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Article

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Testing the Environmental Kuznets Curve Hypothesis in Uruguay using Ecological Footprint as a Measure of Environmental Degradation

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ABSTRACT

This paper, using data for the time period 1971-2014, analyzes the relationship between GDP per capita, foreign direct investment, energy use per capita, and environmental degradation measured by the Ecological Footprint in Uruguay. It also tests whether the Environmental Kuznets Curve (EKC) hypothesis holds. While environmental degradation is positively related with energy use per capita in the long run, its relationship with foreign direct investment in the long-run is negative. The inverted U-shaped relationship between GDP per capita and environmental degradation implies that the EKC hypothesis is verified. The policy recommendations include the implementation of measures leading to more energy saving and more efficient use of energy, investing in cleaner and more efficient technologies, and policies that would increment the share of modern renewable sources in energy consumption.

Keywords: Environmental Kuznets Curve, Ecological Footprint, Gross Domestic Product per Capita, Energy Use, Foreign Direct Investment, Uruguay
JEL Classifications: Q4, Q53

1. INTRODUCTION

Most scientists agree on the effect human activities have on the documented changes in the climate of the Earth. Caused mainly by economic and population growth, the emissions of anthropogenic greenhouse gases (causing increases in the concentration of nitrous oxide, methane, and carbon dioxide in the atmosphere) are currently higher than ever before. Almost 80% of the increment in greenhouse gas emissions are the result of industrial activities and the combustion of fossil fuels (IPCC, 2014). The effects of climate change can be seen in increasing temperatures and the more frequent occurrence of extreme weather events, which are causing the loss of ecosystems, biodiversity, and land, that are affecting the agriculture (Bouwer, 2019).

The growing concern for climate change and environmental problems led to the growth of research in both natural and social sciences focusing on the explanations behind these issues. Following the work by Grossman and Krueger (1991), a vast literature studies the relationship between environmental pollution and GDP growth and examines whether there exists an inverse U-shaped relationship between these two variables, known as the Environmental Kuznets Curve (EKC) Hypothesis. According to this theory, as economies grow, initially, environmental degradation increases. Beyond a certain point, however, more economic growth implies less environmental degradation (Zilio and Recalde, 2011). The presence of such an inverse U-shaped relationship could be explained by three mechanisms (Grossman and Krueger, 1991). Firstly, according to the scale effect, as the volume of economic activity rises, waste, emissions and, hence, pollution and degradation would rise (Zilio and Recalde, 2011). The composition effect rises from a gradual change in the weight of the productive sectors of an economy. Agricultural economies would first become more industrialized and then the share of the service sector would increase as well (Ozcan et al., 2018). So, initially, pollution would rise while an increment in the share of the services sector would have the opposite effect. The third effect is the technological effect. As a country becomes richer, it may invest more in R&D leading to technological progress that would result in more efficient and cleaner technologies (Zilio and Recalde, 2011).

Most of the literature focusing on the EKC Hypothesis uses the emission levels of CO_2 or similar greenhouse gases as a measure of environmental pollution. Using CO_2 emissions as an indicator of the degree of environmental pollution or degradation, however, would mean that only one of the several dimensions of environmental pollution is considered (Ozcan et al., 2018). For this reason, to be able to assess the role that economic growth and energy usage play on several dimensions of environmental degradation, we use a more comprehensive measure (Ozcan et al., 2019): The ecological footprint (EF).

Why do we use EF? The wellbeing of humankind depends strongly on how we can obtain the necessary resources. Since our planet has finite resources, we need to consider them and move forward to a situation of sustainable development (Borucke et al., 2013). There is evidence that our current way of living will be unsustainable in the future, or as Borucke et al. (2013) posit "human demand is likely to be exceeding the regenerative and absorptive capacity of the biosphere" (p. 519). As a consequence, measures of how much pressure humanity is putting on the environment are needed. One of them is EF. It was created by Rees (1992) and Wachernagel and Rees (1996). It measures "the ecological assets that a given population requires to produce the natural resources it consumes (including plant-based food and fiber products, livestock and fish products, timber and other forest products, space for urban infrastructure) and to absorb its waste, especially carbon emissions" (Global Footprint Network, 2017). EF has been used as an indicator of biophysical limitations and sustainability: if this aggregate number (equivalent land area required) is higher than the land area of a country, then the country will have a deficit (or "overshoot") because it is exceeding its resources (Costanza, 2000).

