Cover Letter

An analysis of the energy intensity of Latin American and Caribbean countries: Empirical evidence on the role of public and private capital stock

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Abstract: In this study, we analysed the role of public and private capital stock in the energy intensity of 21 Latin American and Caribbean (LAC) countries from 1970 to 2014. The empirical analysis of this study was based on three methodologies, namely: 1) the panel autoregressive distributed lag (P-ARDL) model; 2) the log t regression test method and the club clustering algorithm, and 3) the ordered-logit regression model. The results from our analysis indicated that, although the decreasing trend of LAC energy intensity, the public and private capital stocks did not contribute to this trend, given that they seem to have had an enhancing effect on long-run LAC energy intensity. We also identified the existence of four convergence in terms of energy intensity, with different transition paths and different levels. By the ordered logit estimation, we found that neither the public nor private capital stocks are determinant in club convergence/formation. The overall conclusion is that LAC governments should increase investment in more energy-efficient equipment and infrastructure. This should be done at the same time as they create, or improve, the laws and the regulatory framework regarding energy efficiency, and create incentives to allow private physical capital to follow the same tendency.

Keywords: energy intensity; public capital stock; private capital stock; Latin American and Caribbean countries; convergence analysis.

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1. Introduction

All over the world, governments and institutions are making additional efforts in order to enable countries to reach a sustainable development path. The increased worries related to the world's environmental degradation are actively contributing to this trend, as researchers increasingly seek to address problems related to this theme.

One question that has been receiving growing research interest in the environmental and energy economics fields is how the countries can improve their energy use. Although we know that countries need to use energy to support their production, the present environmental worries, together with countries' energy security concerns, make demand for energy efficiency a crucial subject of analysis, with this topic gaining more and more importance in worldwide political agendas.

When looking deeper into the case of the Latin America and Caribbean (LAC) region, following the report called "Lights on? Energy Needs in Latin America and the Caribbean to 2040" [1], we see that the regional energy consumption has significantly increased in the last four decades (and has more than tripled since the 1970s), accompanying the growth strategies of this region. The "Washington Consensus" and the "Brady Plan" are some examples of the macroeconomic adjustment programmes that have been put in place in this region in order to increase its levels of liberalisation and openness, and subsequently, boost its economic growth [2]. Moreover, the so-called "commodity boom" (2004-2014) is also frequently pointed out to explain the accelerated increase in the regional economic output [3].

Despite the fast growth of renewable energy in the LAC region [4], most of its countries continue to be fossil-fuel dependent, either as producers or consumers [5]. This means that their productive structure is still very dependent on non-renewable energy consumption, which leads to significant increases on their CO_2 emissions [6], and to an increase in their propensity to be affected by fossil-fuel price fluctuations and further external shocks [7].

All these features seem to indicate that LAC governments should continue to improve their energy structure, alongside their energy use, in order to be able to cope with the expectations related to their future regional energy demand and to surpass their concerns regarding climate change.

Following the previous idea, it can be seen that there are a vast number of relationships which could be investigated in order to help LAC policymakers on the buildout of sustainable development strategies for this region.

One relationship which is very underexplored is that which capital stock has with energy consumption and, more precisely, with concepts such as energy efficiency or energy intensity. Capital and energy are intrinsically linked, with buildings, vehicles, machines, tools (and other types of physical capital) requiring energy to produce the goods and services that populations need. Given this connection, we believe that the analysis of the effects from the LAC public and private capital stocks on the regional energy intensity could be further explored.

Energy intensity is a measure that represents a country's capacity to convert energy into monetary output, and is considered as one of the various proxies that can be used to evaluate a country's energy efficiency [8]. The analysis of this relationship can be used to perceive the way in which this region physical capital has contributed to the evolution of LAC in terms of energy efficiency. To increase interest in the analysis of this relationship, we could also refer to the fact that the LAC region suffers from an identified "infrastructure gap" which could be (and has been) harmful for their economic sustainability and development [9]. This implies that the region will probably need to raise investment in its physical capital soon.

Overall, the main objective of this study is to understand if new and more energy-efficient physical capital investments are needed in the LAC region. In order to achieve this goal, we will assess the effects of LAC capital stock on the region's energy intensity and explore the convergence of LAC countries in terms of energy intensity, dividing them into the so-called "convergence clubs" [10]. Finally, we will investigate whether public and private capital stocks explain the formation of these same convergence clubs. The significance of this study is primarily linked to the above-mentioned fact that this relationship (capital stock-energy intensity) has been very underexplored in previous literature. Additionally, the fact that we used different methodologies to investigate the role of capital stock in energy intensity can also be pointed out as another factor that increases the significance of this study. Given the problems associated with the lack of new physical capital investments in the LAC region (the previously mentioned infrastructure gap) and the accentuated increase in the region's energy consumption in recent decades, it has become especially important to study this relationship in this region, so that future LAC physical capital investments (already recommended by international organisations such as the IMF) can be channelled towards the sustainable development of the region.

This study is organised as follows: Section 2 presents the literature review; Section 3 describes the data and methodology; Section 4 provides both the empirical results and their discussion; and Section 5 concludes and talks about the policy implications of this study.

2. Literature Review

Energy efficiency could be simply defined as "*using less energy to produce the same amount of services or useful output*" [11, p. 377]. In the past few decades, there has been an increase in studies, and also interest regarding their results [12]. This has happened mainly due to the growing need of public and private institutions to find solutions to overcome the previously mentioned problems linked with energy security and environmental degradation [13].

If we review the previous literature, we can find a range of energy efficiency indicators that researchers could use. Especially at the macro level, one indicator which is frequently used is the energy intensity ratio [14]. Energy intensity can be used to measure the energy efficiency of a given economy [8]. It is usually computed via the ratio between the country/region energy use and their respective gross domestic product. The smaller the energy intensity ratio of a country/region, the lower its energy intensity.

The analysis of the energy intensity determinants can be very useful for policymakers in that their results can help them in designing energy policies aimed at lowering energy intensity (and increased energy efficiency). Given this reason, it is natural that this type of analysis has been carried out for several countries and regions with different panel data (and cross-sectional data) estimation techniques [14-16].

Regarding the sample of this study, [1] state that the LAC energy intensity has been declining for the past forty years, which can be a sign that the region has been augmenting its energy consumption productivity. By the decomposition analysis of [16], we see that factors such as per capita income, petroleum prices, fuel-energy mix, and GDP growth are all core determinants of the LAC energy intensity.

According to [8], countries can lower their energy intensity by improving their energy sector extraction and conversion techniques, improving the efficiency of the materials used by their productive system, or by transferring a large part of the manufacturing production to other countries.

There is little doubt on the view that the LAC region will have to increase their capital stock levels in order to support their economic growth [17]. Although, due to the fact stressed above that capital stock needs energy to produce the goods and services that we enjoy, we think that the relationship between capital and energy needs to be further explored, especially in the LAC region, in order to enable future investments to foster the region's sustainable development path.

As an example, there are several studies which have already pointed to the harmful effects that the weak state of LAC infrastructures may have on the region's development [9,18]. However, capital stock not only represents infrastructure (e.g., roads, bridges, buildings) but it also represents other types of physical capital, such as machines and equipment. Following [19], we can see that although the improvements registered in overall LAC energy intensity, its industry sector still demonstrates higher energy intensity compared with other world regions, which could mean that the LAC's machinery and equipment may also need to be upgraded.

