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Article

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On the Stock Market-Electricity Sector Nexus in Latin America: A Dynamic Panel Data Model

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ABSTRACT

The aim of this paper is to assess the impact of the stock market on the consumption of electric power in the major economies of Latin America during the period 1995-2014. To do this, a dynamic panel data model is estimated through the generalized method of moments. The main empirical finding is that electric power consumption is positively affected by the stock market indices of Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Peru, and Costa Rica.

Keywords: Electricity Consumption, Stock Markets, Dynamic Panel Data
JEL Classifications: G10, G15, C33, Q40.

1. INTRODUCTION

The importance of the relationship of the energy sector with several economic and financial variables has been widely examined in various countries and regions, as well as in multiple perspectives; see, for instance, Tatom (1981), Kuosmanen et al. (2013), Ozturk and Acaravci (2011), Tapia-Carpio (2014), Sanchez-Loor and Zambrano-Monserrate (2015), Tugcu et al. (2012), Shahbaz et al. (2014), Nasrazadani and Muñoz-García (2017), and Aali-Bujari (2017). Most of these works highlight the importance of the energy sector (electricity, oil, gas, etc.) in busting economic activity in countries or regions; see also, for instance, the literature review from Ozturk (2010).

Regarding the relationship between the energy sector and the financial variables in Latin-American, Sánchez-Loor and Zambrano-Monserrate (2015) studied electricity consumption, remittances and foreign direct investment in Mexico, Colombia and Ecuador. These authors through a time series analysis found that in Mexico consumption of electricity causes, in Granger's sense, foreign direct investment. In another area, De Miguel et al. (2015) discuss the role of pricing new instruments to promote energy saving within a broader framework of energy efficiency policies and environment protection. Braun and Hazelroth (2015) examine the transition to a cleaner, more environmentally friendly, and smarter energy linked to a financial system that promotes capital intensity and technological innovation in the energy sector. Also, Rannou and Barneto (2016) studied the efficiency of the European carbon market by using an asymmetric GJR-GARCH model. These authors found a unidirectional Granger's (1969) causality from trading volume toward volatility. They also find positive retardation causality between the volume of OTC derivatives and spot prices. Other papers related with the financial sector are those from: Sanchez-Loor and Zambrano-Moserrate (2015), Matar and Bekhet (2015), Braun and Hazelroth (2015), D'Ecclesia (2016), Ching-Chun and Ya-Ling (2016), Tumen et al. (2016), Huang et al. (2017), Shalini and Prasanna (2016), and Salas-Fumás (2016).

This research examines the impact of the stock market in the electricity sector in eight Latin American countries: Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Mexico and Peru, during the period 1995-2014[1]. This paper, specifically, addresses the effect of the stock market on consumption of electric energy expressed in USD using the Purchasing Power Parity (PPP) referred to 2011. To do this, a panel dynamic data analysis is carried out by using data from the World Bank and the Ibero-American Federation of Stock Markets and Securities Markets (FIAB, Spanish acronym of Federación Iberoamericana de Bolsas[2]). Moreover, on the basis of the proposed panel data econometric model, the present research proposes recommendations for promoting stock market activity in favor of the energy sector.

This research distinguishes from other investigations in the current literature in the following features: So far, this is the first work dealing with the stock market-electricity consumption nexus in Latin America; (2) the performed panel data analysis allows a greater number of countries, variables and periods; and (3) problems of multicollinearity and autocorrelation are corrected.

The rest of the paper is organized as follows: The second section deals with the review of the literature regarding the relationship of the stock market with the electricity sector; the third section presents the statistical description of the relevant variables used in this research; the fourth section is responsible for an econometric analysis of panel data; the fifth section discusses the main empirical results in the analyzed countries; finally, the conclusions are presented.