Nonetheless, the measure has several problems: it assumes that the current technologies will be used in the future, and several researchers have pointed out the problems in the aggregation of its different components (Caviglia-Harris et al., 2009). In spite of that, we use this measure because its shortcomings are well documented and it is widely and increasingly used by researchers. Being easily understandable, it is a very useful measure (Costanza, 2000).

Many studies analyze the effect of economic growth on environmental degradation, but most of them measure degradation through the level of CO_2 emissions. The number of studies using EF is much lower. Therefore, our paper contributes to the growing literature using EF as a measure of environmental degradation. Moreover, there is a small number of studies that investigate whether the EKC hypothesis is validated in Latin American countries. We also contribute to this line of research. Uruguay is a small open economy, very dependent on exports of mainly agricultural products, which are very vulnerable to extreme climate events. In the period 1965-2010, the average temperature increased 0.5°C, rainfalls increased around 33%, while the average sea level increased 11 cm in the last century (CEPAL, 2010). These facts contribute to the vulnerability of the country to extreme weather events, which makes it important to study the factors affecting the EF of the country.

The paper is organized as follows. Section 2 provides background information about the geographic, socio-demographic, climatic, and economic characteristics of Uruguay and also about its energy sector. Section 3 reviews the related literature and describes this paper's contribution to the literature. Section 4 describes the data, variables, and methodology used in this study, which is followed by the presentation of the results. The last section concludes and presents policy recommendations based on our findings.

2. BACKGROUND INFORMATION ON URUGUAY

Uruguay is a relatively small country with an area of 176,016 Km^2, located in the southeast of South America, bordering Argentina (separated by the Uruguay river) and Brazil, with the Rio de la Plata to the south and the Atlantic Ocean to the southeast (INE, 2017). Its land consists of mostly rolling plains and low hills, with 90% of it being usable for production purposes (CEPAL, 2010). The population is 3,480,222 people (2016), with 1,380,432 living in its capital city, Montevideo (INE, 2017). Almost 80% of the population is urban, living in towns or cities (CIA Factbook). Uruguay has had a strong economic, political and social stability for years, supported by a consolidated democracy and a strong judiciary system (MVOTMA, 2017). Its poverty rate is 9.4% (2016), unemployment rate is 7.8% (2016), Gini index is 0.383 (2016), Human Development Index is 0.795 (2016), and the annual rate of population growth is 0.4% (2015) (MVOTMA, 2017).

Uruguay has a subtropical climate with four defined seasons. The average annual temperature is 17.7°C while the annual average relative humidity ranges from 70% to 75%, and the average annual rainfall is approximately 1,400 mm (MVOTMA, 2017). There has been an average annual increase of rainfall of 0.7% in the period of 1966-2006 (CEPAL, 2010). The temperature increased at an average annual rate of 0.08% between 1961 and 2005 (CEPAL, 2010). During the years of the predominance of *El Niño*, there is an increase in the rainfall, while in years when *La Niña* predominates, the country suffers prolonged and deep droughts (MVOTMA, 2017).

Uruguay is a small open economy, where the primary sector is agricultural production (Piaggio et al., 2017). Although the country has experienced an increase in the share of the service sectors (MVOTMA, 2017), there has also been observed a parallel increase in the share of manufacturing (Piaggio et al., 2017), which together with the still strong weight of the agricultural sector makes the country highly vulnerable to the variability and change in the climate (MVOTMA, 2017). According to the World Bank, Uruguay is highly vulnerable to climate change, especially in coastal zones, because of the very likely future increase in sea levels, and because in these coastal zones economic and natural resources are highly exposed (World Bank, 2019a). These threats have already impacted on the population, infrastructures, ecosystems, biodiversity, and especially on the agricultural sector (MVOTMA, 2017).

Uruguay has grown at an average yearly rate of 4.6% in the period 2005-2016; this economic growth that was accompanied with income redistribution, put a strong pressure on the energy and transportation sectors (MVOTMA, 2017). This created a very difficult situation considering that the country lacks traditional energy resources such as hydrocarbons reserves and, as a result, the country is dependent on its imports (Piaggio et al., 2017). Electricity has been generated mainly using hydroelectric plants complemented with thermoelectric plants based on liquid fossil fuels. The hydroelectric base presents an important and growing vulnerability to climate change and variability, with the subsequent dependence on fossil fuels increasing greenhouse gas emissions (MVOTMA, 2017).

