Working Paper Series
Department of Economics
University of Verona

Regional spillover effects of renewable energy generation in Italy

Natalia Magnani, Andrea Vaona

WP Number: 12 August 2011

ISSN: 2036-2919 (paper), 2036-4679 (online)

Regional spillover effects of renewable energy generation in Italy

Natalia Magnani

Department of Sociology and Social Research
University of Trento
Via Verdi, 26
38122 Trento
+39 0461 28 1306
natalia.magnani@unitn.it

Andrea Vaona
(Corresponding author)

Department of Economics Sciences
University of Verona
Viale dell'Università 3
37129 Verona
E-mail: andrea.vaona@univr.it

Kiel Institute for the World Economy
Germany

Regional spillover effects of renewable energy generation in Italy

Abstract

In a multivariate setting, we document that renewable energy generation has a positive impact on economic growth at the regional level in Italy. We do so by adopting panel data unit-root and cointegration tests as well as Granger non-causality tests relying on the system GMM estimator. Our results are interpreted in three ways. Renewable energy generation alleviates balance-of-payments constraints and reduces the exposure of a regional economy to the volatility of the price of fossil fuels and to negative environmental and health externalities deriving from non-renewable energy generation. Therefore, our evidence supports policies promoting renewable energy generation.

Keywords: renewable energy generation, economic growth, panel unit root and cointegration tests, Granger causality, Italy, panel error correction model, regions.
JEL Codes: O13, O18, R11, N70, Q42, Q43

Introduction

The energy consumption-growth nexus has become a classical research topic in economics and energy studies. Surveys are offered in Lee (2005, 2006), Yoo (2006), Chontanawat et al. (2006) and Payne (2009, 2010a, 2010b). In particular Payne (2009, 2010a) highlights four hypotheses that have animated the literature. The “growth hypothesis” purports that energy consumption is a complement of labour and capital in producing output and, as a consequence, it contributes to growth. The “conservation hypothesis” implies that conservation policies - aiming at reducing greenhouse emissions, improving energy efficiency and curtailing energy consumption and waste – boost real GDP by enhancing the efficiency of energy use. According to the “neutrality” hypothesis energy consumption and output are not connected. Finally, the “feedback” hypothesis suggests that more (less) energy consumption results in increases (decreases) in real GDP, and vice versa.

Recently the role of renewable energy consumption has attracted a considerable attention within this literature (see for instance Sari and Soytas, 2004, Ewing et al., 2007, Sari et al., 2008, Payne, 2009, Payne, 2010c, Bowden and Payne, 2010). In particular Sadorsky (2009a), Sadorsky (2009b), Apergis and Payne (2010a), Apergis and Payne (2010b) and Apergis and Payne (2011) inaugurated the adoption of panel unit root and cointegration econometric techniques in this research field by studying countries belonging to different geographical areas. We build on these studies under a methodological point of view and upon specifying our econometric model. However, we move into two so far unexplored directions.

In the first place we consider regional data. The focus on regions is particularly relevant for two main reasons. The first one is that, as recently highlighted by the Assembly of European Regions’ study on regional investment in energy projects (AER, 2011, p.7), the sub-national level plays a key role in turning political commitments defined at the European and national levels into concrete action and in determining the actual mix of fuels needed to ensure energy security and sustainable economic growth.

As far as Italy is concerned, the national law 13/2009 established that the European targets for the production of renewable energy were to be shared, in different proportions, among the Italian regions (Colangelo, 2009). In order to do so, all the Italian regions approved by 2010 Regional Energetic/Environmental Plans defining their strategies and choices to foster energy efficiency and the use of the available and most convenient renewable energy sources.

The second reason why focusing on regional data on renewable energy is interesting is because the promotion of sustainable energy production and consumption is increasingly regarded by the European regional policy as a crucial strategy to foster the development of lagging regions both in old and new member states (e.g. Streimikiene et al., 2005; Klevas and Antinucci, 2004).

In the specific case of Italy, Southern regions, traditionally characterised by development problems, received significant economic transfers within the framework of the 2007-2013 structural funds, through the approval of Regional Operational Programmes promoting interventions on renewable energies (Colangelo, 2009, p.105). More in general, the dualistic nature of the Italian economy - due to the South and Islands lagging behind the North and Centre (see for instance Bagnasco, 1977 and Mauro, 2004) - can offer a test of the ability of renewable energy generation to help overcoming regional economic divides.