2. A SHORT REVIEW ON THE STOCK MARKETS-ENERGY SECTOR NEXUS

There is much research about the interrelationship between the stock market and the energy sector from multiple perspectives. The relevance of the stock market for the energy sector has been analyzed in Miralles-Marcelo et al. (2012), Santillán-Salgado et al. (2017). Braun and Hazelroth (2015), D'Ecclesia (2016), Matar and Bekhet (2015), Ching-Chun and Ya-Ling (2016), Tumen et al. (2016), Huang et al. (2017), Rannou and Barneto (2016), Shalini and Prasanna (2016), Salas-Fumas et al. (2016), Most of these studies find that the stock market drives the energy sector.

Manera et al. (2013) find that the S&P500 index significantly affects returns across commodity prices, and there are correlations between energy products and agricultural products with a rebound around 2008. On the other hand, Yen-Hesien et al. (2014) analyze the dynamic correlation between crude oil prices and returns of stock market indices in the group of the seven most industrialized economies (G7) during the period 1998-2012. They study the effect of oil price volatility and stock prices with conditional dynamic correlation. They also analyze the optimal coverage and portfolio ratios finding that coverage effectiveness is high in Canada and low in Japan.

The relationship between energy and financial crisis in the United States has been studied by Rutledge (2015). The author thinks of economic growth, trade, and capital flows as transformations of current and vintage solar energy, stored in the form of natural resources, human capital, physical capital and technology. He shows how global markets of efficient capital accelerate economic growth, but also could create turbulence, financial crises, protectionism and conflict. Moreover, Xu et al. (2016) developed a stylized model to examine the impact of financial options on reducing the price of carbon permits. They find that the existence of an options market provides a mechanism for uncertainty of future spot prices and it is a stimulus for investment in carbon emission reduction technologies. They also show that both the spot price level and the price volatility of carbon permits can be reduced through the negotiation of financial options, while at the same time achieving the objective of reducing emissions. They, finally, show that the introduction of financial options in a banking environment offers more flexibility to risk management in the carbon permit trade.

Recently, Nasrazadani and Muñoz-García (2017) compare energy markets in Spain and Iran by using ARMA and GARCH autoregressive models for energy prices. They also propose and ARMA-TGARCH model as the most appropriate model for the Iranian electricity marking price. They discuss the status of the Iranian market structure as a free market. They conclude that: (1) The stock market facilitates economic agents to expand the production capacity of the energy sector; (2) the stock market facilitates finance innovative energy companies, shares risks with the energy industry, and contributes to raising productivity by stimulating and financing the use of machines and equipment in the production process.

3. STATISTICAL DESCRIPTION OF THE VARIABLES

The data used in this research is obtained from the World Bank and the Ibero-American Federation of Stock Exchanges and Securities Markets (FIAB). Particularly, the information about consumption of electric energy was obtained from the World Bank[3], and it is expressed in USD of the Purchasing Power Parity referred to 2011. While the statistical information of stock indexes was obtained from FIAB. All variables correspond to the period 1995-2014. In this research, a balanced panel data was available. That is, we have the same number of observations for all variables and for all countries. It is worth noticing that the proposed period is restricted to the availability of data. The panel includes eight Latin American economies and the statistics of the variables and their notation are presented in Table 1.

Table 1 shows the variables, in aggregate terms, as well as their averages, standard deviations, and maximum and minimum levels. For the sample of the eight chosen Latin American economies, the average electric energy consumption is 1701.61 USD, the standard deviation is 787.71 USD, the minimum and maximum are 546.37 USD and 3878.91 USD, respectively. The average stock indices

1 It is worth pointing that all of them, except Costa Rica, are important producers of oil and that these countries mainly generate electricity with steam turbines powered by fossil fuels.

2 www.fiabnet.org

3 World Development Indicators.

Table 1: Statistics of the study variables in the eight economies

Variable	Notation	Average	Deviation	Minimum	Maximum
Electricity consumption	Electric	1701.65	787.71	546.37	3878.91
Stock market indices	Indice	10558.03	14688.08	32.25	69304.00

Source: Own elaboration with data from world bank and FIAB

are 10558.03, with a standard deviation of 14688.08, a minimum of 32.25 and a maximum of 69304.

Before dealing with any econometric analysis, it is important to point out that most of the works that have studied the relationship of the energy sector with stock markets support a positive correlation, Figure 1 reinforce this argument for the Latin American case. A graphical-statistical analysis shows the relationship between the growth rate of consumption of electric energy (the dependent variable) with the stock index returns of the economies under study.