One crucial factor which affects the relationship between physical capital and energy is technological progress, which can induce countries to invest in more energy-efficient physical capital [20]. Following this notion, another possible problem arises for the LAC region, given its lack of capacity in absorbing advanced technology through trade [21].

In a more general view, [19] state that LAC energy intensity can also be improved by the efforts of the region's governments and institutions. Among the various efforts which could be made, the authors stress: (1) the development of laws and regulations on energy efficiency; (2) the creation of incentives to support energy efficiency policies; (3) the creation of specific targets regarding energy efficiency for their economic sectors; and (4) an increase in government support on these matters with, for example, the development of auction and financing schemes and providing technical assistance.

For all the above reasons, we believe that analysis of the impacts of LAC capital stock on the region's energy intensity should be further investigated in order to perceive the evolution of the relationship between these two variables in this region and to understand if more energy-efficient capital stock is needed to overcome the LAC energy demand and energy security concerns. The reason for studying this relationship becomes even stronger if we look at the lack of studies that directly address this issue, especially for this region [2]. One reason that can be stressed for this lack of studies was the difficulty that the authors faced in measuring capital stock, which now can be surpassed by the release of the "Investment and Capital Stock Dataset" [22].

Despite the previous observation, mention should be made of the study of [23], which analysed energy capital ratios in Europe and Latin America between 1875 and 1970. Although a historical analysis, its conclusions seem to be quite pertinent, given the current issues, with authors stressing that energy efficiency improvements are needed to enable sustainable growth, not only because it allows the same amount of output to be produced with less energy, but it can also reduce the pollutant emissions.

As was stressed in the introduction, in this study, we will also do additional analysis of the convergence of the countries from this region in terms of energy intensity. Initially, the convergence analysis was mainly applied to test the hypothesis that the countries would eventually converge in terms of per-capita output [24-26]. However, this type of analysis was rapidly extended to other subjects, with some authors exploring countries' convergence in terms of, for example, eco-efficiency and carbon dioxide emissions [27, 28].

The increase in studies focused on this type of analysis was enhanced mainly by the convergence analysis method proposed by [10] – the "log t-test" – which tests the convergence hypothesis based on a nonlinear time-varying factor model. Additionally, to test the general hypothesis of convergence, this method also enables us to test the existence of convergence clubs within the countries included in the sample.

As expected, the method of [10] was also applied for testing the convergence of countries in terms of energy intensity [29], and is considered as an empirical advance when compared to the previous studies that tried to examine this same type of convergence with different econometric methodologies [30-32].

In addition to convergence testing and identification of convergence clubs, there is a large number of authors who also test the determinants of the formation of these clubs [29, 33-35]. Usually, this analysis is conducted by employing ordered logit and ordered probit regressions, with the inclusion of variables that may affect the probability of a country belonging to a particular convergence club [29, 34-36]. Following a similar framework, we will test whether capital stock (public and private) is a factor which affects club convergence in the LAC region.

After this literature review, in the next section we will display the data, which was collected to conduct this study, and also describe the methodology which was used to achieve the goals of our analysis.

3. Data and Methodology

To perform the analysis of this study, we assembled annual data from 1970 to 2014 for a panel of 21 countries from the LAC region (Argentina, Barbados, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay and Venezuela). Data availability was the main criterion for choosing both the countries and the time horizon for this analysis. The econometric analysis of this study was developed through the use of the statistical software package Stata 15. In Table 1, we display the name, definition and sources of the raw variables.

Table 1. Raw variables description

Variable	Definition	Source
Y	Gross domestic product (in billions of constant 2011 international dollars)	Investment and Capital Stock Dataset (IMF))
PEC	Primary energy consumption (in thousands of barrels of oil equivalent)	CEPALSTAT
KPUB	General government capital stock (in billions of constant 2011 international dollars)	Investment and Capital Stock Dataset (IMF)
KPRIV	Private capital stock (in billions of constant 2011 international dollars)	Investment and Capital Stock Dataset (IMF)
CO2PC	CO2 emissions (in metric tons per capita)	World Development Indicators (WB)
EP	Energy (commodities) prices (annual indices, 2010 = 100, real 2010 US dollars)	World Bank Commodity Price Data
POP	Population (total)	World Development Indicators (WB)

In the empirical analysis of this study, we will employ three methodologies, namely: 1) the panel autoregressive distributed lag (P-ARDL) model, in the form of an unrestricted error correction model (UECM), which will allow us to identify the short- and long-run impacts of the independent variables on the dependent variable, i.e. it will allow investigation of the short- and long-run impacts of private and public capital stocks on LAC energy intensity; 2) the log t regression test method and the club clustering algorithm developed by [10], which will permit identification of LAC convergence clubs in terms of energy intensity; and 3) the ordered-logit regression model, which can be used to investigate whether public and private capital stocks are factors which drive the formation of convergence clubs.

The use of the P-ARDL model to study the impacts of the LAC capital stock on the region's energy intensity was based on the fact that this model: 1) allows decomposition of the total effects of the variables into their short- and long-run components; 2) deals properly with cointegration; 3) is robust with the variables being endogenous; and 4) allows the inclusion of I(0), I(1), and fractionally integrated variables in the same estimation.

The dependent variable will be energy intensity (EI), which was achieved through the formula represented in equation (1).

$$EI_{it}=\frac{PEC_{it}}{Y_{it}}, \qquad (1)$$

where "PEC" is the primary energy consumption (in thousands of barrels of oil equivalent) of the country *i* in period *t*, and "Y" is the gross domestic product (in billions of constant 2011 international dollars) of the country *i* in period *t*. The smaller this ratio, the lower the energy intensity [37, 38].

The independent variables will be: 1) general government capital stock as a percentage of the GDP (KPUB), achieved through the ratio between the general government capital stock (in billions of constant 2011 international dollars) and the gross domestic product (in billions of constant 2011 international dollars) multiplied by one hundred; 2) private capital stock as a percentage of the GDP (KPRIV), which was achieved in a similar way as KPUB; 3) gross domestic product per capita (YPC), in billions of constant 2011 international dollars, achieved through the division of “Y” by the total population (POP); 4) CO2 emissions in metric tons per capita (CO2PC); and 5) energy (commodities) prices (EP), annual indices (2011 = 100). The change of the base year from 2010 to 2011 was achieved through the division of all index values by the 2011 value.

The interest variables of the P-ARDL analysis will be the variables KPUB and KPRIV. In contrast, the control variables will be the variables YPC, CO2PC, and EP. The control variables were chosen based on the fact that they have already been demonstrated (theoretically and empirically) to influence a country’s energy consumption patterns and/or their energy intensity/efficiency levels [15, 38-41]. Moreover, as was previously stressed, the data availability also influenced the choice of such variables.

In equation (2) we display the specification of the P-ARDL model, which is already parametrised to obtain the dynamic relations between the variables.

$$DLEI_{it} = \alpha_i + \delta_{1i}TREND_t + \beta_{1i}DLKPUB_{it} + \beta_{2i}DLKPRIV_{it} + \beta_{3i}DLYPC_{it} + \beta_{4i}DLCO2PC_{it} + \beta_{5i}DLEP_{it} + \gamma_{1i}LEI_{it-} + \gamma_{2i}LKPUB_{it-1} + \gamma_{3i}LKPRIV_{it-1} + \gamma_{4i}LYPC_{it-1} + \gamma_{5i}LCO2PC_{it-1} + \gamma_{6i}LEP_{it-1} + \varepsilon_{it}, \quad (2)$$

where α_i denotes the country-specific intercept (or fixed effects), δ_{ki}, β_{ki} and γ_{ki} denote the estimated parameters and the ε_{it} represents the error term. Additionally, we should mention that the variables in equation (2) are represented in natural logarithms and first differences, with the prefixes “L” and “D” denoting natural logarithms and first differences, respectively. Finally, the variable LEI, lagged once, represents the ECM term. The ECM term represents the speed of adjustment of the model; if its coefficient is negative and highly statistically significant, it supports the presence of cointegration/long memory.