Finally, as stressed also by Vaona (2011a) and Bastianelli (2006), adopting an Italian dataset is interesting because it can well represent the challenges facing countries, such as Belgium, Greece, Luxembourg, Portugal, Spain and others that considerably depend on energy imports.

Our second unexplored research path is that we study renewable energy generation and not consumption. With the exception of Yoo and Kim (2006), the literature on the energy-growth nexus has so far neglected the role of renewable energy generation for economic growth, probably also because the data on renewable energy generation and consumption tend to coincide at the country level. However renewable energy generation can have a key role in enhancing economic growth.

By softening the balance constraint of either a region or a country, it can spur both output and productivity growth. So the evidence here presented can be considered to indirectly support

Thrilwall's law, which has been the object of an extensive literature though not directly concerning energy issues (see for instance Thirlwall, 1979, 1991, McCombie and Thirlwall, 1994, 2004, Meliciani, 2002). In other words, our view is that by reducing the import elasticity of income, the generation of renewable energy increases the sustainable level of output, boosting also the productivity of production inputs. In this sense, we argue that renewable energy generation has a positive spillover effect on the whole economy. A regional setting is a suitable one to capture this effect not only because the explanation of regional economic trends played a key role on "balance-of-payment constrained growth" theorizing, but also because the energy balance of single regions can considerably vary and, as shown below, there can be also regions having a positive energy balance even generating only renewable energy.

Furthermore, renewable energy generation reduces the exposure of a region not only to the volatility of the oil market, which can have detrimental effects on economic growth, but also to the negative externalities that non-renewable energy generation can have on the environment and human health (Kaygusuz, 2007).

The rest of this communication is structured as follows. The next section illustrates our data, methodology and results, while the last section offers concluding remarks.

Data, methods and results

Our dataset covers the period from 1997 to 2007 for the 20 Italian NUTS2[1] regions. So its cross-sectional and time-series dimensions are comparable to those of the dataset analyzed by Sadorsky (2009a). As in Apergis and Payne (2010a), Apergis and Payne (2010b) and Apergis and Payne (2011), we adopt a multivariate framework by collecting data on real GDP (*Y*) in constant 2000 prices, real gross fixed capital formation (*K*) in constant 2000 prices, the annual average of employed people in thousands (*L*), and renewable energy net generation in GWh (*RE*) obtained by

[1] NUTS is the French acronym for Nomenclature of Territorial Units for Statistics used by Eurostat. In this nomenclature NUTS1 refers to European Community Regions and NUTS2 to Basic Administrative Units, with NUTS3 reflecting smaller spatial units most similar to counties in the US.

summing the generation of hydroelectric, photovoltaic, wind and geothermal power. The data source of the first three variables are the regional accounts of the Italian national statistical office (ISTAT), while data for renewable energy net generation were obtained from the website of the Italian energy transmission grid operator, Terna S.p.a. (http://www.terna.it/default/home_en/ electric_system/ statistical_data.aspx). All variables are in natural logarithms and, after Sari and Soytas (2007), real gross capital formation can be used as proxy for the capital stock once using the perpetual inventory method and a constant depreciation rate.

Table 1 sets out some energy statistics on Italian regions. As it is possible to see a clear regional pattern emerges. Between 1997 and 2007 the only regions experiencing an increase in renewable energy generation where Southern ones, with the exception of Tuscany in Central Italy. However, these were also the regions with a lower average share of renewable sources in total energy generation. Indeed, the data in the second and in the last columns of Table 1 have a correlation equal to -0.33. Furthermore, by taking the difference between the energy balances in 2007 and in 1997 and computing its correlation to the average percentage change in renewable energy generation returns a value of 0.42, which can be interpreted as some evidence that Italian regions were shifting towards renewable energy generation in order to reduce their energy imports.

Under a methodological point of view, we rely first on panel unit root and cointegration tests. Then we estimate the cointegrating vector between *Y*, *K*, *L* and *RE* and, finally, we perform a Granger causality test within a panel vector error correction model (PVECM).

