermoelectric	E ~Y
	FOR	E ← Y

Note: E ← Y denotes causality from economic activity to energy; E ~Y denotes no causality.

Following Erol and Yu (1988), Soytas and Sari (2003) and Lee (2006), we can state that a strong Granger causality is found from RGDP to ECONS. Similarly, strong causality comes out to go from RGDP to industrial ECONS; this result is not surprising considering that in 2007 the industrial sector consumed 50% of the national electricity supply (Terna, 2010).

More interestingly, a weak Granger causality is detected from RGDP to FOR suggesting that the gradual increase of electricity import can be seen as an effect of the Italian economic growth in 1963-2007. In this vein, Italy seems to use foreign electricity supply as an "energy ATM": if the economy grows, more energy will be withdrawn from foreign countries. Since it is the economic process that controls energy import, it should not impact foreign energy shocks on the Italian economy; this result mitigates the problem of energy dependence.

Returning to the original question on the causal relationship between RGDP and ECONS, Figure 6 and Figure 7 in appendix displays the IRFs of the VEC model as a practical way to visually represent the behaviour of the series in response to various shocks (Enders, 2004). In our case, IRFs help us understand the effect of an innovation in ECONS on RGDP and vice versa. We found a cointegrating relationship between the variables, meaning that IRF functions of each variable can have trace values of the other variables. As shown in Figure 6, shocks in ECONS affect positively RGDP in contrast to the negative impact of RGDP shocks on ECONS. In general, as confirmed by the Granger test, an RGDP shock seems to be greater in magnitude and with a more permanent trace on ECONS. The VDC analysis partitioned the variance of the forecast errors to respect the innovations in each variable in the system. The idea behind this is that the variance of the forecast error in RGDP can be attributable to innovations in ECONS and to its own innovations and vice versa. Figure 7 shows the VDC results in a 20-year scenario. These VDC graphs confirm the result obtained using the Granger causality test. RGDP explains about 40% of the ECONS variance after 10 years and 70% over a 20-year horizon. ECONS explains less than 5% after 10 years and 20% after 25 years. The VDC analysis supports previous empirical results of unilateral causality from economic growth to ECONS. Similar results are presented in Figures 8-9 where IRFs and VDC for RGDP and FOR are presented.

Discussion

Causality is found to go from RGDP to ECONS (industrial consumption included) and from RGDP to FOR. How this latter result impact on the future development of energy sector? In Terna "Development Plan (Piano di Sviluppo) 2009", scenarios with different rates of economic growth and investment in the energy network are hypothesised. RGDP and ECONS should grow by 1.2% to 1.3% per year through 2007–2018. The increase of electricity imports is estimated to range from 46,000 GW in 2007 to 73,000 GW in 2013 (+62%). This means that Italian dependence from electricity import will increase from 15% in 2007 to 21% in 2013. It is worrying for Italy? The finding of this paper, i.e. the causality direction goes from RGDP to FOR, seems to relieve the concern on the dependency issue. But it is the case? If economic growth Granger causes foreign electricity import, the opposite can be stated? It can exist economic growth for Italy without any electricity importation? Considering our results, we should answer in a positive way. However, it seems more realistic to think that electricity import contributes to economic growth. Anyway, Terna forecast states that foreign import will go on being a more and more important source of generation for Italy. This incongruity shows that one should be cautious when drawing policy implications using multivariate causality tests (Zachariadis, 2007).

In addition, we believe in the importance in overcoming the self production-dependence dichotomy giving a new look to the energy policies. This new perspective considers crucial the transmissions for cross-border exchanges in electricity considering two main arguments. First, the national network shows high congestion level in the north of the country, so that importing energy is necessary to run the system efficiently[11] (Terna, 2009). Second the electricity market reform taking place in the European Union[12]. European energy policy goes into the direction of a single internal electricity market (so called market coupling). Italy could play a key role in the Central South Electricity Regional Initiatives[13] (ERI).

In this perception, the Terna plan explicitly mentions higher investment, particularly in the north side of the country. Losing this opportunity not only might decrease the efficiency of electricity market within the country but also slow down the integration process into the European market.

Conclusion

This paper presents an empirical analysis of the relationship between economic activities, energy consumption and electricity import for Italy in the period 1963–2007. Using yearly data, I analyse the causal relationship with other consumption and production components. The results support the hypothesis that a causal relationship exists and goes from income to ECONS, industrial consumption and electricity import from foreign countries. IRFs and VDC analysis confirm the Granger causality test results. A long-run dynamic relationship

[11] In addition, it is important to note that importing electricity is definitely profitable because of the lower foreign price The electricity price in Italy is notably higher than that in other European countries. Setting the Italian price equal to 100, the price is around 55 in Scandinavia, 65 in Germany and Spain and around 67 in Austria and France, which are two large suppliers for Italy (AEEG Autorità per l'energia elettrica e il gas, 2010).

