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Production of non-traditional renewable energy in Latin America: economy and public policies[1]

Enzo Dalmazzo-Bermejo
Universidad de Playa Ancha, Chile
edalmazzo@alumnos.upla.cl

Bárbara Valenzuela-Klagges
Universidad San Sebastián, Santiago, Chile
Barbara.valenzuela@uss.cl

Luis Espinoza-Brito
Universidad de Playa Ancha, Chile
lespinoza@upla.cl

Abstract. The objective of this study is to determine the variables that influenced the development or production of non-traditional renewable energies in Latin America over the period 1995-2007, in order to contribute to the orientation of public policies that promote such production. To this end, we use pool panel and static and dynamic panel data to estimate the factors that influence renewable energy production across 13 Latin American countries. The study identifies the best estimation of the phenomenon, whereby it is the dynamic data panel method that enables the best adaptation to the Latin American reality and orientation of public policies to increased energy production. This study allows a comparison of the results obtained by Dalmazzo-Bermejo and Valenzuela-Klagges (2016), which focuses on a longer period in which behavior subsequent to the subprime crisis is modeled.

Keywords: Renewable energy; public policy; static data; dynamic panel data.

1 Research based on the thesis of Enzo Dalmazzo-Bermejo for the professional degree in Civil Industrial Engineering and the licentiate in Engineering Sciences at the Faculty of Engineering of the Universidad de Playa Ancha (Chile).

Acronyms and abbreviations

EEP	Energy and Environment Partnership with Central America
FOB	Free on Board
GDP	Gross domestic product
IEA	International Energy Agency
MW	Megawatts
OECD	Organisation for Economic Co-operation and Development
R+D	Research and development
RPS	Renewable portfolio standards
USDA	United States Department of Agriculture

Introduction

In our earlier study (Dalmazzo-Bermejo & Valenzuela-Klagges, 2016) we perform an introductory analysis of the relationship between economic growth and energy consumption and cite several authors, including Tverberg 2011; Campo & Sarmiento, 2011; CIGE, 2009; Gómez-López, 2011; Paul & Bhattacharya, 2004; Cheng & Lai, 1997; Asafu-Adjaye, 2000; Soytas & Sari, 2003; Lee, 2006; among others. Tverberg (2011) studies the relationship between energy consumption and gross domestic production (GDP) around the world, and concludes that before 2000, world real GDP – according to the United States Department of Agriculture (USDA) and based on Economic Research Institute data – was increasing more rapidly than energy consumption, at an average annual rate of 2.5% per British Petroleum (now BP) statistical data estimations.

Meanwhile, Campo & Sarmiento (2011) find that both energy-dependent and non-energy-dependent countries have the capabilities to establish energy conservation programs with a low impact on GDP. Barreto & Robledo (2012) observe that on average, 59.5% of Latin American GDP is oriented towards the service sector, which is associated with heavy dependence on the energy production factor and the labor factor. Earlier studies, such as those of Apergis & Payne (2012) and Campo & Sarmiento (2011), also find evidence of energy dependence. This supports the hypothesis that Latin American countries are energy-dependent, which underlines how important it is for these nations to diversify their economies and seek energy substitutes for the future.

For Bolívar, Mostany & García (2006), the growing need for energy will lead to diversification of energy sources and decentralization of the sector, thus enabling better utilization of local advantages. But the issue of incorporating more renewable energy sources is not the result of the risk of energy crisis alone; over the past 20 years, the greenhouse effect, and especially CO2 emissions, has become an increasingly pressing consideration for the electricity sector (Arar & Southgate, 2009). Taking this into account, Kindermann (2012) stresses the importance of implementing policies to promote such renewable sources.

Thus, there is general agreement on the need for alternative energy sources as substitutes for fossil fuels (Maldonado & Márquez, 1996; Honty, 2006; Melle, 1998; Jean-Baptiste & Ducroux, 2003). The benefits of renewable energies can be divided into three broad categories: energy security, sustainable growth, and environmental protection.

However, there are barriers to their implementation. According to various authors (Ramírez, 2011; Maldonado & Márquez, 1996; Molina

& Rudnick, 2011; GreenMax Sustainability & Finance, AF Mercados & Creara International, 2013; Coviello, Altomonte & Lutz, 2003; and Dalmazzo-Bermejo & Valenzuela-Klagges 2016), implementation has been impeded by obstacles that differ from one country to another, and may be: a) regulatory; b) economic; c) technological; or d) technical.