Specifically we adopt two panel unit root tests, those proposed by Im, Pesaran and Shin (2003) and the Fisher test based on region specific Augmented Dickey-Fuller tests proposed by Maddala and Wu (1999). An illustration of these tests is offered in Baltagi (2001) and it will not be given here. Suffice to say that according to Baltagi (2001) the latter test is prefereable to the former one on the basis of their finite sample properties. On the other hand Hsiao (2003) points out that the former test is parametric, while the latter one is based on Monte Carlo simulations. As a consequence, we report both of them to show that our results are robust. The null hypothesis of both tests is the presence of a unit root in all the time series under analysis, while the alternative is that some time series do not have a unit root. Panel A of Table 2 provides strong evidence that the variables under study are integrated of order one.

On the grounds of this result, we move on to panel cointegration tests after Pedroni (1999, 2004), that allow for cross-section interdependence and region specific effects. Our starting point is the model

$$Y_{it} = \alpha_i + \gamma_{1i} RE_{it} + \gamma_{2i} K_{it} + \gamma_{3i} L_{it} + \varepsilon_{it} \tag{1}$$

where $i=1,\ldots, N$ is a region index and $t=1,\ldots,T$ is a time index, γ_{ji} with $j=1,\ldots, 3$ are parameters and ε_{it} are errors. To test the null hypothesis of no cointegration, one considers the estimated residuals, $\hat{\varepsilon}_{it}$, representing deviations from the long-run relationship, and test the hypothesis $\rho_i=1$ in the model

$$\hat{\varepsilon}_{it} = \rho_i \hat{\varepsilon}_{it-1} + w_{it} \tag{2}$$

where w_{it} are errors. In (2) we considered an AR(1) model for explanatory purposes. In fact it is possible to choose the lag length by resorting for instance to a Schwarz criterion as we do here.

Pedroni (1999, 2004) distinguish within and between dimension tests. The former ones – called panel v, panel ρ, panel PP and panel ADF statistics - are based on pooling the ρ_i of the different regions for unit root testing. The latter ones – called group ρ, group PP and group ADF statistics – are based on averaging ρ_i across the regions included in the sample. Panel B of Table 2 shows that all the tests reject the null hypothesis of no cointegration at a 5% level, with the exception of the panel PP one which does so at the 10 per cent level, having a p-value of 0.052.

Next, we estimate the cointegrating vector between Y, K, L and RE. In so doing we resort to the dynamic ordinary least squares (DOLS) estimator after Mark and Sul (2003). From here on, we impose poolability over γ_{ji} with $j=1,\ldots, 3$. We do so because it is well known that heterogeneous estimator can produce results difficult to interpret, displaying implausible variability (Baltagi et al., 2003 and 2004). We first start by including region specific effects and time trends, as well as two leads and two lags of the first differences of explanatory variables. We then drop insignificant variables to obtain the results shown in Panel A of Table 3. As it is possible to see *K*, *L* and *RE* have all positive and significant coefficients. Furthermore, those of *K* and *L* are close to what the income shares of capital and labour are customarily thought to be, namely 2/3 an 1/3 respectively. A 1% increase in renewable energy generation is associated to a 0.02% increase in regional GDP in the long-run, keeping other inputs constant[2]. This suggests that renewable energy generation can enhance labour and capital productivity. On one side, this value is lower than those reported by Sadorsky (2009a), Sadorsky (2009b), Apergis and Payne (2010a), Apergis and Payne (2010b) and Apergis and Payne (2011). On the other, this might suggest that there can be substantial output gains from increasing renewable energy generation, given that its share in total energy generation is very low in many regions.

Our final exercise is to estimate a PVECM in order to infer causal relationship between the variables. We adopt the two-step procedure by Engle and Granger (1987) by inserting the estimated deviations from the long-run equilibrium implied by the model

$$Y_{it} = \alpha + \gamma_1 RE_{it} + \gamma_2 K_{it} + \gamma_3 L_{it} + \varepsilon_{it}$$

into a dynamic error correction model as follows

$$\Delta Y_{it} = \alpha_1 + \sum_{k=1}^{q} \varphi_{11k} \Delta RE_{it-k} + \sum_{k=1}^{q} \varphi_{12k} \Delta K_{it-k} + \sum_{k=1}^{q} \varphi_{13k} \Delta L_{it-k} + \sum_{k=1}^{q} \varphi_{14k} \Delta Y_{it-k} + \lambda_1 \hat{\varepsilon}_{it-1} + u_{1it} \quad (3)$$

$$\Delta RE_{it} = \alpha_2 + \sum_{k=1}^{q} \varphi_{21k} \Delta RE_{it-k} + \sum_{k=1}^{q} \varphi_{22k} \Delta K_{it-k} + \sum_{k=1}^{q} \varphi_{23k} \Delta L_{it-k} + \sum_{k=1}^{q} \varphi_{24k} \Delta Y_{it-k} + \lambda_2 \hat{\varepsilon}_{it-1} + u_{2it} \quad (4)$$