The considerable growth of investments in recent years has had a strong industrial and energetic component: about USD 7,000 million (equivalent to 13% of GDP in 2016) have been invested in recent years in the diversification of the energy mix, especially in the introduction of modern renewable energies for electricity generation (MVOTMA, 2017). In 2015, 60% of the electricity was generated from hydroelectric sources, 28% from other renewables sources including wind, biomass, and solar panels, and 11% from oil sources (WDI, 2019). This transformation in the electricity sector reduced both the climatic vulnerability and the emission of greenhouse gases (MVOTMA, 2017). Nonetheless, there is still a considerable potential for solar and onshore wind power in Uruguay: 809 GW and 163GW, respectively (Teske et al., 2019).

3. LITERATURE REVIEW

The majority of papers studying the EKC hypothesis measure environmental degradation through the level of CO_2 emissions, but for the reasons exposed above, we use the EF. Therefore, we concentrate on papers also using this measure of environmental degradation. We organized this section into three different subsections. In subsection 3.1 we review the relevant literature related to the EKC hypothesis using EF as a measure of the environmental degradation for one country or set of countries. Subsection 3.2 presents papers that study environmental degradation in Latin American and Caribbean countries using CO_2 emissions, because, to the best of our knowledge, there are no papers applied to countries in this region using EF, except for one included in subsection 3.3, where papers studying Uruguay are presented.

3.1. Studies Testing the EKC Hypothesis using the Ecological Footprint

The first studies focusing on the EKC hypothesis using the EF were of a cross-sectional nature. Bagliani et al. (2008), for instance, using data for 2001 in 141 countries, find a positive relationship between GDP per capita (GDPpc) and EF. A later study by Wang et al. (2013), using data for a single year (2005), fails to find evidence of the existence of an EKC relationship in the case of 150 countries.

One of the earliest studies following a panel data approach to test the EKC hypothesis is Caviglia-Harris et al. (2009). Using data for 146 countries for the years 1961-2000, they do not verify the hypothesis. Nonetheless, once energy–one of the seven components making up the EF– is removed, the inverse U-shaped relationship between GDP per capita and EF starts to appear.

Al-Mulali et al. (2015b) study whether the EKC hypothesis holds for 93 countries and the years 1980-2008 classifying countries into four income groups: high, upper-middle, lower-middle, and low income. They find that the EKC hypothesis holds only in the last two groups of countries. They find that energy consumption increases environmental degradation in all four groups of countries, while financial development reduces degradation in all but low-income countries. Ulucak and Bilgili (2018), validate the EKC hypothesis not only for high and middle-level income countries but also for low-income level countries. Their study uses data for 1961-2013 and considers 15 countries in each income level group. Destek and Sarkodie (2019) find an inverse U-shaped relationship between GDPpc and EF for 11 recently industrialized countries for the period 1977-2013. They also find that more energy usage leads to more environmental degradation.

Focusing on 17 predominantly low-income African countries, Sarkodie (2018) finds a U-shaped relationship between GDPpc and environmental degradation for the period 1971-2013. Like Al-Mulali et al. (2015b), and Al-Mulali and Ozturk (2015) for the case of 14 Middle East and North African (MENA) countries and the period 1996-2012, he finds that an increase in energy usage leads to an increase in environmental degradation. A U-shaped relationship between GDPpc and environmental degradation is also found by Destek et al. (2018) in the case of 15 EU countries for the years 1980-2013. Moreover, they observe that renewable energy consumption per capita and trade openness reduce environmental degradation while non-renewable energy consumption per capita increases it.

Analysing 15 MENA countries over the years 1975-2007, Charfeddine and Mrabet (2017) obtain that while the EKC hypothesis is verified for the subsample of oil-exporting countries in the region, the relationship between EF and GDPpc is U-shaped for the non-oil-exporting countries. Like others, they also find that EF and energy use are positively related. Al-Mulali et al. (2016), on the other hand, fail to verify the EKC hypothesis in the case of 58 developed and developing countries and the period 1980-2009.

Focusing on a set of 64 developing countries and covering the time period from 2005 to 2013, Masron and Subramaniam (2018) study the role corruption plays on environmental degradation. They confirm the EKC hypothesis and also find that corruption increases environmental degradation, while a higher share of renewables in energy consumption reduces it.