[12] General conditions for the creation of a single Internal Electricity Market in Europe start with the Directives 96/92/EC and 2003/54/EC and the Regulation 1228/2003. Regulation 1228/2003 will be replaced in March 2011 from Regulation 714/2009.

[13] European Regional Initiatives (ERI), launched in by European Commission in cooperation with the European Regulators' Group for Electricity and Gas (ERGEG).

among electricity and income is detected by applying time series analysis techniques such as the ADF test for unit roots, the Engle–Granger test for cointegration and VEC model. In general, the final outcome of this paper is consistent with other empirical studies on Italy and lead to two main conclusions.

First, ECONS Granger-cause (strong causality) economic growth. A relevant impact of the endogenous variable RGDP on ECONS is found, suggesting that the short-run deviation of RGDP and ECONS responds rapidly to the previous period's deviation from the long-run equilibrium. This result might be interpreted considering the speed of ECONS in the subsequent rate of economic growth. Moreover, it is worthwhile to mention that electricity consumption growth rate series tend to be stationary starting from the end of 1980 (Figure 2). Second, economic growth Granger-causes electricity import. Even if empirical analysis found a weak causality, the main conclusion is that Italy uses energy imports as an "electricity ATM": as the economy increases (decreases), electricity imports from foreign countries increase (decrease). This result relieves the concern on the dependency issue for Italy. However, it must be considered in a larger perspective that overcomes the self production-dependence dichotomy. This perspective is supported by a physical need, i.e. congestion network problems in the north of the country, and by the recent development in the electricity market reform in the European Union. From this point of view, both the positive forecast in economic growth and the market and political direction suggest the importance of an improvement in transmission for cross-border electricity exchanges. Losing this opportunity might decrease the efficiency of electricity management within the country and slow the integration process into the European market.

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APPENDIX

Table 3 Results of the VEC models

		Cointegration Equations			
	l_rgdp_1	1.0000		l_rgdp_1	1.0000
		(0,0000)			(0,0000)
	l_econs_1	–1.0285		l_for_1	–0.1037
		(0.068469)			(0.0267)
	C	0.50842		C	-29.503
		(2.2441)			(2.0097)
	Model 1			**Model 2**	
	Equation 1	Equation 2		Equation 1	Equation 2
	d_RGDP	d_ECONS		d_RGDP	d_FOR
EC	0.1272**	0.1455***	EC	-0.0922***	0.1347
	[2.578]	[3.619]		[-4.403]	[0.269]
d_rgdp_1	–0.4014	–0.7471***	d_rgdp_1	-0.0922	10.8664***
	[–1.465]	[–3.347]		[-0.644]	[3.197]
d_rgdp_2	–0.5206*	–0.3724	d_rgdp_2	-0.0706	-7.1271*
	[–1.719]	[–1.509]		[-0.442]	[-1.880]
d_econs_1	0.3036	0.5438*	d_for_1	-0.0088	-0.1304
	[0.9214]	[2.026]		[-1.487]	[-0.918]
d_econs_2	0.4831	0.4594*	d_for_2	-0.0157***	-0.0194
	[1.574]	[1.837]		[-2.807]	[-1.462]
hdd_cdd	-0.0439**	-0.0497***	hdd_cdd	-0.0707***	0.1256
	[-2.578]	[-3.428]		[-4.128]	[0.308]
Determinant covariance matrix		2.8909E-008	Determinant covariance matrix		6.0027E-005
Log likelihood		245.3498	Log likelihood		84.9441
AIC		–11.0167	AIC		-3.3783
Schwarz criterion		–10.4374	Schwarz criterion		-2.7991

Note: t-statistic and standard error in (...) and [...] brackets respectively. *, ** and *** denote significance of estimates at 10%, 5% and 1% level respectively.