---

[2] We also used a pooled mean group fully modified OLS (FMOLS) estimator after Pedroni (2001). This estimator consists in running a FMOLS regression for each cross-sectional unit and taking as point estimates of the parameters the average of the regional estimates. T-statistics are computed as

$$t_{GFM} = N^{-1/2} \sum_{i=1}^{N} \hat{\beta}_{FMi} \left[\Omega_{11i}^{\;-1} \sum_{t=1}^{T} (\tilde{x}_{it})^2 \right]^{1/2}$$

where N is the number of regions, $\hat{\beta}_{FMi}$ are the region specific FMOLS estimates of a given coefficient, $\boldsymbol{\Omega}_{11}$ is the first element of the joint variance covariance matrix of the residual of the model and of the first differences of the regressors and $\tilde{x}_{it}$ is the deviation of the relevant regressor from its region specific mean. For $\boldsymbol{\Omega}$ we adopt a Newey-West estimator with a Bartlett kernel. The results are very similar to those presented in Table 3 being $\hat{\gamma}_1 = 0.01$, $\hat{\gamma}_2 = 0.05$ and $\hat{\gamma}_3 = 0.92$, with all estimates significantly different from zero at the 1% level.

$$\Delta L_{it} = \alpha_3 + \sum_{k=1}^{q} \varphi_{31k} \Delta RE_{it-k} + \sum_{k=1}^{q} \varphi_{32k} \Delta K_{it-k} + \sum_{k=1}^{q} \varphi_{33k} \Delta L_{it-k} + \sum_{k=1}^{q} \varphi_{34k} \Delta Y_{it-k} + \lambda_3 \hat{\varepsilon}_{it-1} + u_{3it} \quad (5)$$

$$\Delta K_{it} = \alpha_4 + \sum_{k=1}^{q} \varphi_{41k} \Delta RE_{it-k} + \sum_{k=1}^{q} \varphi_{42k} \Delta K_{it-k} + \sum_{k=1}^{q} \varphi_{43k} \Delta L_{it-k} + \sum_{k=1}^{q} \varphi_{44k} \Delta Y_{it-k} + \lambda_4 \hat{\varepsilon}_{it-1} + u_{4it} \quad (6)$$

where Δ is the first difference operator, q is the lag length, u denote error terms and α, φ, λ denote parameters. In order to estimate equations (3) to (6), given that we impose poolability and that we have a greater cross-sectional dimension than the time series one, we adopt a two-step panel system-GMM estimator after Blundell and Bond (1998), with the finite sample correction proposed by Windmeijer (2005). This approach entails estimating the relevant equations both in levels and first differences and using as instruments variables in first differences for the former ones and in levels for the latter ones. Given that equations (3) to (6) involve first differences, this will imply estimating them in first and second differences in our case. We used as instruments for the latter equations the third and fourth lags of the first difference of all the variables and, for the former equations, the second differences of all the variables[3]. We chose q=2 in all the equations not to have second order serial correlation in the residuals after Arellano and Bond (1991). Similar exercises were performed for instance by Huang et al. (2008), Lee and Chang (2007) for various groups of about 20 countries, by Ciarreta and Zarraga (2010) for 12 European countries and by Al-Iriani (2006) for six gulf states.

The statistical significance of partial χ^2 tests associated with right-hand side variables denotes short-run causality, while long-run causality is detected by the statistical significance of the coefficient of the error correction term.