In view of the above, the objective of this study is to determine the variables that influenced the development or production of non-traditional renewable energies in Latin America over the period 1995-2007 with the purpose of contributing to the orientation of public policies that foster production. To this end, we will use static and dynamic panel data to estimate the factors that affect renewable energy production in 13 Latin American countries, and compare these factors with the variables that affect primary energy production.

Our main reason for choosing this period is that it encompasses the beginning of Latin American energy projects, and was not affected by the subprime crisis; this is because the historical dependence of the Latin American economies on the evolution of the U.S. economy, as well as the appreciable reconfiguration of the Latin American macroeconomic outlook, have given rise to clear differences compared with the situation that prevailed little over a decade ago.

This study is divided into four parts: the first consists of a bibliographic review of theories and evidence related to economic factors, and to the barriers and political incompetence that affect the application of renewable energy. In the second part, we present a model and equations based on our estimation methodology. In the third, we present the results of the different equations. In the final section, we set out our conclusions and recommendations.

Past research has shown that dynamic panel data models are best suited to describing the Latin American reality as far as primary and renewable energy production are concerned. It is noteworthy that renewable and primary energy production in previous years has an influence on present-day energy production.

1. Evidence and theories

The development of renewable energy (Fajardo, Ortega, Borobia & López, 2003) requires economic effort and considerable political will. The justification for demanding these outlays and this political resolve are expressed by society and its agents from different standpoints, one being the environmental problems that traditional energies have inflicted upon the modern world. For instance, through its Renewable Energy Plan

2011-2020 (Plan de Energías Renovables 2011-2020), Spain has made a firm commitment to reach 20% renewable energy usage by 2020. Collell *et al*. (2010, p.3) propose a new energy model for the same country: "Free of CO2 emissions and free of nuclear energy in 2050, with total coverage of energy demand (100%) using renewable energy"[2] (2010, p. 3). Navarra was one of the first Spanish regions to implement specific energy plans related to renewable energies, giving rise to a highly dynamic and high-tech business sector as well as expenditure on research and development (R+D) and research-intensive activities. However, the main limitation on the development of Spain's renewable energy sector has been a lack of qualified personnel, especially in terms of professional training and technical university qualifications.

In Germany, the growth and development of renewable energy began in the 1990s (Arizmendi, 2010), due in large part to the premium system introduced in 1991. This system was based on the market energy price, to which a premium was added. Electricity companies were required to buy energy from renewable energy generators and to pay this premium (calculated on the basis of the average price of electricity sold to consumers). It also assured photovoltaic electricity generators of access to the grid for the first time, and investors of a return on their financing. During this period, 42 megawatts (MW) were installed. For Isaac, Biechl & Gonzalez (2008), Germany's renewable achievements surpassed the original targets set: "for 2010, it was expected that 12.5% of total consumption would be met through these resources, and this was raised to 15%; for 2020, 27% was expected and 45% for 2030"[3] (2008, p. 50).

In 2010, Denmark's renewable energy share was the eighth highest of all members of the International Energy Agency (IEA), as a proportion both of total primary energy supply and of electricity production; wind energy accounts for 20.2% of electricity produced, and biomass and waste for 13.2%. In 2011, the Danish government announced its intentions to do away with fossil fuels altogether by 2050 (André, De Castro & Cerdá, 2012). It should be noted that Denmark does not possess hydroelectric resources (International Energy Agency, IEA, 2012).

The case of New Zealand is also interesting. Renewable energy there contributed more than 33% to the total primary supply in 2008. Particularly prominent were hydroelectric and geothermal energy. In that same year, 64% of electricity production came from renewable energies, rising

2 Translation by *Apuntes.*
3 Translation by *Apuntes.*

to 73% in 2009. New Zealand's renewables share is the third highest of the Organization for Economic Co-operation and Development (OCDE) countries, behind only Norway and Austria. But New Zealand particularly stands out for making the decision in 2007 to become carbon-neutral – that is, with zero net emissions. This effort involves government-led initiatives in the design of efficient consumption in public buildings, elimination of waste in consumption, increased recycling, substitution of business travel with teleconferences, and greater use of energy-efficient vehicles (André *et al.*, 2012).

According to Arizmendi (2010), these success stories would not have been possible without policy support. This is necessary and will remain so in the foreseeable future if renewable technologies are to be improved and developed to the point where they can compete with other energy sources.