Uddin et al. (2017), on the other hand, find that income has a positive impact on EF in 27 developing and developed countries for 1991-2012.

Several papers examine the EKC hypothesis in a single country using time series analysis. The EKC hypothesis is confirmed by Sarkodie and Strezov (2018) for Australia in the time period from 1974 to 2013. It is also confirmed by Hassan et al. (2018) for Pakistan (time span 1970-2014), Ahmed et al. (2019) for the D-8 countries, Ozturk et al. (2016) for 144 countries, Sharif et al. (2020) for Turkey, and Mrabet and Alsamara (2017) for Qatar (for the years 1980-2011). Mrabet and Alsamara also find that financial development has a significant positive impact on EF, while in the case of trade openness, the effect is negative. Hellen (2017), however, fails to confirm the EKC hypothesis for Kenya for the 1970-2012 period.

In another study focusing on Qatar, Charfeddine (2017) finds evidence of a U-shaped relationship between real GDPpc and EF for the period 1970-2015. He also finds that the environment is further degraded with increases in trade openness, in urbanization, and in financial development. His finding implies that a continuous increase in real GDPpc will degrade the environment, which coupled with the fact that electricity consumption impacts positively on the EF and the existence of a bidirectional causality between economic growth and electricity consumption, means that cutting the electricity consumption is not a feasible alternative if Qatar wants to increase its citizens' income. Therefore, Charfeddine (2017) recommends increasing renewable energy consumption, among other measures.

Ozcan et al. (2018), using data for the time period 1961-2013 do not verify the EKC hypothesis in Turkey, while Imamoglu (2018) finds that energy consumption per capita has a positive effect on environmental degradation in Turkey for the time span 1970-2014.

3.2. Studies Testing the EKC Hypothesis in Latin America

Focusing on six Central American countries for the years 1971-2004, Apergis and Payne (2009) establish that the EKC hypothesis holds when pollution is measured by CO_2 emissions. While they find that there is bidirectional causality between energy use per capita and emissions per capita, in the short run there is a unidirectional causality running from energy consumption to emissions. The hypothesis is also verified by Al-Mulali et al. (2015a) for a panel of 18 Latin American countries including Uruguay for the time span 1980-2010. Their results show that while renewable energy consumption has no effect on CO_2 emissions in the long-run, financial development actually reduces emissions. Zilio and Recalde (2011), on the other hand, test whether an inverse U-shaped relationship exists between GDPpc and energy usage and between GDPpc and energy usage per capita. Using data for 21 Latin American and Caribbean countries and covering the 1970-2007 period, they fail to find such relationships.

De Souza et al. (2018) study the effect of income and energy consumption from non-renewable and renewable sources on CO_2 emissions, controlling for the effect of trade openness, financial development, and urbanization in the MERCOSUR (Argentina, Brazil, Paraguay, Uruguay, and Venezuela) countries. They find that CO_2 emissions are affected positively by income per capita and the consumption of non-renewable energy, while they are negatively affected by the consumption of renewable energy. Moreover, they find evidence that supports the EKC hypothesis.

Some papers test the EKC hypothesis for CO_2 emissions focusing on a single country and following a time series approach. Testing the EKC hypothesis for CO_2 emissions in Peru for the time span 1980-2011, Zambrano-Monserrate et al. (2018) fail to verify it. Pao and Tsai (2011a), using data for the time period 1980-2007, find that although the EKC hypothesis holds for Brazil, the GDPpc level did not reach the turning point yet implying that there is still a positive relationship between income and CO_2 emissions. Zambrano-Monserrate et al. (2016b) also investigate the validity of the EKC hypothesis for Brazil (for the period 1971-2011). They verify the EKC hypothesis in the long run, although they do not verify it in the short run. They also find that CO_2 emissions increase with energy use, but decrease when the percentage of the total production of electricity that comes from hydroelectric sources increases.

Robalino-López et al. (2014) fail to validate the EKC hypothesis for Ecuador for the period 1980-2010 and estimate that Ecuador will be able to reach a situation of environmental stability around 2019-2021 if the country promotes energy efficiency and the use of renewables. Similar results are also obtained for Venezuela by Robalino-López et al. (2015). Also, focusing on Ecuador, the EKC hypothesis is verified by Zambrano-Monserrate et al. (2016a) for the period 1971-2011. They also find that the relationship between energy usage per capita and CO_2 emissions, is positive in the long run.