Panel B of Table 3 shows our results regarding Granger causality tests[4]. First of all, it is worth noting that our model performs well in terms of absence of second-order serial correlation in the residuals. Furthermore, our choice of instruments is supported by Hansen tests for overidentifying restrictions. The error correction term drives to a significant extent the short-run dynamics of

[3] Note that we collapsed the instruments once estimating our model after Roodman (2005).
[4] Our results would not change inserting in equations (3) to (6) the residuals of the pooled mean group FMOLS estimator instead of those of the DOLS one.

employment and capital. On the other hand renewable energy generation is not Granger caused by any other variable. Output instead is Granger caused in the short-run by renewable energy generation and employment. The short run effect of renewable energy generation is greater than the one in the cointegration vector, as a 1% higher growth rate in RE increases output growth by 0.1%. The result that an increase in employment by 1% decreases output by 0.2%, instead, is not robust to the exclusion of the statistically insignificant second lag of ΔL from the model. In this case there would not appear to be any Granger causality from ΔL to ΔY. Therefore the sign of the sum of the coefficients of ΔL_{it-1} and ΔL_{it-2} is possibly due to some collinearity in these variables. Furthermore, once dropping ΔL_{it-2} the support of specification tests for the model does not wither. We preferred to show in Table 3 the results including ΔL_{it-2} than those excluding it, for sake of symmetry among equations (3) to (6)[5].

The lack of evidence of any long-run causality between output and renewable energy might be explained by the relatively recent increases in renewable energy generation due to the introduction of photovoltaic and wind power, so that convergence towards the long-run equilibrium might take time to appear.

Concluding remarks

The present contribution analyses the link between renewable energy generation and output at the regional level in Italy from 1997 to 2007 within a multivariate framework and adopting unit root and cointegration tests, as well as estimation of the cointegrating vector and Granger causality tests within a PVECM.

According to our results 1% increases in renewable energy generation, employment and real gross capital formation are significantly associated in the long-run with increases in output of 0.02%, 0.76% and 0.27% respectively.

[5] One further possible explanation for this result is the disappointing performance of labour productivity in Italy under the period of analysis. On this point see for instance Vaona (2011b).

Regarding the short-run, we find evidence that there is uni-directional causality from renewable energy generation to output. We interpret this evidence as supporting the theories of “balance-of-payments constrained growth”, whereby an increase in renewable energy generation softens one economy’s external constraint allowing it to grow faster. In our view, therefore, renewable energy production promotes sustainable development because it does not compromise “the ability of future generations to meet their own needs” (WCED, 1987) not only on environmental grounds but also because it helps not burdening them with a large external debt. Other possible economic interpretations of our results are that renewable energy generation reduces the exposure of regions to the price volatility of fossil fuels and to the negative environmental and health externalities deriving from the production of non-renewable energy, which can hamper economic growth.

Under these respects, our results support the adoption of pro-renewable energy policies such as tax credits, subsidies, renewable energy portfolio standards, the establishment of markets for renewable energy certificates and the enhancement of the link between the financial sector and the renewable energy one.

References

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

Apergis N. and J.E. Payne, Renewable energy consumption and economic growth: evidence from a panel of OECD countries, Energy Policy 38 (2010a), pp. 656–660.

Apergis Nicholas, James E. Payne, Renewable energy consumption and growth in Eurasia, Energy Economics, Volume 32, Issue 6, November 2010b, Pages 1392-1397, ISSN 0140-9883, DOI: 10.1016/j.eneco.2010.06.001.

Apergis, N. and J.E. Payne (2011) “The Renewable Energy Consumption-Growth Nexus in Central America”, Applied Energy, 88, 343-347.

Arellano M, Bond S (1991) Some tests of Specification for Panel Data: Monte Carlo Evidence and an Application to an Employment Equation. Review of Economic Studies 58: 153-182.

Bagnasco, A (1977), Tre Italie, Il Mulino, Bologna.

Baltagi, B., 2001. Econometric Analysis of Panel Data, Wiley, Chichester.

Baltagi, Badi H., Bresson, Georges, Griffin, James M. and Alain Pirotte (2003), "Homogeneous, heterogeneous or shrinkage estimators? Some empirical evidence from French regional gasoline consumption, Empirical Economics, Vol. 28, pp. 795-811.

Baltagi, Badi H., Bresson, Georges and Alain Pirotte (2004), "Tobin q: Forecast performance for hierarchical Bayes, shrinkage, heterogeneous and homogeneous panel data estimators", Empirical Economics, Vol. 29, pp. 107-113.

Bastianelli, F. (2006), La politica energetica dell'Unione Europea e la situazione dell'Italia, La comunità internazionale, 61, pp. 443-468.

Blundell R, Bond, S (1998) Initial Conditions and Moment Restrictions in Dynamic Panel Data Models, Journal of Econometrics 87: 115-143.