The second methodology which will be used is the log t-test proposed by [10], which will allow us to test the null hypothesis of convergence. If the null hypothesis is not rejected, then the entire sample tends to converge. If it is rejected, we can try to identify convergence clubs (i.e. convergence of subgroups) through the clustering algorithm originally proposed by [10] and later modified by [42]. See [10] and [42] to a detailed explanation of the steps and mathematical expressions from the log t-test and clustering algorithm methods.

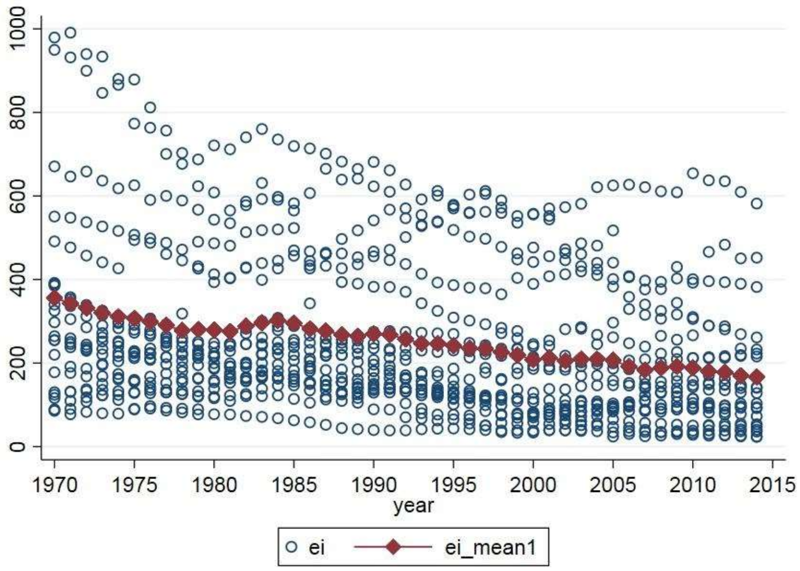
After this approach, if we prove the existence of convergence clubs, we can explore the formation of these clubs through the investigation of possible influencing factors. Following the previous literature [29,34], we used an ordered-logit regression model to this end. The model is described as:

$$y_i^* = X'_i\beta + \varepsilon_i$$
$$y_i = j, \text{ if } \alpha_{j-1} \leq y'_i \leq \alpha_j, j = 1, 2, \ldots, J, \quad (3)$$

where y is the ordinal response variable denoting the club to which a determined country belongs, y^* is the latent variable which indicates a country’s individual steady-state energy intensity level, X' is the vector of independent variables, β denotes the vector of regression coefficients, ε_i represents the disturbance term, the 'α's are unknown cut-points (also known as transition (threshold) parameters) in the distribution of y^* which will be estimated assuming $\alpha_0 = -\infty$ and $\alpha_j = \infty$, and J is the number of clubs. Essentially, the latent variable y^* represents the tendency of a country to belong to one of the clubs and the transition parameters α_j separate the clubs. When the y^* crosses a threshold α_j, the country club membership shifts.

4. Results and Discussion

Before proceeding with the presentation and analysis of the preliminary tests, it is of interest to observe the evolution of the energy intensity (EI) in the LAC.



Notes: This graph was achieved through Stata "twoway graphs" features; The blue dots represent the energy intensity (EI) values of each country in the respective year, while the red "diamonds" represent the mean of the energy intensity (EI) value for the region.

Figure 1. Energy Intensity (EI) in Latin America and the Caribbean.

According to Figure 1, we see that in the LAC region, the overall energy intensity (EI) has been in a decreasing trend since 1970, with only a few periods of exception. This appears to indicate that the LAC region has managed to increase its energy consumption productivity, following the trend of doing more with less. In fact, according to past studies [1], LAC is becoming one of the least energy-intensive regions in the world, and the fact that this happened without the implementation of regular and significant energy-saving programmes makes investigation of their energy intensity determinants even more appealing.

Among the factors that could be important determinants of the LAC energy intensity, we choose to investigate the role of LAC physical capital, mainly because it is believed that newer and more efficient capital equipment can make an essential contribution to the decrease in energy intensity [43]. However, as is noted in the book by [44], the LAC countries' low total factor productivity (TFP) usually discourages investment in new equipment and infrastructure, which can lead the previous effect not occurring.

We now turn our attention to the analysis of the results from our estimation, starting with the descriptive statistics and the cross-section dependence (CD) test [45], which are displayed in Table 2.

Table 2. Descriptive statistics and cross-sectional dependence test

	Descriptive statistics					Cross-section dependence (CD)		
Variables	**Obs**	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**CD-test**	**Corr**	**Abs(corr)**
LEI	945	5.246113	0.7797871	3.147825	6.898546	27.64***	0.284	0.575
LKPUB	945	4.0292	0.698626	2.054651	5.52382	17.01***	0.175	0.476
LKPRIV	945	4.927698	0.336838	4.141868	5.789673	11.25***	0.116	0.427
LYPC	945	-11.75664	0.7540923	-13.34477	-9.048695	50.88***	0.523	0.702
LCO2PC	945	0.3358615	0.9066564	-3.230116	2.041447	45.47***	0.468	0.566
LEP	945	3.636263	0.6506555	2.061044	4.685315	n.a.	n.a.	n.a.
DLEI	924	-0.0206048	0.1171919	-1.312275	0.8867016	2.54**	0.026	0.122
DLKPUB	924	0.0040989	0.0519413	-0.1795859	0.3264704	22.01***	0.229	0.254
DLKPRIV	924	0.0032835	0.0470015	-0.1878452	0.3207264	21.31***	0.222	0.242
DLYPC	924	0.015127	0.0423243	-0.3375359	0.1506739	22.75***	0.237	0.252
DLCO2PC	924	0.017039	0.1094636	-0.8105836	1.080082	3.73***	0.039	0.138
DLEP	924	0.0564872	0.2550738	-0.6603057	0.9982629	n.a.	n.a.	n.a.

Notes: The CD test has N(0,1) distribution under the H_0: cross-sectional independence, *** and ** denote statistical significance at the 1% and 5% levels, respectively; n.a. denotes not applicable; Stata commands *sum* and *xtcd* were used to compute the descriptive statistics and the CD test, respectively

Looking at the results from the CD test, we observe that all variables reject the null hypothesis of cross-section independence, meaning that a correlation seems to exist between our series across the included crosses. This fact can probably be related to the mutual shocks that the countries from our sample share. It is important to note that the variable EP has common values for all countries, which makes the applicability of the CD test for this variable null.

The next step of the estimation was to investigate the order of integration of the variables. In Table 3, we display the results from the cross-sectionally augmented IPS (CIPS) test [46].