Figure 1 indicates that an increase of the stock market indices (expansion of the stock markets) tends to raise the demand of consumption of electrical energy. In summary, the development of the stock markets is positively associated with the electricity sector.

4. PANEL DATA ANALYSIS

The use of panel data analysis is becoming more frequent due to its usefulness for applied research in comparing different quantitative characteristics of countries through time. The panel data is a combination of time series data with cross section. The general model is given by:

$$y_{it}=\alpha y_{it-1}+\beta X_{it}+u_{it} \quad (1)$$

where y_{it} is the dependent variable that changes as a function of i (countries) and t (years), y_{it-1} is the lagged dependent variable, X_{it}, denotes exogenous variables, and u_{it} are random disturbances. Estimators by ordinary least squares (OLS) are biased and in order to avoid this, alternative models are proposed for nesting data regression with fixed effects (FE) and random effects (RE), which will be discussed below.

The use of panel data may have several advantages because it examines a greater number of observations with more information, supports a greater number of variables, and generates less multicollinearity between data from explanatory variables, as well as provides a great efficiency in the estimation procedure. Another advantage is that it is possible to keep track of each observation unit. It also overcomes the problem of omitted variables that do not change over time because they can be eradicated by using differences.[4] Certainly, the panel data analysis also has some disadvantages because the data are more complex, panel data do not consider heterogeneity or individuality. If all the qualities of the country are not observable, then errors will be correlated with the observations and the OLS estimators will be inconsistent. The fixed effects (FE) model is given by:

$$y_{it}=\alpha y_{it-1}+\beta X_{it}+\varepsilon_{it} \quad (2)$$

4 For more details analysis of panel data see Baltagi (1995).

In this case, we assume that $\varepsilon_{it}=v_i+u_{it}$, therefore

$$y_{it}=\alpha\, y_{it-1}+\beta X_{it}+v_i+u_{it} \quad (3)$$

Here, the error term, ε_{it}, can be decomposed in two parts, a fixed part for each country v_i and a random part u_{it} that meets the requirements OLS ($\varepsilon_{it}=v_i+u_{it}$), which is equivalent to performing a general regression and gives each individual a different origin point (ordinate).

The random effects (RE) model has the same specification as the fixed effects except that the terms v_i rather than being fixed values for each country is a random variable with a mean value $E[v_i]$ and variance Var (v_i) ≠0. Thus, the model specification is:

$$y_{it}=\alpha\, y_{it-1}+\beta X_{it}+v_i+u_{it} \quad (4)$$

where now v_i is a random variable. The RE model is more efficient[5] but less consistent than that of fixed effects. For the estimation of a dynamic panel data, we use the Generalized Method of Moments (GMM), proposed by Arellano and Bond (1991), and the GMM in differences as an extension of Arellano and Bover (1995); the latter is based on regressions in differences in order to control unobservable effects.

The GMM model in differences has some limitations, as remarked by Blundell and Bond (1998), especially when the explanatory variables are persistent over time. Lagged levels of these variables are weak instruments for the equation in differences. Moreover, this approach biases the parameter estimators if the lagged variables (in this case the instrument) are close to being persistent. These authors propose the introduction of new moments on the correlation of the lagged variable and the error term. To do this, the condition of covariance between the dependent and lagged variable and the difference of the errors, as well as the change in the lagged dependent variable are added; the error level must be zero. The GMM estimators in the "system" use a set of equations in differences that are instrumented with the lags of the equations in levels. These estimators are also related to a set of equations in levels instrumented with the lags of the difference equations (Bond, 2002).