As in these European cases, in Latin America these is a need for greater support in the form of government policies (Coviello *et al.*, 2003). However, the problem of supportive policies is that they respond to local or national contexts, and as such, there is no one-size-fits-all policy that can work in all countries; thus, many countries repeat the same mistakes that others made previously (Arizmendi, 2010).

In this study, we propose that primary and renewable energies are a fundamental component in any sustainable development strategy, not only because of their particular ubiquity in all human activity, but also because of the decisive role that the different energy options play in the quality of life in society as a whole (Maldonado & Márquez, 1996) and to economic growth. Below, in Table 1, we provide a selective overview of the literature on the economic factors that affect the application of renewables, and the barriers and political incompetence to which they are subject, in Latin America and elsewhere.

Table 1
Selective overview of economic factors, barriers, and incompetence in the application of renewable energies

Issue	Description and results	Sources
Relationship between economic growth and energy consumption	For some economies there is a bidirectional relationship between economic growth and energy consumption, while others find that GDP growth pushes up energy consumption; and still others identify Granger causality between energy consumption and economic growth (Soytas & Sari, 2003; Lee, 2006).	Tverberg (2011); Campo & Sarmiento (2011); CIGE (2009); Gómez-López (2011); Paul & Bhattacharya (2004); Cheng & Lai (1997); Asafu-Adjaye (2000); Soytas & Sari (2003); Lee (2006)
Oil collapse and progression to new energy sources	Considering that 80% of oil comes from wells discovered in the 1970s that are nearing their daily extraction ceilings, if the fuel consumption curve is increasing while oil extraction is decreasing, two options open up: either reduce consumption by changing the direction of the curve, or urgently find a substitute (Honty, 2006). For Albavera (2006), these considerations form a clear basis for discussion about a new global energy order; simply put, countries that enjoy greater well-being consume more energy than they produce.	Honty (2006); Bolívar, Mostany & García (2006); Albavera (2006); Maldonado & Márquez (1996); Laherrere (2001); Ramírez (2011); Melle (1998); Ballenilla (2004)
Importance of new policies to the inclusion of renewable energies in the energy matrix	The scope of these policies and the economic viability of their implementation depends on factors that are specific to each country (Ramírez, 2011; Molina & Rudnick, 2011), such as the exploitable potential of renewable resources, their geographical location, and the characteristics of the energy markets in which they compete. The non-inclusion of renewable sources in energy policies constitutes, in one way or another, a failure of public policy formulation, and even of international cooperation. In those countries with an interest in implementing clean energy, there is no market designed for all of the technology options that now exist.	Ramírez (2011); Molina, & Rudnick (2011); Coviello *et al.* (2003); Reddy & Painuly (2004); Vleuten, & Raven (2006); Cadena, Botero, Táutiva, Bentancur & Vesga (2009); Sovacool (2009); Altomonte (2008); Meisen & Krumpel (2009); Urdaneta (2008); Koehler (2012)

(Continued overleaf)

(Continued)

Issue	Description and results	Sources
Barriers to the implementation of renewable energies in Latin America	The barriers to the utilization of renewable energies are well documented, and can be grouped into four categories: technical; social and information-related; economic and financial; market-related; and legal and regulatory (Coviello *et al.*, 2003). However, few studies have devised a ranking that characterizes the importance of these barriers for a given country. In general, these depend greatly upon the circumstances in each country; for example, the technical barrier related to "limited technical capacity" in Chile has translated into overcosts for emerging industries such as wind, in which early projects even had to import specialized labor for installation (García & Delgado, 2011); on the other hand, in countries where the outlook is different, such as Denmark, companies have developed new energy technology solutions, thereby reducing investment costs and positioning themselves as leaders in wind turbine production (Ramírez, 2011).	Painuly (2001); Ramírez (2011); Maldonado & Márquez (1996); Molina & Rudnick (2011); GreenMax Sustainability & Finance *et al.* (2013); Coviello *et al.* (2003); Zhang, Shen & Chan (2012); Reddy & Painuly (2004); García & Delgado (2011)
Mechanisms for the use of renewables in Latin America	Energy supply is a complex matter, encompassing a great many political, economic, and environmental variables. On the international level, there are three main incentives to increase the usage of renewable energy (Kindermann, 2012): feed-in tariffs; mandatory quotas (renewable portfolio standards, RBS) and competitive bidding processes. The Latin American countries that have recorded the highest growth levels in renewables employ either competitive bidding processes (Uruguay and Brazil) or mandatory quotas (Chile). Meanwhile, in the case of developed countries, such as those in Europe, the mechanism that has yielded the best results is feed-in tariffs.	Arar & Southgate (2009); Kindermann (2012); Molina & Rudnick (2011); Jean-Baptiste & Ducroux (2003)