Table 3. Panel Unit Root tests (CIPS)

	Cross-sectionally augmented IPS (CIPS)	
	without trend	**With trend**
LEI	-2.215**	0.522
LKPUB	1.701	0.409
LKPRIV	-1.208	-1.003
LYPC	-2.016**	-1.493*
LCO2PC	-2.141**	1.277
LEP	n.a.	n.a.
DLEI	-13.011***	-12.128***
DLKPUB	-8.813***	-8.096***
DLKPRIV	-10.698***	-9.044***
DLYPC	-10.575***	-8.962***
DLCO2PC	-14.531***	-13.260***
DLEP	n.a.	n.a.

Notes: H_0 for CIPS is that the series is I(1); ***,** and * denote statistical significance at the 1%, 5%, 10% levels, respectively; n.a. denotes not applicable; the Stata command *multipurt* was used to compute this test.

The use of the CIPS 2nd generation unit root test to examine the order of integration of the variables was mainly linked with the fact that it is robust to the presence of cross-sectional dependence. Following [47, p. 31], when cross-sectional dependence is present in the variables, the first-generation unit root tests "*are not trustworthy*" and, because of this fact, the CIPS test should be performed. As could be perceived by the outcomes of Table 3, none of the variables seems to be I(2); they all seem to be stationary at least at first differences, with some of them appearing to be in the borderline between the I(0)/I(1) orders of integration, which can be considered as one additional reason to use the P-ARDL methodology.

As was already stressed, the variable EP is different from all of the other variables because it has the same values for all countries during the time horizon of this study, which makes it closer to a time series variable which is common to all the countries under study. Given this characteristic, we applied the augmented Dickey-Fuller (ADF) [48] and Kwiatkowski, Phillips, Schmidt, And Shin (KPSS) [49] tests exclusively for this variable. For this same reason, we did not perform the cross-sectional dependence test for the EP variable (the values are the same for all the countries). The results from the ADF and KPSS tests demonstrated that the order of integration of this variable was I(1).

The second-generation cointegration test of Westerlund [50] was computed to check for cointegration. The null hypothesis of this test is "no cointegration". The results of the Westerlund cointegration test can be seen in Table 4.

Table 4. Westerlund cointegration test

		None		
Statistics	Value	Z value	p-value	Robust p-value
Gt	-1.801	1.790	0.963	0.626
Ga	-5.343	3.808	1.000	0.959
Pt	-6.481	1.752	0.960	0.691
Pa	-3.241	2.761	0.997	0.919
		Constant		
Statistics	Value	Z value	p-value	Robust p-value

Gt	-2.346	1.444	0.926	0.419
Ga	-9.387	3.107	0.999	0.763
Pt	-7.710	2.928	0.998	0.784
Pa	-4.536	3.728	1.000	0.956
		Constant and Trend		
Statistics	Value	Z value	p-value	Robust p-value
Gt	-2.758	1.277	0.899	0.369
Ga	-9.405	4.901	1.000	0.990
Pt	-8.049	4.736	1.000	0.936
Pa	-4.914	5.469	1.000	0.990

Notes: Bootstrapping regression with 800 reps. H_0: No cointegration; H_1 Gt and Ga test the cointegration for each country individually, and Pt and Pa test the cointegration of the panel as a whole.

As shown in Table 4, the p-values do not reject the null hypothesis of no cointegration, for the panel nor for each country individually. As [5] stress, this could be an additional incentive to the use of econometric techniques which are less strict about the integration of the variables, for example, the P-ARDL model.

4.1 Panel Autoregressive Distributed Lag

Before proceeding with the P-ARDL estimation, it is necessary to compute a series of specification tests in order to allow the suitability of this approach. In Table 5, we display the results from the correlation matrix and the variance inflation factor (VIF) test [51].

Table 5. Correlation matrices and VIF statistics

	LEI	**LKPUB**	**LKPRIV**	**LYPC**	**LCO2PC**	**LEP**
LEI	1.0000					
LKPUB	-0.1621	1.0000				
LKPRIV	-0.1746	0.0183	1.0000			
LYPC	-0.5106	0.1810	-0.0321	1.0000		
LCO2PC	-0.5807	0.2819	0.1355	0.8211	1.0000	
LEP	-0.2210	0.0373	0.1034	0.1758	0.1640	1.0000
VIF		1.10	1.10	3.35	3.54	1.04
Mean VIF		2.03				
	DLEI	**DLKPUB**	**DLKPRIV**	**DLYPC**	**DLCO2PC**	**DLEP**
DLEI	1.0000					
DLKPUB	0.2146	1.0000				
DLKPRIV	0.2044	0.7910	1.0000			
DLYPC	-0.2597	-0.7613	-0.8437	1.0000		
DLCO2PC	-0.0590	-0.2505	-0.2604	0.3195	1.0000	
DLEP	-0.0024	-0.0800	-0.0859	0.1348	-0.0425	1.0000
VIF		2.91	4.26	3.97	1.12	1.03
Mean VIF		2.66				

As it can be seen, overall, the correlation between the variables seems to not cause significant concerns to the estimation, except possibly for the correlation values between LYPC and LCO2PC, and between DLYPC and DLKPRIV. However, given that the low VIF and mean VIF values strongly support the absence of multicollinearity problems, we can proceed with the estimation (the VIF and mean VIF values are lower than the accepted benchmarks of 10 and 6, respectively).

The next step of the estimation was to compute the Hausman test [52] in order to compare the random effects (RE) and the fixed effects (FE) specifications. In Table 6, the results from the Hausman test and the Hausman test with the *sigmamore* and *sigmaless* options are all presented.

Table 6. Hausman tests (FE vs. RE)

Hausman test	**Hausman test with *sigmamore***	**Hausman test with *sigmaless***
FE vs RE	FE vs RE	FE vs RE
Chi2(12) = 45.77***	Chi2(9) = 42.43***	Chi2(9) = 44.06***

Notes: *** denotes significance at the 1% level; H_0: difference in coefficients not systematic/RE is preferable

From the achieved chi-square (Chi2) statistics, we see that the null hypothesis of the Hausman test is rejected for all the specifications (with and without the *sigmamore* and *sigmaless* options), meaning that the FE specification is the most suitable for the model's estimation.

When working upon macro panels, another characteristic that should be tested is the panel heterogeneity/homogeneity. The mean group (MG) and pooled mean group (PMG) estimators, developed by [53] and by [54], respectively, are usually used to deal with the slope heterogeneity of parameters. In Table 7, we exhibit the results from the Hausman test between the MG, PMG, and FE estimators.

Table 7. Hausman tests (MG vs. PMG vs. FE)

Hausman test	**MG vs PMG**
	Chi2(13) = 12.26
	PMG vs FE
	Chi2(13) = 4.94
	MG vs FE
	Chi2(13) = 0.81

Notes: H_0: difference in coefficients not systematic; the Stata commands *xtpmg*, and Hausman (with the options, sigmamore alleqs constant) were used.

From the three Hausman tests that were computed, we conclude that for MG vs PMG, PMG is the preferable estimator, whereas for PMG vs FE and MG vs FE, the FE is preferable. The null hypothesis is similar to the previous one (RE vs FE); however, instead of the RE being preferable, the null is that the PMG is the most suitable for MG vs PMG and FE is the most suitable for PMG vs FE and MG vs FE. These results mean that there is strong evidence that the panel is homogeneous, or that the slope heterogeneity of parameters was not verified given that the FE seems to be the most suitable estimator.