Bowden, N. and J.E. Payne, "Sectoral Analysis of the Causal Relationship between Renewable and Non-Renewable Energy Consumption and Real Output in the U.S.", Energy Sources, Part B:, Economics, Planning, and Policy **5** (4) (2010), pp. 400–408.

Chontanawat, J., Hunt, L.C., Pierse, R., 2006. Causality between energy consumption and GDP: evidence from30 OECD and 78 non-OECD countries. Paper No. SEEDS 113. Surrey Energy Economics Discussion Paper Series. University of Surrey.

Ciarreta A., A. Zarraga, 2010. Economic growth-electricity consumption causality in 12 European countries: A dynamic panel data approach, Energy Policy, 38, 3790-3796.

Colangelo, A. (2011), Le regioni ed il territorio in Caminiti, N. M. (ed.), Politiche e misure nazionali sui cambiamenti climatici, ENEA, Rome.

Engle RF, Granger CWJ. Cointegration and error correction: representation, estimation, and testing. Econometrica 1987; 55: 251–76.

Ewing B.T., R. Sari and U. Soytas, Disaggregate energy consumption and industrial output in the United States, Energy Policy 35 (2007), pp. 1274–1281.

Hsiao, C., 2003. Analysis of Panel Data, Cambridge University Press, Cambridge, UK.

Huang et al., 2008 B.N. Huang, M.J. Hwang and C.W. Yang, Causal relationship between energy consumption and GDP growth revisited: a dynamic panel data approach, Ecological Economics 67, pp. 41–54.

Im, K. S., M. H. Pesaran, and Y. Shin (2003) Testing for Unit Roots in Heterogeneous Panels. Journal of Econometrics, 115, 53–74.

Chien-Chiang Lee, Chun-Ping Chang, Energy consumption and GDP revisited: A panel analysis of developed and developing countries, Energy Economics, Volume 29, Issue 6, November 2007, Pages 1206-1223, DOI: 10.1016/j.eneco.2007.01.001.

Kaygusuz, K. (2007) Energy for Sustainable Development: Key Issues and Challenges. Energy Sources, Part B, 2, 73–83.

Klevas V. & M. Antinucci (2004) Integration of national and regional energy development programs in Baltic States. Energy Policy, 32(3), 345-355.

Lee, C.-C., 2005. Energy consumption and GDP in developing countries: a cointegrated panel analysis. Energy Economics 27 (3), 415–427.

Lee, C.-C., 2006. The causality relationship between energy consumption and GDP in G-11 countries revisited. Energy Policy 34, 1086–1093.

Maddala, G. S. and S. Wu (1999). A Comparative Study of Unit Root Tests with Panel Data and A New Simple Test. Oxford Bulletin of Economics and Statistics, 61, 631–52.

Mark Nelson C. & Donggyu Sul, 2003. "Cointegration Vector Estimation by Panel DOLS and Long-run Money Demand," Oxford Bulletin of Economics and Statistics, Department of Economics, University of Oxford, vol. 65(5), pages 655-680, December.

Mauro (2004), The macroeconomics of Italy: a regional perspective, Journal of Policy Modeling, 26, 927-944.

McCombie, J.S.L. and Thirlwall, A.P. (1994), Economic Growth and the Balance of Payments Constraint (London: Macmillan).

McCombie, J.S.L. and Thirlwall, A.P. (2004), Essays on Balance of Payments Constrained Growth: Theory and Evidence (London: Routledge).

Meliciani, V. (2002), The impact of technological specialisation on national performance in a balance-of-payments-constrained growth model, Structural Change and Economic Dynamics, 13, 101–118.

Ng, Serena and Pierre Perron (2001). “Lag Length Selection and the Construction of Unit Root Tests with Good Size and Power,” Econometrica, 69(6), 1519-1554.

Payne, James E., On the dynamics of energy consumption and output in the US, Applied Energy, Volume 86, Issue 4, April 2009, Pages 575-577.

Payne, J.E., 2010a. Survey of the international evidence on the causal relationship between energy consumption and growth. Journal of Economic Studies 37, 53–95.

Payne, J.E., 2010b. A survey of the electricity consumption-growth literature. Applied Energy 87, 723–731.

Payne, J.E. (2010c), “On Biomass Energy Consumption and Real Output in the U.S.”, Energy Sources, Part B: Economics, Planning, and Policy, forthcoming.