2. Estimation of the model

In this study we determine a linear equation to represent Latin American energy production, supported by a review of the evidence and theories. We adapt and estimate this equation using random effect, fixed effect, and pooled static panel data, as well as with dynamic effects (Arellano-Bover/Blundell-Bond), to examine the variables that may be influencing energy production in 13 Latin American countries, ten of which are in South

America (Argentina, Bolivia, Brazil, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela, and Chile); two in Central America (Costa Rica and Panama); and one in North America (Mexico) [4] for the period 1995-2007.[5]

In order to obtain and compare the variables that influence energy production in Latin America, we present two different dependent variables: the first is electricity production from renewable sources (excluding hydroelectricity); and the second is primary energy production. The renewable energy produced in the aforementioned countries, according to International Energy Agency (IEA) data, accounts for almost 29% of the total primary energy supply in Latin America – a relatively high figure compared with the 5.7% for OECD countries (Canseco, 2010, p. 4).

In this study, we follow the econometric method proposed by Dalmazzo-Bermejo and Valenzuela-Klagges (2016), except that we also include the real GDP of the producer country as an explanatory variable and exclude the variables related to the subprime crisis, since our study only covers the period prior to the crisis. We choose to include real GDP in order to analyze the effects of economic growth and its factors of production on energy production, which is fundamental to shaping public policy. The extended model that forms the basis of our estimation is provided by the following equations expressed in natural logarithms:

Equation 1
Production of electrical energy based on renewable sources

$$ln\,(Pfr_{it}) = \beta_0 + \alpha\, ln\,(Gcg_{it}) + \varepsilon\, ln\,(Ic_{it}) + \rho\, ln\,(Dp_{it}) + \varphi\, ln\,(Gg_{it}) + \omega\, ln\,(Expb_{it}) + \mu\, ln\,(Ile_{it}) + \sum_{k} \delta_k P_{it} + u_i$$

Equation 2
Production of primary energy

$$ln\,(Pep_{it}) = \beta_0 + \alpha\, ln\,(Gcg_{it}) + \varepsilon\, ln\,(Ic_{it}) + \rho\, ln\,(Dp_{it}) + \varphi\, ln\,(Gg_{it}) + \omega\, ln\,(Expb_{it}) + \mu\, ln\,(Ile_{it}) + \sum_{k} \delta_k P_{it} + u_i$$

4 Some Latin American countries were not included due to a shortage or absence of data for five or more consecutive years during the period of study.

5 We chose this period based on availability of data (Banco Mundial, 2012) and in order to take the subprime crisis (which is not covered by this research) as the cut-off point. The lack of post-2007 World Bank data for many Latin American countries limited the possibilities of including more years of study.

Where[6]:

i: Country

t: Time

Pfr_i: Electricity production based on renewable sources of country *i* (equation 1)

Pep_i: Primary energy production of country *i* (equation 2)

Gcg_i: Real GDP of country *i*

Ile_i: Index of economic freedom of country *i*[7]

Ic_i: Corruption index of country *i*

Dp_i: Population density of country *i*

Gg_i: Government expenditure of country *i*

$Expb_i$: Total FOB goods exports by product group of country *i*

Moreover, equations 1 and 2 incorporate the dummy variables $[\sum_k \delta_k P_{it}]$, taking the value of 1 in case of the stated event occurring, or the value of 0 otherwise. The dummy variables included in the model are:

Imp_i: Energy imports of country *i*

Pen_i: Nuclear energy production of country *i*

The number of observations per year is 11, including the countries that import energy and those that produce nuclear energy in Latin America. The total number of observations is 143.

Since a large sample of countries and years is generally used in the application of a model, it is possible that some observations in the endogenous variables (such as renewable energy production) take the value of 0. Because log transformation is generally not possible in these cases, the observation is discarded or Tobit estimations are employed; see Wang & Winters (1992), and Soloaga & Winters (2001). For this reason, Kume & Piani (2000), Azevedo (2001), and Wall (2003) have addressed 0 observations by substituting them with small values (0.01) in the dependent variable (electricity production from renewable sources), while Eichengreen & Irwin (1997) and Wall (2003) do so by adding 1 to all observations.