Pablo-Romero and De Jesús (2016) study the so-called "Energy-Environmental Kuznets Curve," that is, they investigate the EKC hypothesis using absolute energy consumption as a measure of environmental pressure for 22 Latin American countries for the period 1990-2011. They find a positive relationship between Gross Value Added per capita and energy consumption and do not find evidence supporting the EKC hypothesis.

Other studies on Latin American countries focus on the drivers of CO_2 emissions, without testing the EKC hypothesis. Several of these papers are reviewed below. Chang and Carballo (2011) study the nexus between energy usage, GDP growth, and CO_2 emissions for 20 Latin American countries for the period 1971-2005, to find in which countries "energy conservation policies" could be implemented without affecting their GDP growth negatively. They find that it would be possible only in four countries (Argentina, Dominican Republic, Mexico, and Panama). Moreover, they find that CO_2 emissions are caused by GDP in Costa Rica, Ecuador, Jamaica, Nicaragua, and Peru, while CO_2 emissions are caused by energy consumption in Costa Rica, Ecuador, Jamaica, Nicaragua, Paraguay, Peru, and Trinidad and Tobago.

Similarly, Fuinhas et al. (2017) study the effect of renewable energy policies on CO_2 emissions for 10 Latin American (LA) countries for the period 1991-2012. They find that policies that encourage the use of renewable energies reduce CO_2 emissions, while GDP growth increases them in the long run. Koengkan et al. (2019) find that GDP growth, financial openness, and primary energy usage affect positively CO_2 emissions, while renewable energy consumption has a negative effect, for 21 Latin American and Caribbean countries for the period 1980-2014.

Other studies focus on subgroups of LA countries. Koengkan (2018) investigates the effect of renewable energy usage on CO_2 emissions in the MERCOSUR countries for the period 1980-2014. He finds that CO_2 emissions rise with GDP growth and the consumption of fossil fuels, while they decrease when more renewable energy is consumed. Koengkan et al. (2018) find that CO_2 emissions increase with financial openness, economic growth, primary energy consumption, and agricultural production in the MERCOSUR countries in the period 1980-2014.

3.3. Studies Testing the EKC Hypothesis in Uruguay

To the best of our knowledge, there are only two studies that focus on explaining the determinants of environmental pollution and degradation in Uruguay. Piaggio et al. (2017) aim to explain the nexus between CO_2 emissions and economic activity for a very long time span: 1882-2010. They fail to validate the EKC hypothesis in Uruguay, but their results show that as GDPpc increases, emissions increase at a decreasing rate. They also find that emissions increase as the share of the industry in total output rises while trade openness and CO_2 emissions are negatively related. Moreover, emissions have a negative relationship with the share of clean sources in the supply of energy.

Hervieux and Darne (2015) test the EKC hypothesis for EF in seven Latin American countries using data for the time span 1961-2007. The study tests the hypothesis in Uruguay as well. When using an error-correction model, they obtain a positive relationship between GDPpc and EF.

The conflicting results obtained by the studies using a panel of countries to test the EKC hypothesis using EF suggest that the study of the hypothesis country by country is warranted. The present study contributes to the relatively scarce literature (particularly for Latin American countries) on single-country studies testing the EKC hypothesis for the EF by focusing on Uruguay. Ours is the second study using the EF in Uruguay following Hervieux and Darne (2015). Different from their study, we use more up to date data and, more importantly, we control also for the effect that energy use per capita and foreign direct investment have on EF, thereby reducing a potential omitted variable bias. Doing so leads to different conclusions than Hervieux and Darne (2015).

4. DATA AND METHODOLOGY

4.1. Data and Variables

The objective of this study is to investigate the effect of energy consumption, foreign direct investment, and economic growth on environmental degradation and to check the validity of the EKC hypothesis in Uruguay. Table 1 presents a brief description of the variables used in the analysis together with the source of the data.

As explained in the introduction, the EF measures how much pressure human consumption places on the biosphere. We use EF per capita, that is, the nation's total EF divided by the population.

Apart from testing the EKC hypothesis, we also study the effect of energy use per capita and foreign direct investment on EF. In the case of energy consumption, as the previously reviewed literature points out, there is a positive relationship between energy use and environmental pollution and degradation in countries from any part of the world and any income level. Hence, we expect to observe a positive nexus between energy usage per capita and EF.