The GMM estimator in the "system" provides sufficient orthogonality conditions to ensure consistent estimators of the parameters, even with endogeneity problems and unobserved individual-country effects. This approach, developed by Arellano and Bover (1995), will be used to estimate the parameters. Several improvements were made by Blundell and Bond (1998). The obtained estimator has advantages over other estimators as that of FE and others. GMM optimal estimator has the following form:

5 The variance of the estimate is smaller, that is, it is more efficient.

$$\hat{\theta}_{GMM} = \begin{pmatrix}\hat{\alpha}_{GMM}\\ \hat{\beta}_{GMM}\end{pmatrix} = \left[\left(y_{-1}^{*};x^{*}\right)' z^{*}V_N^{-1}z^{*'}\begin{pmatrix}y_{-1}^{*}\\ x^{*}\end{pmatrix}\right]^{-1} \left[\left(y_{-1}^{*};x^{*}\right)' z^{*}V_N^{-1}z^{*'}y^{*}\right] \quad (5)$$

The above equation is a system consisting of a regression that contains information on levels and differences in terms of time. The condition.

$$E[X_{i,t=s}\,(v_{it}\text{-}v_{i,t=1})]=0, \text{ for } s\geq 2;\ t=3,\ldots,T, \quad (6)$$

will be applied to the first part of the system. The regression in differences, which is written below, is applied to the second part in the regression in levels:

$$E[(X_{i,t=s}\text{-}X_{i,t\text{-}s\text{-}1})(v_{it}\text{-}v_{i,t=1})]=0, \text{ for } s=1;\ t=3.,T \quad (7)$$

The lags of the variables in levels are used as instruments in the regression in differences. Only the most recent differences are used as instruments in the regression in levels. The model generates consistent and efficient estimators in such a way that:

$$y_i^{*} = \alpha y_{i-1}^{*} + \beta x_i^{*} + v_i^{*} \quad (8)$$

The error component v_i^{*} proceeds from both models, levels and differences, which can be defined as:

$$v_i^{*} = \begin{bmatrix}\Delta v_i\\ u_i\end{bmatrix} \rightarrow \begin{cases}\Delta v_i = \left[\Delta v_{i3}, \Delta v_{i4}, \ldots, \Delta v_{iT}\right]\\ u_i = \left[\Delta u_{i2}, \Delta u_{i3}, \ldots, \Delta u_{iT}\right]\end{cases} \quad (9)$$

The matrix of instruments for the model of differences includes information about the explanatory variables and the lagged dependent variable, and is given by:

$$Z_i = \begin{bmatrix} y_{i0} & x_i^2 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 & \cdots & 0 & 0\\ 0 & 0 & y_{i0} & y_{i1} & x_i^3 & \cdots & 0 & 0 & 0 & \cdots & 0 & 0\\ 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 & \cdots & 0 & 0\\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots\\ 0 & 0 & 0 & 0 & 0 & \cdots & y_{i0} & y_{i1} & y_{i2} & \cdots & y_{T-2} & x_i^T \end{bmatrix} \quad (10)$$

In the array of instruments for levels only enter the explanatory variables without the lagged dependent variable

$$Z_j = \begin{bmatrix} x_j^2 & 0 & 0 & \cdots & 0\\ 0 & x_j^3 & 0 & \cdots & 0\\ 0 & 0 & x_j^4 & \cdots & 0\\ \cdots & \cdots & \cdots & \cdots & \cdots\\ 0 & 0 & 0 & \cdots & x_j^T \end{bmatrix} \quad (11)$$

The instruments matrix takes the following form and is included in the estimator GMM:

$$\boldsymbol{Z} = \begin{bmatrix} \boldsymbol{Z}_1\\ \boldsymbol{Z}_2\\ \boldsymbol{Z}_3\\ \vdots\\ \boldsymbol{Z}_{\boldsymbol{N}} \end{bmatrix} \quad (12)$$

Finally, the covariance matrix of constraints of the moments, V_N, for the optimal is:

$$V_N = E[Z'\Delta v \Delta v' Z] \quad (13)$$

Additional tests to ensure the proper functioning of GMM suggested by Arellano and Bond are the autocorrelation tests of first and second orders and the Sargan test of over-identification that considers the statistics

$$s = v' Z\left[\sum_{i=1}^{N} Z_i' v v' Z_i\right]^{-1} Z' v \sim \chi^2\left(p-k-1\right) \quad (14)$$

This test considers a x^2distribution where v is the vector of residuals, Z is the number of conditions imposed, k stands for the number of parameters included in the vector β, and p is the number of columns of matrix Z. Sargan's test examines the overall validity of the analyzed instruments. Subsequently, the existence of serial autocorrelation of the second order of the differentiated error is examined. This test is performed under the null hypothesis of no second order autocorrelation.