Figure 6 IRFs, RGDP vs ECONS

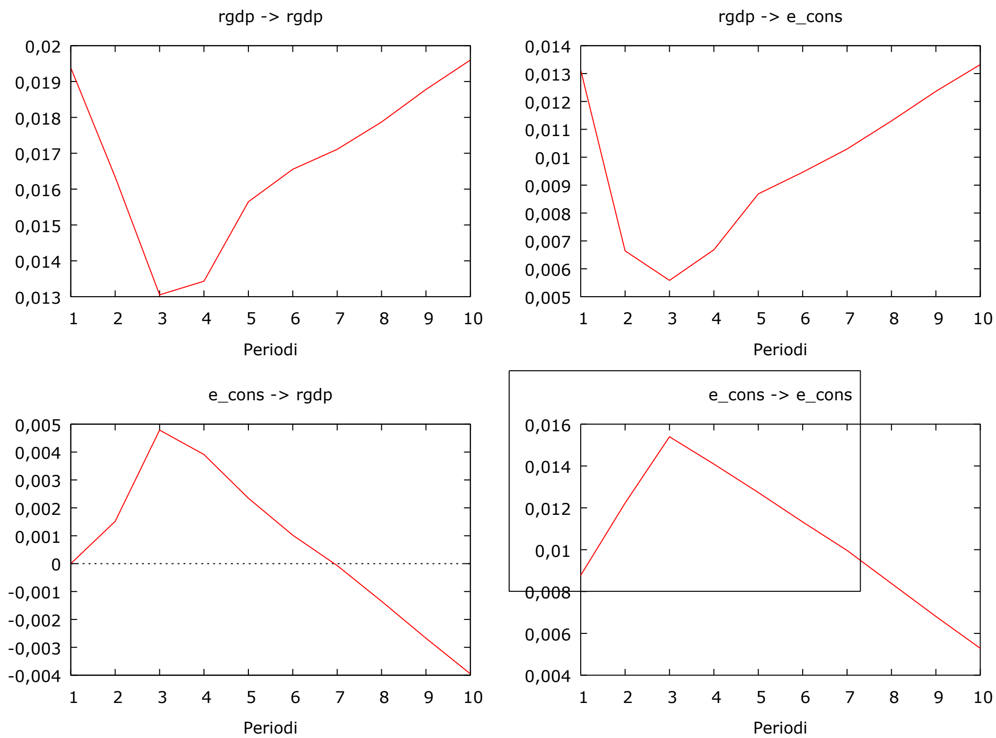

Figure 7 VDC, RGDP and ECONS

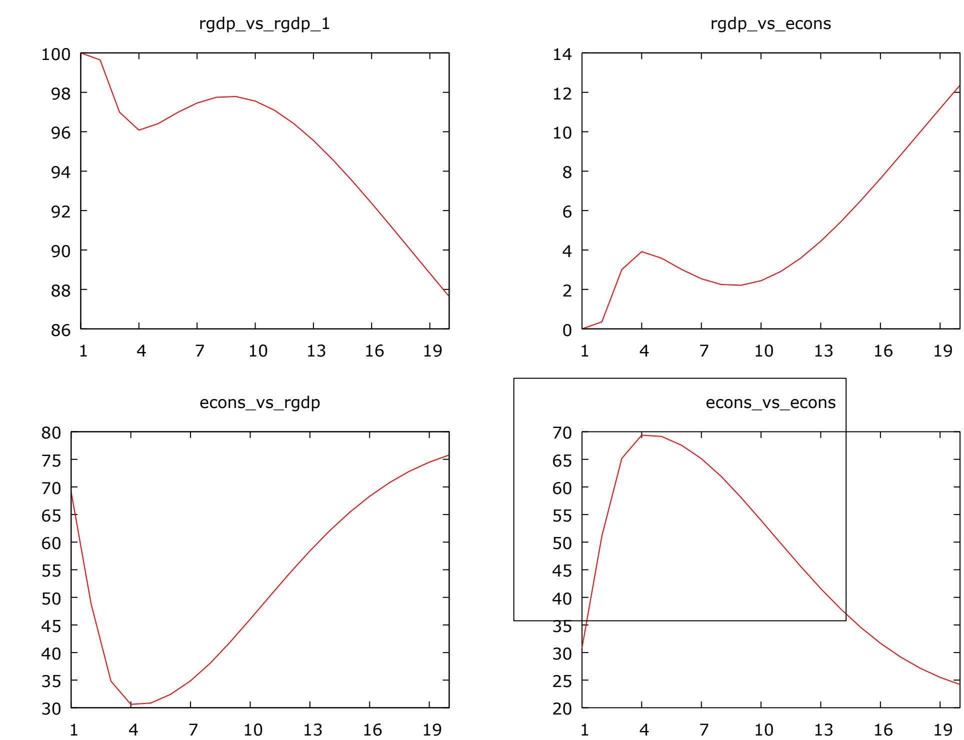

Figure 8 IRFs, RGDP vs FOR