The way foreign direct investment (FDI) would impact on environmental pollution and degradation depends on where FDI is channeled to. Fakher (2019) argues that in developing countries, lower levels of environmental standards may lead to investments running into polluting industries leading to higher environmental degradation. The negative impact of FDI on the environment is known as the "Pollution Haven" hypothesis (Dean et al., 2009; Jensen, 1996; Xing and Kolstad, 1996, among others), On the other hand, FDI flowing in from multinationals using cleaner technologies would extend those technologies in the receiving countries. The positive impact FDI has on the environment is called the "Pollution Halo" hypothesis (Birdsall and Wheeler, 1993; Eskeland and Harrison, 2003; Pao and Tsai 2011b; Zarsky, 1999). Moreover, FDI may also lead to more R&D and hence less pollution (Frankel and Romer, 1999).

Regarding the empirical findings, Fakher (2019) finds a positive impact of FDI on the ecological carbon footprint in the case of seven OPEC member countries. Similarly, Pao and Tsai (2011) find a positive relationship between FDI and CO_2 emissions for the BRIC countries, Al-Mulali (2012) for 12 Middle Eastern countries, Seker et al. (2015) in Turkey, Shahbaz et al. (2013b) in Malaysia and Zhang and Zhang (2018) in China. Sarkodie and Strezov (2019) find that the pollution haven hypothesis is verified in China, India, Indonesia, Iran, and South Africa when pollution is measured as greenhouse gas emissions. Omri et al. (2019), on the other hand, find an inverse U-shaped relationship between FDI and CO_2 emissions in Saudi Arabia.

A study finding no significant effect of FDI on CO_2 emissions is Chandran and Tang (2013) who study Indonesia, Malaysia

Table 1: Variables and sources

Variable	Description	Unit	Source
EF	Ecological footprint of consumption per capita	Global hectares	Global footprint network
GDPpc	Gross domestic product per capita	Constant 2010 US$	World Development Indicators, World Bank
FDI	Foreign direct investment, net inflows	% of GDP	World Development Indicators, World Bank
Energy	Energy use: Kg of oil equivalent per capita	Kg	World Development Indicators, World Bank

and Thailand. There are also some studies finding a negative relationship between FDI and CO_2 emissions: Al-Mulali and Tang (2013) for the Gulf Cooperation Council member countries and Mert and Bölük (2016) for 21 mainly developed countries. Focusing on countries in the ASEAN region, Merican et al. (2007) find that FDI increases CO_2 emissions in Philippines, Malaysia, and Thailand, while it decreases them in Indonesia and has no significant effect in Singapore. Paramati et al. (2017) obtain that FDI has a positive impact on CO_2 emissions in developed G20 countries and a negative effect in developing G20 countries. Finally, Solarin and Al-Mulali (2018) study the impact of FDI on EF in 20 countries. They find that while FDI has a positive impact on EF in Brazil, China, Egypt, Nigeria, and Poland, the impact is negative in France, Japan, and Korea.

Based on the conflicting findings in the literature regarding the impact of FDI on pollution, we do not have an a priori expectation about the relationship between FDI and EF.

4.2. Econometric Model and Methodology

Several different methodologies have been used to study the impact of GDP growth on the environment in the case of single country studies. Our study follows the methodology applied by Ahmed and Long (2012), Farhani et al. (2014), Lau et al. (2014), Shahbaz et al. (2012; 2013a), Tiwari et al. (2013), and Zambrano-Monserrate et al. (2018), among others.

The nexus between income per capita, foreign direct investment, energy use per capita, and Ecological Footprint per capita can be represented as:

$$EF_t = f(GDP_t, GDP_t^2, FDI_t, Energy_t) \quad (1)$$

To obtain efficient and consistent empirical results, we use the following log-linear model:

$$lnEF_t = \alpha + \beta_1 lnGDP_t + \beta_2 lnGDP_t^2 + \beta_3 lnFDI_t + \beta_4 lnEnergy_t + \varepsilon_t \quad (2)$$

where all variables are in logarithms, and ϵ_t denotes the error term. Since the variable FDI takes negative values for some years (1971, 1972, 1974, 1982, and 1985), to apply the logarithmic transformation to FDI, we first transformed the variable adding a constant (0.17) such that all the values are positive.