In this study, in which we focus on the period 1995-2007, we deal with 0 observations using the approach of Kume & Piani (2000), Azevedo

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6 We use the following databases and information: Transparency International: corruption index; Economic Commission for Latin America and the Caribbean, ECLAC: primary energy production and total energy consumption in thousands of barrels of oil equivalent and total FOB goods exports in millions of dollars; World Development Indicators 2007-2012, Banco Mundial (2012); and the index of economic freedom of Miller, Holmes & Feulner (2017).

7 The index of economic freedom is obtained from a list of 50 independent variables grouped into the following categories: trade policy; fiscal burden of government; government intervention in the economy; monetary policy; capital flows and foreign investment; banking and finance; property rights; regulations; and black market.

(2001), and Wall (2003): we substitute them for small values (0.01) in the electricity production variable (excluding hydroelectricity).

We estimate equations 1 and 2 using pooled and random effects panel data. In the case of this latter effect, the intercept of regression β_0 is considered as $\beta_0 = \beta + u_i$

These equations are adapted to the fixed effects panel data estimation in equations 3 and 4, excluding all fixed variables that remained throughout the period of study, and intersections can be observed for all countries studied.

Equation 3
Production of electrical energy based on renewable sources

$$ln\,(Pfr_{it}) = \beta_{it} + \alpha\, ln\,(Gcg_{it}) + \varepsilon\, ln\,(Ic_{it}) + \rho\, ln\,(Dp_{it}) + \varphi\, ln\,(Gg_{it}) + \omega\, ln\,(Expb_{it}) + \mu\, ln\,(Ile_{it}) + u_i$$

Equation 4
Production of primary energy

$$ln\,(Pep_{it}) = \beta_{it} + \alpha\, ln\,(Gcg_{it}) + \varepsilon\, ln\,(Ic_{it}) + \rho\, ln\,(Dp_{it}) + \varphi\, ln\,(Gg_{it}) + \omega\, ln\,(Expb_{it}) + \mu\, ln\,(Ile_{it}) + u_i$$

Where β_{it} is a fixed number for each country.

In addition, equations 1 and 2 are adapted to the dynamic panel data estimation in equations 5 and 6.

Equation 5
Production of electrical energy based on renewable sources

$$\ln\,(Pfr_{it}) = \beta_0 + \beta_1 \ln\,(pfr_{it-1}) + \alpha \ln\,(Gcg_{it}) + \varepsilon \ln\,(Ic_{it}) + \rho \ln\,(Dp_{it}) + \varphi \ln\,(Gg_{it}) + \omega \ln\,(Expb_{it}) + \mu \ln\,(Ile_{it}) + u_i$$

Equation 6
Production of primary energy

$$ln\,(Pep_{it}) = \beta_0 + \beta_1 ln\,(pep_{it-1}) + \alpha\, ln\,(Gcg_{it}) + \varepsilon\, ln\,(Ic_{it}) + \rho\, ln\,(Dp_{it}) + \varphi\, ln\,(Gg_{it}) + \omega\, ln\,(Expb_{it}) + \mu\, ln\,(Ile_{it}) + u_i$$

In which $ln\,(pfr_{it-1})$ and $ln\,(pep_{it-1})$ are the first lag of the dependent variables of electrical energy production from renewable sources, and primary energy production for country *i*. In the dynamic panel data estimations, we will include a second lag.

3. Results

Table 2 shows the results of equations 1 and 2 (pooled); while Table 3 presents those of 1 and 2 (random effects); and Table 4, those of equations 3 and 4 (fixed effects). Later on, the results of equations 5 and 6 (dynamic effects) are set out in tables 5 and 6. We estimate these equations using dynamic panel data (Arellano-Bover/Blundell-Bond) with one and two lags, respectively.