5. ANALYSIS AND DISCUSSION OF EMPIRICAL RESULTS

This section is devoted to develop a panel data model that will allows us to study the relationship between the stock market and the electricity sector in eight Latin American economies: Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Mexico and Peru. The variables are expressed in logarithms: The logarithm of the electric energy consumption in USD using the PPP (2011) is denoted as Lelectric, and the logarithm of the stock indices is denoted by Lindice. The period under study is 1995-2014, which allows for 8 countries, 20 years, and 160 observations. It is worth pointing out that the proposed period is restricted to the availability of data. A balanced panel was estimated by using Stata 14.0 econometric package. The main results for the estimators of static panel data are provided in Table 2.

The first column, in Table 2, indicates that the dependent variable is the logarithm of the electric energy consumption, the explanatory variable is the logarithm of the stock market indices, and there is a constant. For the all the models the coefficient of determination is estimated, and both the Lagrange multiplier test and the Hausman test are performed. The second column shows the estimate by OLS indicating a positive and significant coefficient of the logarithm

Table 2: Static panel data estimates

Dep. variable: Lelectric	OLS	BE	FE	RE
Lindice	0.1561908 (0.000)	0.1444134 (0.199)	0.1564415 (0.000)	0.1561908 (0.000)
Constant	6.04819 (0.000)	6.144575 (0.000)	6.046138 (0.000)	6.04819 (0.000)
R^2	0.4320	0.4320	0.4320	0.4320
ML BP				Prob> χ^2=0.0000
Hausman				Prob> χ^2=0.9167
Number of countries	8	8	8	8
Number of observations	160	160	160	160

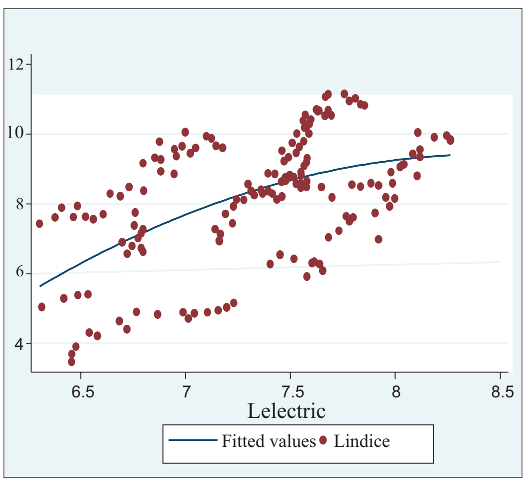
Source: World bank and FIAB. Dependent variable: logarithm of electric consumption. Standard error in brackets

Table 3: Dynamic panel data estimates with GMM

Lelectric.L1	0.9790495 (0.000)	1.198656 (0.001)
Lindice	0.0002187 (0.0933)	0.0026288 (0.114)
Constant	0.1832149 (0.072)	−1.459535 (0.365)
AR (1) Prob> Z =	0.000	0.010
AR (2) Prob> Z =	0.842	0.343
Sargan Test Prob> χ^2=	0.326	0.326
Number of countries	8	8
Number of observations	152	152

Source: World bank and FIAB. Dependent variable: logarithm of electric consumption. Standard error in brackets

Figure 1: Relationship between growth rate of electricity consumption and returns of the stock indices



Source: Own elaboration with data of World Bank and the FIAB

of the stock indices. Notice also that the constant has significant and positive sign. Finally, it is important to point out that R^2 is 0.4320, which indicates a low coefficient of determination. The third column of Table 2 shows the results of the between (BE)[6] estimates, a positive coefficient is observed. However, it is not significant, while the constant is positive and significant. Observe that R^2 is 0.432, which is a low coefficient of determination.

