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Abstract

In the present paper the link between renewable energy generation and imports dynamics is explored in import demand equations. We find that renewable energy generation reduces import growth. Results display a considerable robustness.

Keywords: renewable energy generation, import demand, panel data

JEL Codes: F10, Q20, Q43, C23

Introduction

The present paper investigates the connection between renewable energy generation and import demand. This research question is interesting because a recent stream of literature found that renewable energy generation can spur economic growth, once analyzing both cross-country and cross-region datasets and relying on panel data econometrics (Sadorsky 2009a, 2009b, Apergis and Payne 2010a, 2010b, 2011, Magnani and Vaona 2013). One of the proposed intuitions for this result is that renewable energy can hasten economic growth because it softens the balance-of-payments constraint of an economy, which would support Thrilwall's law (see for instance Thirlwall, 1979, 1991, 2011; McCombie and Thirlwall, 1994, 2004; Meliciani, 2002). In other words, renewable energy generation raises the sustainable level of output, boosting the productivity of production inputs[1].

In principle, one can think, for instance, that renewable energy reduces external demand for traditional energy sources, while increasing at the same time the external demand for inputs for its production process. Therefore, we do not focus here on the energy balance, but on the overall imports of the economy because we want to capture the overall effect of renewable energy generation. However, there is scant evidence concerning renewable energy generation and

[1] Other possible interpretations are that renewable energy generation is able to reduce the exposure of an economy to the volatility of the oil market - and, therefore, uncertainty - and to the negative effects stemming from non-renewable energy generation to the environment and human health (see the literature quoted in Magnani and Vaona, 2013). In addition, Chien and Hu (2007) used a data envelopment analysis, covering 45 countries over the period 2001-2002. They showed that macroeconomic efficiency can be boosted by renewable energy sources.

foreign trade magnitudes available in the literature. To our knowledge the only one study following such research path is Chien and Hu (2008). They adopted a structural equation model and they assessed how renewable energy sources affect the trade balance and capital accumulation. Support was found for the latter relation, but not for the former one. Their analysis is path breaking. However, it is necessary to deepen our knowledge of this research field. This is because in their analysis only the year 2006 is considered and the equation of trade balance and energy imports has only two regressors. For these reasons, we believe more research is needed in this area.

Specifically, we believe a better understanding of the issue at stake can be gained building on a consolidated framework in the economics literature, namely that of import demand equations.

This approach models imports, M, as a function of their relative price, P_m, and of the income level of a country, Y:

$$M = P_m^{\beta} Y^{\pi} \tag{1}$$

where β and π are coefficients.

Taking logs and first differences one can write:

$$m = \beta p_m + \pi y \tag{2}$$

where lower case letters denote percentage changes.

Usually (2) is estimated in partial adjustment form

$$m_t = \beta_0 + \alpha m_{t-1} + \beta_1 p_{m,t} + \pi y_t + \epsilon_t \tag{3}$$

where t is a time index, β_0, β_1, α are coefficients and ϵ is a stochastic error.

Many studies investigated the determinants of import demand. Regarding developed countries it is possible to list Urbain (1992), Deyak, Sawyer, and Sprinkle (1989, 1993), Clarida (1994), Mah (1994), Marquez (1994), Carone (1996), Masih and Masih (2000) and Pattichis (1999). Regarding developing countries, instead, one can mention Marquez and McNeilly (1988), Mah, (1992, 1993, 1997), Bahmani-Oskooee and Rhee (1997), Bahmani-Oskooee and Niroomand (1998), Senhadji (1998), Reinhart (1995) and Wang and Lee (2002). All in all, these studies concluded that import demand is driven by income and relative prices, but to a greater extent by the former than by the latter ones.

A recent twist of this literature focused on the effect of trade liberalization policies. For instance see Santos-Paulino (2002) and Santos-Paulino and Thirlwall (2004). They added to (3), further regressors to control for import duties, d, and for the timing of liberalization policies. Their findings are that import duties have a negative impact on import growth, which, instead, rises after the reduction of trade distortions. We build on their approach by further adding renewable energy generation. In the appendix, we experiment with fossil and nuclear energy too.

The rest of this paper is structured as follows. First we describe our dataset and data sources. Then we illustrate our results and robustness checks. Finally, we conclude.

The data

The World Development Indicators, produced by the World Bank, are our data source. Table 1 lists our variables and their definitions. There is a good variability in the data, as showed by Table 2. We consider 26 countries over different time periods. More information about this is provided in Table 3, which also sets out the percentage change in renewable energy generation for each country over the period of observation. Note that we consider n and f to perform robustness checks only. Therefore in the main body of the text we do not devote them further attention.

Table A1 in the Appendix also shows that there is no evidence of collinearity among our main variables of interest.