Table 2
Pooled estimation (equations 1 and 2)

Variables	Production of renewable energy	Production of primary energy
Constant	- 25.125*** (5.628)	10.338*** (2.459)
GDP	0.026 (0.046)	0.008 (0.020)
Corruption	- 0.356 (0.552)	- 0.229 (0.241)
Government expenditure	0.011 (0.046)	0.193*** (0.020)
FOB manufactured exports	1.040*** (0.118)	0.583*** (0.051)
Population density	- 0.398** (0.189)	- 0.302*** (0.082)
Production of nuclear energy	0.644 (0.453)	- 1.128*** (0.198)
Energy imports	1.384** (0.407)	- 2.169*** (0.177)
Index of economic freedom	6.340*** (1.245)	- 1.295** (0.544)
R^2	0.775	0.913

Notes
(1) Values with heteroscedasticity corrected by way of the White test.
(2) Level of significance: *** = error of 0%; ** = 0% < P ≤ 5%; * = 5% < P ≤ 10%

Table 3
Random effects estimation (equations 1 and 2)

Variables	Production of renewable energy	Production of primary energy
Constant	2.252 (5.177)	3.084* (1.639)
GDP	0.0009 (0.029)	- 0.009 (0.005)
Corruption	- 0.884** (0.424)	- 0.103 (0.083)
Government expenditure	- 0.038 (0.114)	0.287*** (0.061)
FOB manufactured exports	0.891*** (0.164)	0.127** (0.041)
Population density	- 0.265 (0.508)	0.646** (0.206)
Production of nuclear energy	1.461 (1.134)	- 0.035 (0.623)
Energy imports	2.389** (0.750)	- 2.731*** (0.421)
Index of economic freedom	0.373 (0.911)	0.116 (0.179)
R^2	0.771	0.824

Notes
(1) Values with heteroscedasticity corrected by way of the White test.
(2) Level of significance: *** = error of 0%; ** = 0% < P ≤ 5%; * = 5% < P ≤ 10%

Table 4
Fixed effects estimation (equations 3 and 4)

Variables	Production of renewable energy	Production of primary energy
Constant	- 24.621 (15.306)	2.078 (2.924)
GDP	0.007 (0.028)	- 0.009* (0.005)
Corruption	- 1.017** (0.427)	- 0.115 (0.081)
Government expenditure	1.326* (0.682)	0.212 (0.130)
FOB manufactured exports	0.543** (0.228)	0.074* (0.043)
Population density	- 0.470 (1.460)	1.140*** (0.279)
Index of economic freedom	0.219 (0.924)	0.196 (0.176)
R_2	0.414	0.409

Notes
(1) Values with heteroscedasticity corrected by way of the White test.
(2) Level of significance: *** = error of 0%; ** = 0% < P ≤ 5%; * = 5% < P ≤ 10%

The significant coefficients obtained through the different estimations allow significant differences to be observed, depending on the method used. To this end, and in order to compare the differences between the coefficients, we apply the Breusch and Pagan test and the p-value (Prob > chi2 = 0,000) for the two dependent variables, rejecting the null hypothesis and indicating that the random effects are relevant in the case of the pooled estimation. Then, we apply the Hausman test in order to compare the differences between the fixed and random effect coefficients, obtaining a Prob > chi2 = 1.000 for primary energies, and Prob>chi2 = 0.9033 for renewables, which confirms that the random effects static panel estimation is optimal for analysis of the Latin American reality when it comes to the production of primary and renewable energies.

The results for the random effects panel data are set out in Table 3. Primary energy production, manufactured exports, government spending, and population density have a positive effect, while energy-importing countries have a negative effect. In the case of renewable energy production, if the country is an energy importer, manufactured exports mean that the greater the perception of corruption (lower corruption index), the greater the production of renewables in Latin America.

Tables 5 and 6 provide the results for dynamic panel data with one or two lags, respectively. In Table 5, it can be seen that production of primary and renewable energies from the previous year have a positive effect on the subsequent year's production. However, in Table 6, with two lags, the picture is different. In this case, the second-from-last and past years condition primary energy production in Latin America. Meanwhile, as regards renewables, production from the second-from-last year has a negative effect, and production in the past year has a positive effect. This is probably because of the high initial investment in the development of renewables and the slow return on investment, which is likely to discourage investors from reinvesting in the third year. In keeping with these results, it is possible to conclude that the government spending coefficient is positive and significant.