Pedroni P. Critical values for cointegration tests in heterogeneous panels with multiple regressors. Oxford Bull Econ Stat 1999;61:653–70.

Pedroni P. (2001) Purchasing power parity tests in cointegrated panels, Review of Economics and Statistics, 83(4): 727–731.

Pedroni P. Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis: new results. Econom Theory 2004;20:597–627.

Roodman, D.: xtabond2: Stata module to extend xtabond dynamic panel data estimator. Center for Global Development, Washington. http://econpapers.repec.org/software/bocbocode/s435901.htm (2005).

Sadorsky, P. Renewable energy consumption and income in emerging economies, Energy Policy **37** (2009a), pp. 4021–4028.

Sadorsky, P. Renewable energy consumption, CO2 emissions and oil prices in G7 countries, Energy Economics **31** (2009b), pp. 456–462.

Sari, R. and U. Soytas, Disaggregate energy consumption, employment, and income in Turkey, Energy Economics **26** (2004), pp. 335–344.

Sari, R. and U. Soytas, The growth of income and energy consumption in six developing countries, Energy Policy 35, 2007, pp. 889-898.

Sari, R., B.T. Ewing and U. Soytas, The relationship between disaggregate energy consumption and industrial production in the United States: an ARDL approach, Energy Economics **30** (2008), pp. 2302–2313.

Streimikiene, D. et al., Use of EU structural funds for sustainable energy development in new EU member states, Renewable and Sustainable Energy Reviews, 11,6 (2007) pp.1167-1187.

Thirlwall, A.P. (1979), The Balance of Payments Constraint as an Explanation of International Growth Rate Differences, *Banca Nazionale del Lavoro Quarterly Review*, March.

Thirlwall, A.P. (1991), Professor Krugman's 45-Degree Rule, Journal of Post Keynesian Economics, 14, 23-28.

Vaona, A. (2011a), Granger non-causality tests between (non)renewable energy consumption and output in Italy since 1861: the (ir)relevance of structural breaks, Working Papers 19/2010, Università di Verona, Dipartimento di Scienze economiche.

Vaona, A. (2011b), Profit rate dynamics, income distribution, structural and technical change in Denmark, Finland and Italy, Structural Change and Economic Dynamics, 22, 3, 247-268.

Windmeijer, F (2005), A finite sample correction for the variance of linear efficient two-step GMM estimators, Journal of Econometrics, 126, 25-51.

WCED, World Commission on Environment and Development (1987), Our Common Future. Oxford: Oxford Univ. Press.

Yoo, S.-H., 2006. The causal relationship between electricity consumption and economic growth in the ASEAN countries. Energy Policy 34 (18), 3573–3582.

Yoo, S.-H. and Y. Kim, 2006, Electricity generation and economic growth in Indonesia, Energy 31, 2890–2899.

Table 1 - Energy statistics for Italian regions, selected years

	1997			2007			1997-2007
Region	**Renewable energy generation in GWh**	**Renewable energy generation as % of total generation**	**Energy balance in GWh**	**Renewable energy generation in GWh**	**Renewable energy generation as % of total generation**	**Energy balance in GWh**	**Average % change in renewable energy production**
Northern Italy							
Lombardia	11045	32.06%	-22732	8987	16.60%	-18542	-2.80
Trentino-A.A.	8376	97.16%	3476	6996	92.47%	720	-2.75
Friuli-Venezia G.	1315	15.34%	169	1283	11.23%	712	-2.09
Liguria	232	1.77%	6624	162	1.40%	4755	-5.42
Veneto	3759	12.75%	29477	3204	18.01%	-14876	-2.58
Piemonte	7380	54.90%	-13357	6138	29.43%	-9235	-2.20
Emilia-Romagna	1210	10.59%	-10817	1143	4.37%	-3796	-0.86
Valle D'Aosta	3100	100.00%	2132	2731	99.86%	1552	-1.97
Central Italy							
Umbria	1591	53.73%	-2333	923	18.16%	-1398	-9.30
Marche	522	63.12%	-5139	209	5.51%	-4550	-16.28
Lazio	1123	4.36%	6113	623	3.78%	-8752	-10.70
Toscana	4259	23.13%	244	5769	29.87%	-2827	2.82
Southern Italy and Islands							
Basilicata	254	24.90%	-1415	489	31.82%	-1625	3.51
Molise	162	26.64%	-586	264	4.91%	3772	2.51
Sardegna	462	4.27%	131	1197	8.74%	670	6.69
Campania	1302	42.87%	-13457	2539	27.00%	-11191	5.76
Abruzzi	1757	57.53%	-2773	1262	29.32%	-3137	-5.59
Puglia	81	0.37%	6415	1080	2.92%	17403	20.69
Calabria	977	12.68%	2205	720	8.07%	2639	-8.17
Sicilia	870	4.12%	2681	1559	6.47%	1421	4.72