Table 1 - Description of variables

Variable	Description
m	Imports of goods and services (constant 2000 US$), percentage change
p_m	Opposite of the percentage change in the real effective exchange rate index (2005 = 100)
y	Percentage change in GDP (constant 2000 US$)
d_m	Customs and other import duties as percentage of imports of goods and services
re	Electricity production from renewable sources (kWh), % change
n	Electricity production from nuclear sources (kWh), % change
f	Electricity production from oil, gas and coal sources (Kwh), % change

Table 2 - Descriptive statistics

Variable	Observations	Mean	Std. Dev.	Min	Max
m	192	0.04	0.16	-0.69	0.57
p_m	192	-0.02	0.21	-1.73	0.75
y	192	0.03	0.05	-0.16	0.11
d_m	192	0.05	0.05	0.00	0.21
re	192	0.02	0.23	-0.93	0.94
n	45	0.08	0.34	-0.20	2.07
f	192	0.01	0.45	-3.27	1.97

Notes. For variable description see Table A1

Table 3 - Average percentage change in renewable electricity generation by country

Country	Time period	Percentage change in renewable electricity generation
Algeria	2006-2009	-0.15
Australia	2005-2011	0.04
Bulgaria	1997-2001	-0.10
Cameroon	1990-1999	0.01
China	2002-2005	0.12
Congo, Dem. Rep.	1990-2010	0.01
Costa Rica	2008-2010	0.02
Cote d'Ivoire	2003-2010	0.00
Dominican Republic	2004-2009	0.05
Ecuador	1990-1993	0.04
Iceland	1998-2010	0.09
Iran, Islamic Rep.	1994-1995	-0.15
Macedonia, FYR	2005-2008	-0.14
Malaysia	1996-2010	0.01
Mexico	1990-2000	0.05
Morocco	2005-2010	0.14
Nicaragua	1990-1992	-0.06
Norway	2007-2011	0.00
Romania	2002-2004	0.03
Russian Federation	2002-2010	-0.01
South Africa	2004-2010	0.23
Togo	2004-2010	-0.06
Tunisia	1990-2010	0.08
Ukraine	1999-2010	-0.01
Uruguay	1990-2003	0.06
Zambia	1992-1994	-0.03

Results and robustness checks

Following the example of Santos-Paulino (2002) and Santos-Paulino and Thirlwall (2004) we adopted the panel system-GMM estimator proposed by Blundell and Bond (1998) and coded by Roodman (2005). We also used the finite sample correction proposed by Windmeijer (2005). This approach is necessary because standard methods, such as the least squares dummy variables one, are well known to provide biased estimates in dynamic panel data models (Nerlove, 1971).

We preferred this estimator not only because its properties above, but also because it is an instrumental variables one, able to overcome possible problems of endogeneity. The system-GMM estimator by Blundell and Bond (1998) 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.

As it is possible to see in Table 4 the most significant variables are p_m, y and re. The results for the first two variables, as well as the magnitude of their coefficients and the weakness of the other regressors, are similar to those obtained by Santos-Paulino (2002) and Santos-Paulino and Thirlwall (2004), for instance. The result concerning re lends support to our hypothesis that renewable energy generation reduces external dependence to a significant extent.

It is well known that estimates obtained by system-GMM can be sensitive to the instrument set. So we experimented by progressively reducing the number of instruments. First we started with all the lags of the regressors in levels, for differenced equations, and, for equations in levels, the first differences of all the regressors (Model 1 in Table 4). Next we excluded the levels and first differences of m (Model 2 in Table 4). In model (3) levels and first differences of d_m were dropped. Finally, model (4) omits the sixth and further lags of p_m, y and re from the instrument set. Our results are not affected.

In principle, it could be that our results are driven by outliers, given the diversity of countries considered. So we projected the residuals of model 4 in Table 4 on a box plot in order to single out the largest and smallest ones (Figure A1). We considered residuals greater than 0.5 and smaller than -0.5. They turned out to belong to three countries, the Democratic Republic of Congo, Zambia and Cameroon. We excluded these countries from the sample. Once again results were not affected as it is possible to see in Column 5 in Table 4. Finally, our sample includes both net energy importers and exporters. Net energy imports are estimated as energy use less production, both measured in oil equivalents. Negative values denote net energy exporters. As a further robustness check, we omitted them from our sample. As showed by the sixth column in Table 4, our results are not affected.

We also tried to substitute *n* and *f* for *re*. Both nuclear and fossil energy generation did not turn out to be significant determinants of import growth. See Table A2 in the Appendix. Further note that considering in the same model *n*, *fe* and *re* reduces the sample to only 34 observations, making it too small. Considering *fe* and *re* in the same model would not alter our results: *f* is not significant, while *re* is negative and significant. The magnitude of the coefficients is the same as those set out in Tables 4 and A2[2].

We ran a number of further robustness checks. In the first place, we check for the stability of our results across time. We split our period of observation into three sub-periods: from 1990 to 1997, from 1998 to 2004 and from 2005 to 2011. We generated three time dummies, one for each sub-period, and we interacted them with *re*. We next inserted the three resulting variables into our model, after dropping *re* not to fall into the dummy variables trap. Finally, we tested for the equality of the coefficients of the three interaction variables. A χ^2 test with two degrees of freedom did not reject the null, returning a p-value of 0.96.

[2] More details are available from the author upon request.