The fourth column presents the results of the estimation with FE. We observe an appropriate sign for the logarithm of the stock indices, both the coefficient and the constant are positive and significant, however a low coefficient of determination is observed,R^2 = 0.432. The last column shows the results of the estimation by RE indicating adequate signs and significant coefficient and constant, but a low coefficient of determination, R^2= 0.432. The Lagrange multiplier test leads to prob> χ^2 = 0.0000, which indicates that RE estimation is preferable to OLS. Finally, Hausman's test[7] has prob> χ^2 = 0.9167 indicating that the estimation by RE is preferable to that of EF.

In summary, Table 2 presents estimates for the four static panel data methods: OLS, Between, FE and RE. The Lagrange Multiplier[8] and Hausman tests indicate that the estimation by RE is more preferable. However, the adjustment of the model is weak, which does not allow us to explain the impact of the stock indices on electric energy consumption by means of these static models. As an alternative to the above, and to avoid problems of autocorrelation, models of dynamic panel data will be estimated by using the Generalized Moment Method (GMM). The main results of the dynamic panel data estimates are shown in Table 3.

The first column, in Table 3, indicates that the dependent variable is the logarithm of the electric energy consumption and the explanatory variables are: The lag of the logarithm of the electric energy consumption and the logarithm of the stock indices. In this dynamic framework, serial autocorrelation tests of first and second order, and Sargan and Hansen's tests are performed.[9] The second column presents the estimates by GMM system in one step, both the coefficient of the lag of the logarithm of the electric energy consumption and the coefficient of the logarithm of the stock indices, as well as the constant have the appropriate signs, and all of them are significant. Hence, we do not reject the autocorrelation of first order. However, the second order autocorrelation is rejected. The Sargan test rejects the null hypothesis, thus the general validity of the instruments is admitted. The third column presents the estimates by the GMM system in two stages, in which the coefficient of the lagged dependent variable (Lelectric. L1) presents the appropriate sign and is significant. In addition to the above, the coefficient of the logarithm of the stock indices (Lindice) has the appropriate sign, but is not significant. On the other hand, first order autocorrelation is not rejected and second order autocorrelation is rejected. Sargan's test rejects the null hypothesis of over-identification and therefore the used instruments are valid. The estimation of GMM in a single-stage system is more preferable and adequate regarding the rest of the estimates. Therefore, this will be the chosen model to explain

6 "Between" is a cross section estimation using means of the variables.

7 The null hypothesis of the Hausman test is that the random effects and fixed effect estimators do not differ substantially, if it rejects the null hypothesis, then it is convenient to chose FE, however when it is not rejected (as in this case) RE is preferable

8 The null hypothesis of this test is . If the test is $\sigma_u^2 = 0$ rejected, there is a difference between OLS and RE, and it is preferable to use the RE method.

9 It was instrumented with two lags at most.

the impact of the stock indices on the consumption of electric energy. Estimates point to that the best fit belongs to the GMM system in one stage, indicating that the consumption of electric energy is positively related to the consumption of lagged electric energy (Lelectric.L1), and also it is positively related to stock market indices. The model estimated in GMM in a one-stage system indicates that a 1% increase in the stock indices will have an impact of 0.02187% in the consumption of electric power in the 8 Latin American economies that were object of this study during the period 1995-2014.

6. CONCLUSIONS

The empirical evidence presented in this research shows that the stock markets have relevant positive effects on the consumption of electric energy. Therefore, a greater effort in developing the financial sector will contribute to boosting the energy sector, in particular the electricity subsector.

In this research, it was shown, firstly, through the graphical analysis that the increase of the stock indices has a positive relation with the growth rate of consumption of electrical energy in the eight studied Latin-American economies. Subsequently, estimates of both static and dynamic panel data indicated that the stock market positively influences the electricity sector. In summary, the empirical evidence presented here supports the hypothesis of our work: There is a positive impact of the stock markets on the consumption of electric power. As a result of this research, it is recommended that policy and decision makers should seek the appropriate instruments and incentives to promote the growth of stock markets in order to boost the electricity sector, and thereby contribute to economic growth.

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