Before the presentation of the results, there are still some phenomena which need to be tested. Therefore, a battery of specification tests was computed for the P-ARDL model from equation (2) with FE, namely: the time fixed effects test, the modified Wald test [55], the

Pesaran test for cross-sectional independence [45], Frees' test of cross-sectional independence [56,57], Friedman's test of cross-sectional independence [58], the Breusch and Pagan Lagrangian multiplier (LM) test of independence [59], and the Wooldridge test [60]. In Table 8, we present the results from all these tests.

Table 8. Specification tests

	Statistics
Time fixed effects	1.13
Modified Wald test	1732.95***
Pesaran's test	0.019
Frees' test	0.185***
Friedman's test	46.863***
Breusch Pagan LM test	238.332*
Wooldridge test	64.428***

Notes: H_0 of Time fixed effects test: dummies for all years are equal to 0 (no time fixed effects are needed); H_0 of modified Wald test: sigma(i)^2 = sigma^2 for all I; H_0 of Pesaran's, Frees', Friedman's, and Breusch-Pagan LM tests: residual are not correlated; H_0 of Wooldridge test: no first-order autocorrelation; * and *** denote statistical significance at the 10% and 1% levels, respectively.

Following the outcomes from Table 8, we see that no time fixed effects are needed, but that there is a strong signal of the presence of group-wise heteroscedasticity, cross-sectional dependence and first-order autocorrelation in the model. Although the Pesaran test of cross-sectional independence seems to support the fact that the residuals are not correlated across entities, the remaining tests support the idea that there is cross-sectional dependence in the model. Accordingly, we will choose an estimator capable of dealing with this phenomenon.

Given these outcomes, the Driscoll and Kraay estimator (DK) [61], with FE, was selected to estimate the model, mainly because it produces standard errors robust to the presence of heteroscedasticity, cross-sectional dependence and first-order autocorrelation. In Table 9, the results from the estimation of the P-ARDL model from equation (2) with the DK-FE estimator are presented.

Table 9. P-ARDL estimation results

Dependent Variable: **DLEI**	
Constant	-0.0134154
TREND	-0.0015759***
DLKPUB	0.1490815
DLKPRIV	-0.2467661
DLYPC	-0.790175***
DLCO2PC	0.031556
DLEP	0.0287212*
LEI (-1)	-0.0728701***
LKPUB (-1)	0.017512
LKPRIV (-1)	0.0313937*
LYPC (-1)	-0.0116969
LCO2PC (-1)	-0.0467759***
LEP (-1)	0.0208794***
Diagnostic statistics	
N	924
R^2	0.1125
F	F(12, 43) = 34.80***

Notes: ***, ** and * denote statistical significance at the 1%, 5%, and 10% levels, respectively; the Stata command *xtscc* was used to estimate the model.

It is important to note that Table 9 does not give us the long-run elasticities because they had to be calculated. To reach them, we had to compute a ratio between the variable's coefficients and the LEI coefficient, both lagged once, and multiply the achieved ratio by − 1. The long-run elasticities are now displayed in Table 10, jointly with the short-run impacts and with the adjustment speed of the model, i.e. the error correction mechanism (ECM), which is the coefficient of the LEI variable.

Table 10. Elasticities, short-run impacts, and speed of adjustment

Dependent Variable: **DLEI**	
Short-run impacts	
DLKPUB	0.1490815
DLKPRIV	-0.2467661
DLYPC	-0.790175***
DLCO2PC	0.031556
DLEP	0.0287212*
Long-run (computed) elasticities	
LKPUB (-1)	0.2403187*
LKPRIV (-1)	0.4308173*
LYPC (-1)	-0.1605173
LCO2PC (-1)	-0.6419077***
LEP (-1)	0.286529***
Speed of adjustment	
ECM	-0.0728701***

Notes: *** and * denote statistical significance at the 1% and 10% levels, respectively; the ECM denotes the coefficient of the variable LEI lagged once.

After performing a first estimation of the P-ARDL model with the DK-FE estimator, it was observed that the variables DLKPUB, DLKPRIV, DLCO2PC and LYPC were all not statistically significant. This fact leads us to remove these variables from the model, following the principle of parsimony [62]. Thus, the P-ARDL model from the equation (2) was replaced by:

$$DLEI_{it} = \alpha_i + \delta_{1i}TREND_t + \beta_{1i}DLYPC_{it} + \beta_{2i}DLEP_{it} + \gamma_{1i}LEI_{it-1} + \gamma_{2i}LKPUB_{it-1} + \gamma_{3i}LKPRIV_{it-1} + \gamma_{4i}LCO2PC_{it-1} + \gamma_{5i}LEP_{it-1} + \varepsilon_{it} \quad (4)$$

The model was then re-estimated without the variables DLKPUB, DLKPRIV, DLCO2PC and LYPC, in accordance with the most parsimonious specification (Equation (4)). All specification tests were redone to ensure that all assumptions remained the same (see Table A1, Table A2, and Table A3 in the Appendix). The results from the parsimonious model (equation (4)) with the DK-FE estimator are presented in Table 11.

Table 11. P-ARDL estimation results (parsimonious)

Dependent Variable: **DLEI**	
Constant	0.0571923
TREND	-0.0017403***
DLYPC	-0.6522905***

DLEP	0.0281748*
LEI (-1)	-0.0705164***
LKPUB (-1)	0.0258047**
LKPRIV (-1)	0.0358277**
LCO2PC (-1)	-0.0510826***
LEP (-1)	0.0216925***
Diagnostic statistics	
N	924
R^2	0.1097
F	$F(8, 43) = 36.05$***

Notes: ***, ** and * denote statistical significance at the 1%, 5%, and 10% levels, respectively; the Stata command *xtscc* was used to estimate the model.

Once again, it is essential to note that Table 11 does not give us the long-run elasticities; as in the previous case (Table 9), they had to be calculated. The long-run elasticities are now displayed in Table 12, jointly with the short-run impacts and with the adjustment speed of the model, i.e. the error correction mechanism (ECM).

Table 12. Elasticities, short-run impacts, and speed of adjustment (parsimonious)

Dependent Variable: **DLEI**	
Short-run impacts	
DLYPC	-0.6522905***
DLEP	0.0281748*
Long-run (computed) elasticities	
LKPUB (-1)	0.3659384***
LKPRIV (-1)	0.5080759***
LCO2PC (-1)	-0.7244074***
LEP (-1)	0.3076233***
Speed of adjustment	
ECM	-0.0705164***

Notes: *** and * denote statistical significance at the 1% and 10% levels, respectively, the ECM denotes the coefficient of the variable LEI lagged once.

Looking at the outcomes from Table 10 and Table 12, we can see that the results from the non-parsimonious and parsimonious models are quite similar. DLYPC and DLEP seem to be the only variables that demonstrated to have a statistically significant effect on the dependent variable (DLEI) in the short run. However, whereas DLYPC seems to contribute to a reduction in the energy intensity of the LAC countries, the variable DLEP seems to show an opposite effect, contributing to an increase in these countries' energy intensity.

Concerning the long-run analysis, we see that, firstly, both the interest variables, LKPUB and LKPRIV, seem to contribute to the increase of long-run LAC energy intensity (the statistical significances are higher in the most parsimonious model), with LKPRIV showing an effect with a relatively larger magnitude than LKPUB. Second, we see that the energy commodity prices (LEP) continue to demonstrate a positive coefficient, meaning that it also has an enhancing effect on the energy intensity of these countries in the long-run. Finally, LCO2PC seems to be the only variable of those included in the models that has a depressing effect on the long-run energy intensity.