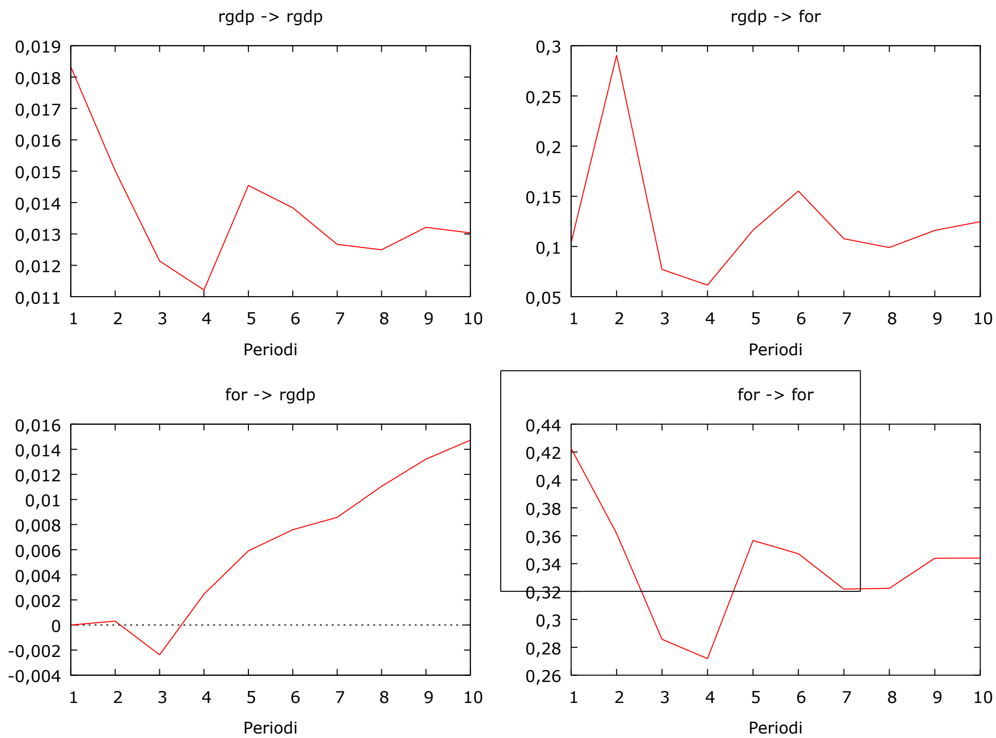

Figure 9 VDC, RGDP and FOR

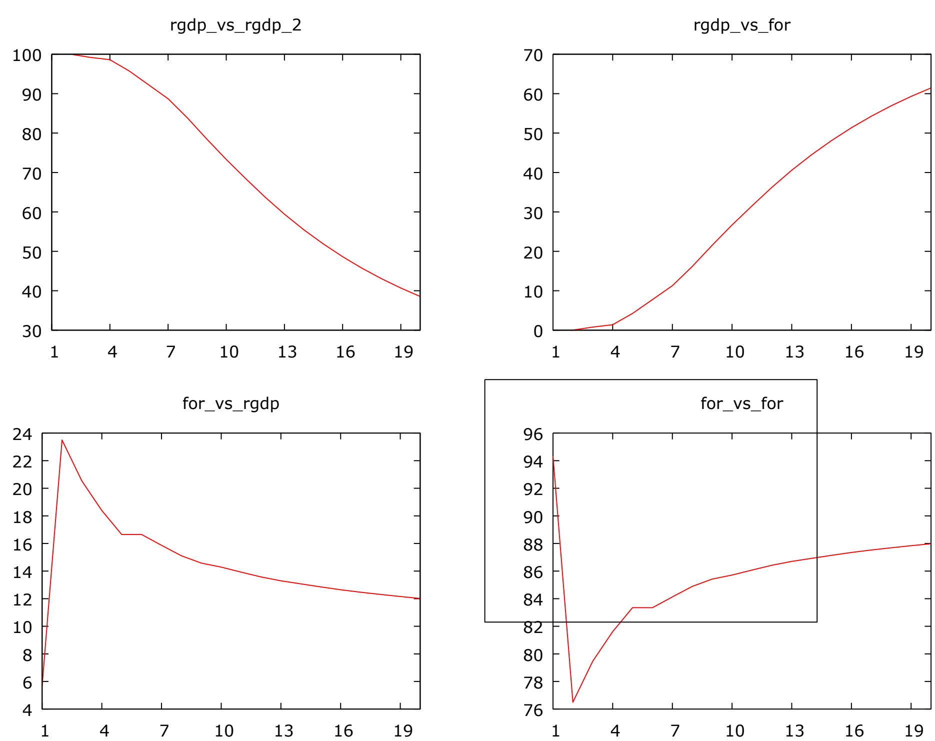

Figure 10 Variables in level and log