Table 4 - Regression results. Dependent variable: percentage growth rate of imports

	(1)	(2)	(3)	(4)	(5)	(6)
m_{-1}	0.002	0.013	0.059	0.089	-0.113	-0.019
z-stat	0.030	0.170	0.600	0.580	-1.600	-0.110
p_m	-0.149***	-0.153***	-0.14***	-0.109***	-0.352***	-0.312***
z-stat	-6.370	-6.250	-5.260	-2.190	-6.850	-3.820
y	2.112***	2.228***	2.206***	2.392***	2.347***	1.826***
z-stat	8.050	7.240	4.200	3.230	10.810	3.560
d_m	-0.335	-0.058	-2.087	-3.826	-0.567	-0.332
z-stat	-0.430	-0.080	-0.920	-0.910	-0.730	-0.330
re	-0.081***	-0.089***	-0.080***	-0.092***	-0.086***	-0.121***
z-stat	-3.420	-3.900	-2.560	-2.140	-2.910	-3.630
Constant	0.002	-0.018	0.090	0.176	-0.002	-0.012
z-stat	0.070	-0.600	0.710	0.760	-0.060	-0.210
Number of instruments	81	69	55	19	19	19
Arellano-Bond test for 2nd order serial correlation (p-value)	0.270	0.266	0.298	0.433	0.139	0.210
Hansen test of overid. restrictions (p-value)	1.000	1.000	1.000	0.419	0.543	0.850
Wald test that all coeff. are zero	0.000	0.000	0.000	0.001	0.000	0.000
Observations	157	157	157	157	129	77

Notes. For the description of variables see Table A1. Specifications differ in terms of used instruments, with the exception of specification (5) an (6). The instrument set in specification (1) includes, for differenced equations, all the lags of the regressors in levels and, for equations in levels, the first differences of all the regressors. In specification (2) the lags of *m* were excluded from the instrument set. In specification (3) levels and first differences of d_m were excluded from the instrument set. In specification (4), sixth and further lags of p_m, *y* and *re* were excluded from the instrument set of equations in differences. In model (5) the Democratic Republic of Congo, Zambia and Cameroon were excluded from the sample. Model (6) excludes net energy exporters.

We next checked for the stability of our results across different groups of countries. We split the observations in our sample according to whether a country belongs to different continents, namely Africa, Asia, Europe, Latin and Central America and Oceania. We proceeded as with time sub-periods above, but defining different dummies with different continents. A χ^2 test with four degrees of freedom did not reject the null, returning a p-value of 0.53. We tried also with a different partition of countries, namely we considered three sub-groups according to the growth rate in the electricity generated from renewable sources. Once again the null of the stability of our results was not rejected, as a χ^2 test with two degrees of freedom returned a p-value of 0.67.

Finally, we checked for any nonlinearity in the connection between *re* and *m*, by inserting powers of the former variable in our baseline model. Once inserting re^2, the null hypotheses of its coefficient being equal to zero was not rejected. The p-value of a χ^2 test with one degree of freedom was equal to 0.58. Once inserting both re^2 and re^3, the test statistic had a p-value of 0.69 and, when also adding re^4, one of 0.63. All the robustness checks, therefore, support our model.

Conclusions

The aim of this paper is to investigate the link between imports and renewable energy generation. This is because an intuition recently offered in the literature for the finding that renewable energy fosters economic growth is that it softens the external balance-of-payments constraint. Our results support this intuition and they display a considerable robustness.

The policy implications already discussed in Magnani and Vaona (2013) - in terms of the debate surrounding feed-in-tariffs and quota systems, the necessity to coordinate different policy tools, providing proper administrative procedures and coherent regulations - find, therefore, further strength. Renewable energy generation contributes to the sustainability of an economy, not only reducing environmental and health externalities of fossil and nuclear energy, but also helping to reduce its external dependence and debt.

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Appendix

Table A1 - Correlation matrix

Variable	m	p_m	y	d_m	re
m	1				
p_m	-0.24	1			
y	0.56	-0.08	1		
d_m	-0.07	-0.07	-0.14	1	
re	-0.02	0.00	0.03	0.00	1

Notes. For variable description see Table A1

Table A2 - Regression results. Dependent variable: percentage growth rate of imports

	(1)	(2)
m_{-1}	0.019	-0.527
z-stat	0.140	-0.490
p_m	-0.091	0.230
z-stat	-1.590	0.380
Y	2.370***	1.937
z-stat	4.370	0.700
d_m	-4.269	5.837
z-stat	-1.340	0.740
n	-	-0.201
z-stat	-	-1.210
f	-0.031	-
z-stat	-1.200	-
Constant	0.173	-0.117
z-stat	1.530	-1.700
Number of instruments	19	19
Arellano-Bond test for 2nd order serial correlation (p-value)	0.330	0.190
Hansen test of overid. restrictions (p-value)	0.690	1.000
Wald test that all coeff. are zero	0.000	0.000
Observations	157	34

Notes. For the description of variables see Table A1. The instrument set is the same as in Model (5) of Table 3, with the exception that n and f have been used instead of re where necessary.

Figure A1 - Box plot of the residuals of model (4) in Table 3