Regarding the ECM values, we can say that they are negative and statistically significant at the 1% level in both models, suggesting that cointegration/long memory exists between the variables, a fact that contradicts the results of the Westerlund cointegration test (Table 4). This outcome is not new given that this contradiction has already occurred in some previous studies [5,63]. Finally, we should stress that the relatively small ECM coefficient value indicates that the speed at which our dependent variable returns to equilibrium after changes in the independent variables is quite slow.

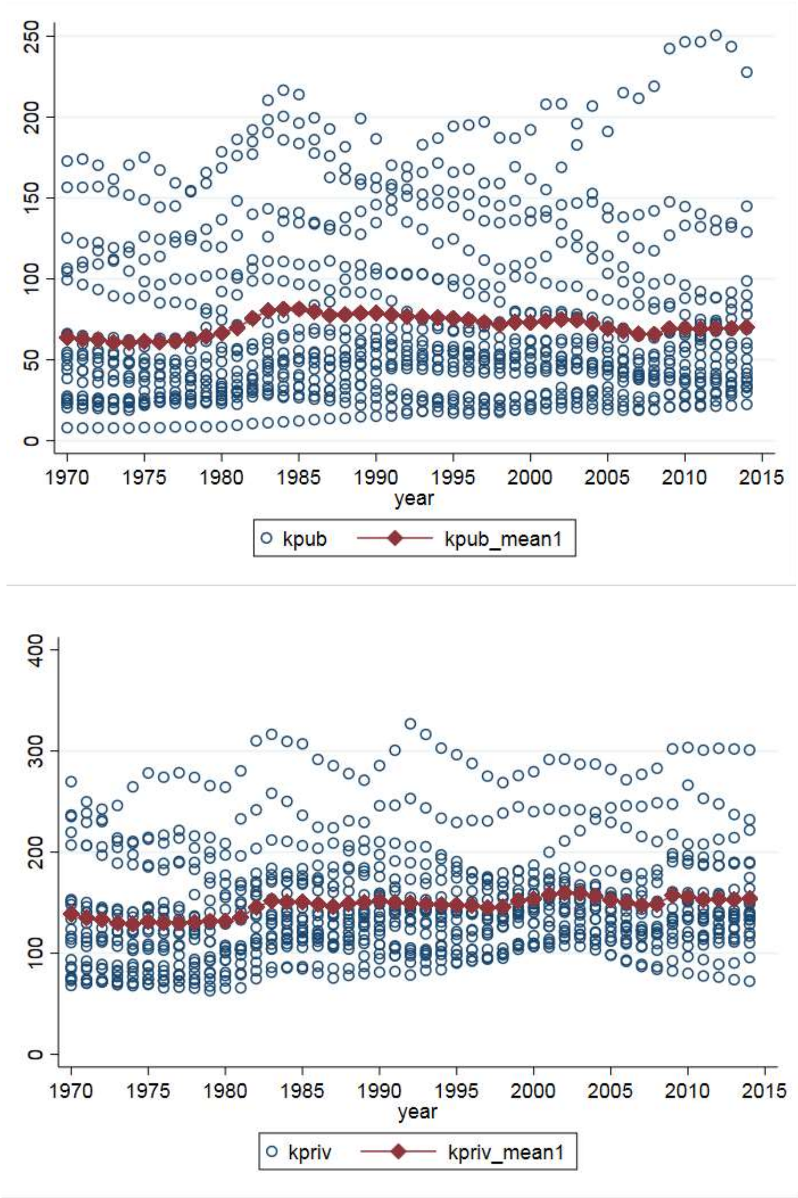
Discussing the main results from our estimation, we can see that, as was also found by [16] in their study on Latin American countries, income (DLYPC) is negatively related to energy intensity (DLEI). However, in our estimation, this effect was only noticed in the short run, which means that, initially, these countries seemed to have taken advantage of their economic development to increase their production processes efficiency. Yet as [41] stress, when countries reach a certain income level, the income effect on energy intensity seems to vanish, and the development and application of energy efficiency policies starts to be much more critical for reducing energy intensity.

A result that suggests the importance of developing policies to decrease energy intensity is that of LCO2PC. As can be seen in Table 10 and Table 12, CO_2 emissions are shown to have a negative impact on energy intensity (DLEI), contributing to its decrease in the long run. We can say that the problems related to environmental pressure (in this case, proxied by CO_2 emissions per capita) create incentives for governments to develop policies and more environmentally-friendly technology and innovations in order to support the environmental and energy sustainability of their countries [64, 65]. Therefore, the development, for example, of energy efficiency policies due to the pressures exerted by factors as CO_2 emissions can probably explain the achieved outcome.

Concerning energy commodities prices (LEP and DLEP), the results showed that they increase energy intensity (DLEI) both in the short and long run. This outcome implies that the higher energy commodities prices induce the LAC countries to increase their rents. A significant part of them have abundant energy commodities, leading to higher energy consumption from their economies which, ultimately, can drive an increase in energy intensity. A similar result was found for OPEC (Organization of the Petroleum Exporting Countries) in the case of oil prices [15].

Now, regarding the variables of interest for this study, the public (LKPUB) and private (LKPRIV) capital stocks, we see that they are far from being responsible for the decreasing trend of LAC energy efficiency. The results point to an enhancing effect from both types of capital on energy intensity (DLEI) in the long run. These outcomes seem to follow the view held [44] that there is a lack of investment in new equipment and infrastructure in the LAC countries.

The fact that this effect is primarily captured in the long-run probably means that the intensification of the LAC economic activity was not accompanied by investment in more energy-efficient capital stock. Over time, the effect of this lack of investment on these countries' energy intensity has become more and more significant. To corroborate these statements, in Figure 2 we present the evolution of the LAC KPUB and KPRIV from 1970 to 2014.



Notes: This graph was achieved through Stata "twoway graphs" features; The blue dots represent the public capital stock (KPUB) and private capital stock (KPRIV) values of each country in the respective year, while the red "diamonds" represent the mean of the public capital stock (KPUB) and private capital stock (KPRIV) value for the region.

Figure 2. Public capital stock (KPUB) and private capital stock (KPRIV) in Latin America and the Caribbean in the percentage of GDP.

As can be perceived, the levels from the LAC public and private capital stocks have followed a steady trend since the 1970s. This raises some doubts around the capacity of the LAC region to invest in new (and more efficient) physical capital. Some previous studies also point to another problem regarding the LAC physical capital development: the lack of maintenance of their existing capital stock [18].

All these issues seem to lead to the assumption that the LAC physical capital does not contribute to the decrease in the regional energy intensity. It seems that the LAC physical capital is still very energy-intensive and needs to be upgraded, both in the public and private sectors. Outdated capital seems to prevent this region from reaching an even lower energy intensity level.

4.2 Convergence Clubs

The first step of the convergence analysis of [10] is to test the convergence hypothesis for the whole sample through the log t regression test. However, before the estimation, we should remove the cyclical component from the series. Accordingly, the Hodrick-Prescott filter [66] was used to remove the trend component from the variable LEI. The log t regression test results are given in Table 13.

Table 13. Log t regression test results (whole sample)

Variable	Coefficient	Standard Error	t Statistic
log(t)	-1.6554	0.1023	-16.1778

Notes: H_0: convergence for the whole panel; if t statistic < -1.65, H_0 is rejected at the 5% statistical significance level.