Table 5
Dynamic panel data estimation (equations 5 and 6 with one lag)

Variables	Production of renewable energy	Production of primary energy
Constant	- 8.315* (4.723)	- 5.625 (1.486)
GDP	- 0.020 (0.019)	- 0.022** (0.006)
Corruption	0.607* (0.321)	- 0.208* (0.115)
Government expenditure	0.552** (0.163)	0.048 (0.043)
FOB manufactured exports	- 0.167 (0.139)	0.031 (0.043)
Population density	1.621*** (0.356)	0.046 (0.070)
Index of economic freedom	- 1.180* (0.712)	0.192 (0.280)
L1	0.578*** (0.049)	0.933*** (0.044)

Notes
(1) Values with heteroscedasticity corrected by way of the White test.
(2) Level of significance: *** = error of 0%; ** = 0% < P ≤ 5%; * = 5% < P ≤ 10%

Table 6
Dynamic effects estimation (equations 5 and 6 with two lags)

Variables	Production of renewable energy	Production of primary energy
Constant	- 2.779 (4.911)	- 2.241* (1.287)
GDP	- 0.022 (0.020)	- 0.023*** (0.006)
Corruption	0.884** (0.343)	- 0.128 (0.104)
Government expenditure	0.390** (0.165)	0.120** (0.038)
FOB manufactured exports	- 0.049 (0.147)	0.001 (0.040)
Population density	1.022** (0.407)	0.079 (0.059)
Index of economic freedom	- 1.316* (0.718)	0.120 (0.242)
L1	0.671*** (0.058)	0.504*** (0.069)
L2	- 0.134** (0.061)	0.455*** (0.060)

Notes
(1) Values with heteroscedasticity corrected by way of the White test.
(2) Level of significance: *** = error of 0%; ** = 0% < P ≤ 5%; * = 5% < P ≤ 10%

In addition to these results, Table 6 shows that the corruption index and population density coefficients are positive and significant, and the index of economic freedom is negative and significant in the case of renewables production.

4. Conclusion

This study shows that estimations using static panel data with random effects and dynamic panel data are suited to analyzing the Latin American reality as far as primary and renewable energy production is concerned. It can also be concluded that the dynamic model is better supported by its variable than is the case of the estimation using static panel data. Based on these conclusions, it can be seen that the perception of corruption index has a direct effect on renewable energy production, but not on primary energy production. Moreover, the population density coefficient is found to be significant and positive for renewable energy production; it is notable that the countries with high population density (Costa Rica, Mexico, Ecuador, and Panama) have a tropical climate that favors renewable energy production at lower costs, while Costa Rica and Panama are also members of the Energy and Environment Partnership with Central America (EEP) – supported by Finland and the Central American Commission for Environment and Development –, which has promoted the development of renewables. Moreover, government spending on promoting the production of renewable and primary energy has a positive effect, but the effect is greater in the case of renewable energy. It is also observed that energy production in previous years affects the current year's production.

As to fiscal policy, various laws have been passed in order to foster renewables, while several programs have been implemented with a view to raising public awareness and subsidizing private production of this form of energy. However, only some laws, such as those of Brazil and Nicaragua, assure direct financial subsidies (Koehler, 2012). According to Altomonte (2008), despite these changes and the government support, the countries in question have not enjoyed much success with the use of renewable energy sources. Save for "the big hydroelectric power plants and the production of unsustainable biofuels,"[8] which make up much of the renewables used in Latin America, the share of renewable resources in the energy matrix is scarce (Meisen & Krumpel, 2009). The main obstacles to large-scale renewables projects are

8 Translation by *Apuntes*.

a dearth of long-term policy planning, legal barriers, and a lack of political will, knowledge, and sophisticated technical expertise (Urdaneta, 2008).

These general trends, in addition to all the economic and political changes that have taken place in recent years, have led to higher demands regarding living conditions, taking into account the environmental and social aspects posed as part of the current global energy challenge: fundamentally, how to meet growing demand in a context of dwindling traditional fossil resources, major concerns about climate change, and market instability, accentuated by prevailing international and local political factors (Seguel & Ovando, 2009).

The results obtained through the dynamic model and compared with those obtained in Dalmazzo-Bermejo and Valenzuela-Klagges (2016) show that before the subprime crisis, Latin American countries had a lower public spending effect in renewables production, and stronger effects related to the index of economic freedom and population density. The impact of the perception of corruption index in the period of study is positive and the opposite of what is observed in the Dalmazzo-Bermejo and Valenzuela-Klagges (2016) study, implying that the subprime crisis altered the effects of public spending, institutional quality, and economic freedom in the production of renewable energy. This comparison of studies attests to the evolution of public policies in Latin America towards endogenous growth theories.

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