Table 2 - Panel unit root and cointegration tests, Italian regions from 1997 to 2007

Panel A: Panel Unit Root Tests. Null hypothesis: all the series have a unit root

	Y	ΔY	RE	ΔRE	K	ΔK	L	ΔL
Im, Pesaran and Shin W-stat	1.43 (0 to 1)	-3.92a (0 to 1)	0.78 (0 to 1)	-4.58a (0 to 1)	-0.55 (0 to 1)	-7.00a (0 to 1)	3.50 (0)	-3.26a (0 to 1)
ADF - Fisher Chi-square	26.22 (0 to 1)	81.33a (0 to 1)	33.09 (0 to 1)	97.11a (0 to 1)	43.71 (0 to 1)	130.64a (0 to 1)	13.64 (0)	72.89a (0 to 1)

Panel B: Panel Cointegration Tests. Null hypothesis: no cointegration

Within dimension Test statistics		Between dimension Test statistics	
Panel v-statistic	-2.434947b	Group rho-statistic	4.215586b
Panel rho-statistic	2.080451b	Group PP-statistic	-2.014797c
Panel PP-statistic	-2.221799b	Group ADF-statistic	-2.038989b
Panel ADF-statistic	-2.225728b		

Notes: variables expressed in natural logarithms. Panel unit root test includes intercept. Including also a trend would not alter our results to a significant extent. Automatic lag length selection (MAIC) used after Ng and Perron (2001). Of the seven cointegration tests, the panel v-statistic is a one-sided test where large positive values reject the null hypothesis of no cointegration, whereas large negative values for the remaining test statistics reject the null hypothesis of no cointegration. All the cointegration tests are carried out without including a trend. For lag selection in the cointegration tests we used the Schwarz information criterion. Upon including hydiosincratic trends, the tests would all reject the null of no cointegration at the 1 per cent level. 1 percent significance level denoted by ‘‘a’’, 5 per cent significance denoted by "b" and 10 per cent by c.

Table 3 - Panel DOLS long-run estimates and causality tests for Italian regions, 1997-2007

Panel A: DOLS estimates

$$Y = \underset{(18.58)a}{2.96} + \underset{(2.37)b}{0.02RE} + \underset{(4.24)a}{0.27K} + \underset{(12.94)a}{0.76L}$$

Notes: t-statistics are reported in parentheses. Significance at the 1 percent level is denoted by "a" and at the 5 per cent level by "b". As result of specification testing based on t-statistics, the model includes two leads, a contemporary value and two lags in ΔRE. All variables are expressed in natural logarithms.

Panel B: Panel causality test results

Dependent variable		Sources of causation (independent variables): Short run				Long-run			Specification tests: Arellano-Bond test for second order serial correlation	Hansen test for over-identifying restriction
		ΔY	ΔRE	ΔK	ΔL	Error correction term				
ΔY	Sum of lagged coefficients	-	0.10	0.05	-0.22	Coefficient	0.01	p-values	0.59	0.61
	χ^2 p-values	-	0.02	0.38	0.01	p-value	0.15			
ΔRE	Sum of lagged coefficients	0.02	-	-0.38	-1.63	Coefficient	0.01	p-values	0.24	0.63
	χ^2 p-values	0.71	-	0.86	0.19	p-value	0.92			
ΔK	Sum of lagged coefficients	2.09	-0.08	-	-2.59	Coefficient	0.02	p-values	0.93	0.78
	χ^2 p-values	0.14	0.72	-	0.29	p-value	0.02			
ΔL	Sum of lagged coefficients	0.00	0.00	0.00	-	Coefficient	0.01	p-values	0.24	0.38
	χ^2 p-values	0.04	0.12	0.41	-	p-value	0.00			

Notes: the model includes two lags in order to avoid second order serial correlation in the residuals. All variables are expressed in natural logarithms