As can be seen, the t statistic value (-16.1778) rejects the null hypothesis of convergence for the whole sample at the 5% significance level (the t statistic is below the critical value of -1.65), meaning that the LAC countries do not converge to the same steady-state equilibrium in terms of energy intensity.

Then, using the club clustering algorithm of [10], we tested the hypothesis of club convergence within the sample. This algorithm can be summarised in the following five steps: (1) sorting; (2) core group formation; (3) sieve individuals for club membership; (4) recursion and stopping rule; and (5) club merging. For a more in-depth explanation of these steps, i.e. on how the clubs are identified by the algorithm, see [67, pp. 885-7]. The results are shown in Table 14.

Table 14. Convergence test results of the initial clubs.

Clubs	Number of countries	Coefficient	t Statistic	Countries
1	2	-1.181	-1.073	Haiti, Honduras
2	8	0.221	3.088	Argentina, Bolivia, Brazil, Guatemala, Nicaragua, Paraguay, Uruguay, Venezuela
3	7	0.107	0.805	Barbados, Chile, Costa Rica, El Salvador, Grenada, Mexico, Peru
4	2	1.251	1.602	Ecuador, Panama
Divergent group	2	-4.234	-18.893	Colombia, Dominican Republic

Notes: H0: countries in clubs are converging; if t statistic < -1.65, H0 is rejected at the 5% level.

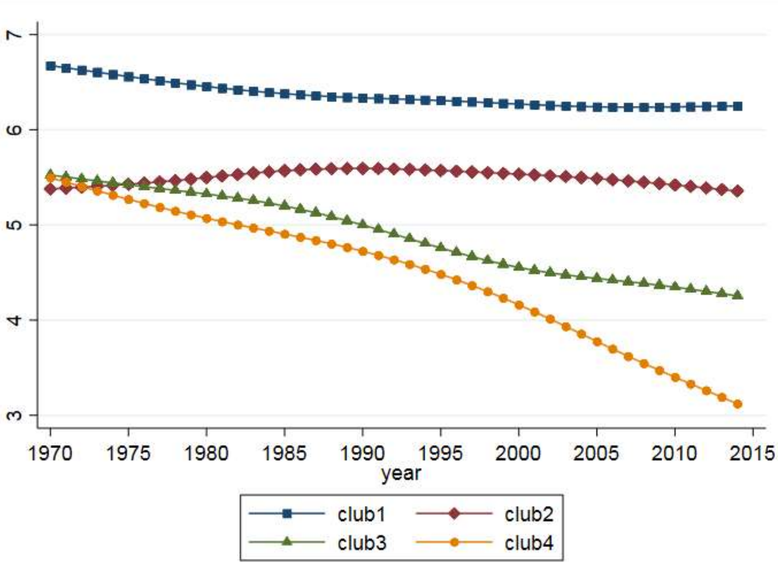
The outcomes indicate that there seems to exist four convergence clubs, whose t statistics are higher than -1.65, and one divergent group composed by countries that do not converge to any club (Colombia and Dominican Republic). Additionally, the modified method of [42] was used to investigate the hypothesis of possible club merging, and its results can be seen in Table 15.

Table 15. Club merging test

Clubs	Coefficient	t Statistic
1+2	-0.212	-7.467
2+3	-1.007	-34.056
3+4	-0.911	-11.541
4+5	-3.000	-29.315

Notes: H0: clubs can be merged; if t statistic < -1.65, H0 is rejected at the 5% level.

By these results, we can see that the null hypothesis is rejected for all combinations as the t statistics are all lower than -1.65. This means that the convergence clubs are indeed the ones which were previously achieved. Figure 3 shows the averages of the relative energy intensity transition paths for the four identified clubs.



Notes: This graph was achieved through Stata “twoway graphs” features, after the computation of the means of the energy intensity of each club for each year.

Figure 3. Average relative energy intensity transition paths for different convergence clubs.

Following the graph from Figure 3 and the information from Table 16, we can see that “club 1”, composed by Haiti and Honduras, has the highest average energy intensity level, with its initial energy intensity being the highest among the clubs. “Club 2”, composed by Argentina, Bolivia, Brazil, Guatemala, Nicaragua, Paraguay, Uruguay and Venezuela, comes right after “club 1”, followed by “club 3”, which is composed by Barbados, Chile, Costa Rica, El Salvador, Grenada, Mexico, and Peru. “Club 4”, composed by Ecuador and Panama, has the lowest average energy intensity.

Table 16. Descriptive statistics of the energy intensity of the convergence clubs.

Clubs	Obs	Mean	Std. Dev.	Min	Max
1	90	6.364524	0.1284383	6.237211	6.674018
2	360	5.497266	0.0729173	5.356544	5.593428
3	315	4.894103	0.4226166	4.254727	5.524538
4	90	4.479531	0.6945355	3.120902	5.496629

Although club 2 has an initial energy intensity below that of club 3 and club 4, its transition path followed a stable tendency between 1970 and 2014. In fact, we can see a slight increase until the 1990s. Conversely, if we look at the transition paths from club 3 and club 4, we see a robust decreasing tendency which starts right after 1970. From all the previous information, we conclude that the countries in club 1 and club 2 probably need to make an additional effort to reduce their energy intensity levels.

4.3 Ordered Logit

As previously stressed, in addition to the identification of the clubs, we also employed an ordered logit model to see whether capital stock is responsible to some extent for the formation of the LAC convergence clubs.

The ordinal response variable, which in our case was named CLUB, is the dependent variable, representing the club to which a determined country belongs, and it can take values from 1 to 4. This variable is an ordinal variable because the clubs can be ranked following their energy intensity, i.e. the higher the value, the lower the energy intensity (see Table 16).

In the ordered logit model, we considered two specifications, following [34] and [36]: 1) with the averages of the public and private capital stocks in the percentage of the GDP between 1970 and 2014 (KPUB_M and KPRIV_M); and 2) with the public capital stock and private capital stock annual % averages over 1970-2014 (KPUB_G and KPRIV_G).[1]

The variable initial energy intensity (EI_1), represented the energy intensity of the countries in 1970 and was chosen as the control variable following the study of [29]. They followed the principle which states that similar initial conditions are an essential factor for convergence [68]. In Table 17, we display the results from the ordered logit estimation.

Table 17. Ordered logit estimation results

Dependent Variable: CLUB			
Specification I		**Specification II**	
EI_1	-0.0039757**	**EI_1**	-0.0038458***
KPUB_M	-0.0071272	**KPUB_G**	0.1807698
KPRIV_M	0.0096617	**KPRIV_G**	0.1400534
Diagnostic statistics		**Diagnostic statistics**	
N	19	**N**	19
Pseudo R^2	0.1217	**Pseudo R^2**	0.0973
Log pseudolikelihood	-20.126745	**Log pseudolikelihood**	-20.685004
Wald chi2(3)	7.58	**Wald chi2(3)**	7.87
Prob > chi2	0.0556	**Prob > chi2**	0.0488

Notes: ** and *** denote statistical significance at the 5% and 1% levels, respectively; the Stata command *ologit* was used to estimate the model.

Looking at the results, we see that EI_1 is an essential determinant for the country's membership in a specific club. The negative coefficient in both specifications means that a positive change in the initial energy intensity reduces the probability of being a member of a low-energy intensity club. Conversely, it also means that a higher initial energy intensity increases the chance of a certain country belonging to clubs with a high energy intensity level. This result is in accordance with past empirical investigations [29].

Regarding the variables KPUB_M and KPRIV_M, and KPUB_G and KPRIV_G, we see that none of them were demonstrated as having a statistically significant effect, which

[1] For the calculation of the annual % averages we used the data on public and private capital stocks from the [22] in billions of constant 2011 international dollars.

means that they are not determinants of club membership. The possible explanations for this lack of effect can be that, first, as seen above, both types of capital have an enhancing effect on the LAC energy intensity (see Table 10 and Table 12). In contrast, the tendency is for countries (and clubs) to converge to a lower level of energy intensity in the long run (see Figure 3). Second, the evolution of both types of capital and their subsequent effects on energy intensity may be similar in most of the countries under analysis, meaning that capital stock is not a differentiating factor in club formation. Therefore, we can say that there is a reinforcement that the conclusions regarding the need for new physical capital investments can be applied to all countries.

5. Conclusion and Policy Implications

In this study, we use different methodologies to analyse the role of public and private capital stock on the energy intensity of a group of 21 LAC countries. First, we used a P-ARDL model to investigate the short- and long-run impacts of public and private capital stocks on these countries' energy intensity. Given the fact that cross-section dependence, heteroscedasticity, and first-order autocorrelation were present in the P-ARDL model, we had to use the Driscoll and Kraay estimator (with fixed effects) in order to control for the presence of all these phenomena. As in the extended model (equation (2)), the variables DLKPUB, DLKPRIV, DLCO2PC and LYPC were all not statistically significant. We re-estimated the P-ARDL model without these variables (equation (4)) to produce a more parsimonious model.

Nevertheless, the results from the non-parsimonious (Table 10) and parsimonious model (Table 12) were very similar, with the outcomes indicating an enhancing effect from both public and private capital stocks on these countries' long-run energy intensity. This can be a sign of the lack of investment in newer and more energy-efficient physical capital in the LAC region over the years. In sum, the results seem to point to the fact that the LAC physical capital is still very energy-intensive and needs to be upgraded, both in the public and private sectors. From the P-ARDL models, we also saw that income has a decreasing effect on energy intensity in the short run, that CO2 emissions contribute to the LAC energy intensity decrease in the long run, and that energy commodity prices seem to induce the LAC countries to increase their energy intensity levels both in the short and long run.

In the next step of this investigation, we used the log t regression test method and the club clustering algorithm to identify the LAC countries that converge to different equilibriums in terms of energy intensity. The outcomes showed that the 21 LAC countries do not converge to the same steady-state equilibrium in terms of energy intensity; in fact, from the results we were able to identify four convergence clubs and one divergent group (composed by countries that do not converge to any club): club 1 is composed by Haiti and Honduras, club 2 is composed by Argentina, Bolivia, Brazil, Guatemala, Nicaragua, Paraguay, Uruguay and

Venezuela, club 3 is composed by Barbados, Chile, Costa Rica, El Salvador, Grenada, Mexico and Peru, club 4 is composed by Ecuador and Panama, with the divergent group being composed by Colombia and the Dominican Republic. As was noted, the clubs were ordered by their energy intensity levels (Table 13), with club 1 being the most energy-intensive club and the club 4 the least energy-intensive. From this information, jointly with the analysis of their average energy intensity transition paths (Figure 3), we can conclude that the countries in club 1 and club 2 need to make an additional effort to reduce their energy intensity levels, mainly when compared with the ones in club 3 and club 4 where we can see a stable decreasing trend in energy intensity.

Despite the valuable conclusions that were retrieved from the analysis of the convergence clubs, we should recall that the aim of this investigation was to study the role that public and private capital stocks play in the energy intensity of these LAC countries. Thus, the principal purpose of the convergence club analysis was to find an ordinal response variable (representing the club to which a country belongs). We can use this as the dependent variable in an ordered logit regression model to see if the capital stocks were responsible for the formation of the LAC energy intensity convergence clubs. Looking at the results of the ordered logit model (Table 17), we find that, conversely to these countries' initial energy intensity, none of the capital stocks was a determinant of club membership. As public and private capitals do not drive the formation of convergence clubs, this means that the difference of these clubs, in terms of energy intensity, comes from other factors, with the effects from both types of capital on energy intensity being similar in most of the countries under analysis. This outcome supports the conclusions previously drawn from the P-ARDL estimation: investment in newer and more energy-efficient physical capital is needed in all the countries of this region, regardless of their club membership.

Based on these results and conclusions, we believe that the LAC governments should increase investment in more energy-efficient equipment and infrastructure, with improved public financing instruments or with the help of institutional investors. At the same time, they should create (or improve) the laws and the regulatory framework regarding energy efficiency (e.g., setting energy efficiency targets for their various economic sectors, developing energy efficiency norms and regulation for equipment and appliances, setting efficiency standards and promoting energy audits for buildings/infrastructures). In some cases, it could be easier to invest in the maintenance and upgrade of the existing capital than to invest in new physical capital. Additionally, the LAC governments should create incentives to enable private physical capital to follow the same tendency. The development of new financing schemes, such as loans and lines of credit strictly directed to investment in energy efficiency projects, and the creation (or improvement) of financial incentives as subsidies and/or fiscal incentives for energy efficiency investments (e.g., tax reductions, tax credits, among others) are some of the tools that can be used to achieve this end. The increased support of financial institutions should complement the role of the governments. Finally, given that investment in more energy-efficient physical capital is a necessity for the whole LAC region, the discussion, creation and promotion of measures focused on the transition of this region to more efficient energy use should be firmly present on the agendas of regional organisations such as the Economic Commission for Latin America and the Caribbean (ECLAC), and the Latin American Energy Organization (OLADE).

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Appendix

Table A1. Hausman tests (FE vs RE) – Parsimonious model

Hausman test	**Hausman test with *sigmamore***	**Hausman test with *sigmaless***
FE vs RE	FE vs RE	FE vs RE
Chi2(8) = 44.18***	Chi2(5) = 43.79***	Chi2(5) = 45.74***

Notes: *** denotes statistical significance at the 1% level; H_0: difference in coefficients not systematic/RE is preferable

Table A2. Hausman tests (MG vs PMG vs FE) – Parsimonious model

Hausman test	**MG vs PMG**
	Chi2(9) = 22.74***
	PMG vs FE
	Chi2(9) = 1.60
	MG vs FE
	Chi2(9) = 0.17

Notes: *** denotes statistical significance at the 1% level; H_0: difference in coefficients not systematic; the Stata commands *xtpmg*, and Hausman (with the options, sigmamore alleqs constant) were used.

Table A3. Specification tests – Parsimonious model

	Statistics
Time fixed effects	1.12
Modified Wald test	1687.97***
Pesaran's test	-0.073
Frees' test	0.183***
Friedman's test	48.969***
Breusch Pagan LM test	242.808*
Wooldridge test	64.217***

Notes: H_0 of Time fixed effects test: dummies for all years are equal to 0 (no time fixed effects are needed); H_0 of Modified Wald test: sigma(i)^2= sigma^2 for all I; H_0 of Pesaran's, Frees', Friedman's, and Breusch-Pagan LM tests: residual are not correlated; H_0 of Wooldridge test: no first-order autocorrelation; * and *** denotes statistical significance at the 10% and 1% levels, respectively.

***Declaration of Interest Statement**

Declaration of interests' statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.