The EKC hypothesis would be verified if the sign of β_2 is positive and β_3 is negative. That is, if $\beta_2 > 0$ and $\beta_3 < 0$, economic growth will have a positive impact on the EF (it will degrade the environment) initially, but when the income (GDP) per capita reaches certain point, more economic growth will decrease EF (it will have a positive effect on the environment).

The methodology followed in this study consists of several steps. The first one is to check the level of integration of the series used in the analysis. Actually, since we will use the Autoregressive Distributed Lag (ARDL) cointegration test in step 2, not all the variables need to be integrated of order 1, I(1), some can be I(0) without causing a problem, but we have to check that they do not have an order of integration larger than 1. As unit root tests we use the augmented Dickey-Fuller (ADF; Dickey and Fuller, 1979), PP (Phillips-Perron, 1988), Dickey-Fuller Generalized Least Squares (ADF-GLS; Elliott et al., 1996), and KPSS (Kwiatkowski et al., 1992) tests.

The second step is to analyze if the variables are cointegrated. To that end, we use the ARDL bounds test created by Pesaran, Shin, and Smith (Pesaran et al., 2001) which has better properties than other cointegration tests in small samples (Haug, 2002). As mentioned above, this test can be applied when the series are I(1), I(0), or a combination of both. The ARDL equation is as follows:

$$\begin{aligned}\Delta lnEF_t = \alpha_0 &+ \sum_{k=1}^{\pi_1} \alpha_{1k} \Delta lnEF_{t-k} + \sum_{\kappa=0}^{\pi_2} \alpha_{2k} \Delta lnGDP_{t-k} \\ &+ \sum_{\kappa=0}^{\pi_3} \alpha_{3k} \Delta lnGDP_{t-k}{}^2 + \sum_{\kappa=0}^{\pi_4} \alpha_{4k} \Delta lnFDI_{t-k} \\ &+ \sum_{\kappa=0}^{\pi_5} \alpha_{5k} \Delta lnEnergy_{t-k} + \lambda_1 lnEF_{t-1} + \lambda_2 lnGDP_{t-1} \\ &+ \lambda_3 lnGDP_{t-1}{}^2 + \lambda_4 lnFDI_{t-1} + \lambda_5 lnEnergy_{t-1} + e_t\end{aligned} \quad (3)$$

Where e_t is the error term and Δ indicates the difference operator. In our study, the optimal lag length of the variables is determined using the Akaike Information Criteria (AIC) method. The first part of equation (3) refers to the short-run dynamics (the αs being the short run parameters) while the second part explores the long-run relationship between the variables (the λs are the long-run terms). The existence of a long-run relationship –cointegration– is verified via the F and t statistics. The null hypothesis of no cointegration implies that $\lambda_1 = \lambda_2 = \lambda_3 = \lambda_5 = 0$, while the alternative hypothesis implies that at least one λ is different from zero. The test provides critical values (a lower and an upper bound) for 10%, 5%, and 1% significance levels for the t and F statistics. The lower critical bound implies that the variables are I(0) whilst the upper critical bound assumes them to be I(1). H_0 is rejected if both F and t statistics are more extreme than the upper critical values, H_0 is not rejected if both F and t are below the lower critical values. The test is inconclusive when the statistics are between the lower and upper bounds. If a long-run relationship between the variables exists (i.e. if H_0 is rejected in the ARDL bounds test), the third step of the procedure is to estimate the error correction model that shows the short-run relationship of the variables as follows:

$$\begin{aligned}\Delta lnEF_t = \alpha_0 &+ \sum_{\kappa=1}^{\pi_1} \alpha_{1k} \Delta lnEF_{t-k} + \sum_{\kappa=0}^{\pi_2} \alpha_{2k} \Delta lnGDP_{t-k} \\ &+ \sum_{\kappa=0}^{\pi_3} \alpha_{3k} \Delta lnGDP_{t-k}{}^2 + \sum_{k=0}^{\pi_4} \alpha_{4k} \Delta lnFDI_{t-k} \\ &+ \sum_{\kappa=0}^{\pi_5} \alpha_{5k} \Delta lnEnergy_{t-k} + \lambda ECT_{t-1} + e_t\end{aligned} \quad (4)$$

where ECT_{t-1} denotes the lagged error correction term. If a long-run relationship exists, then λ shows how fast the variables go back to their long-run equilibrium values. Therefore, λ should be between −1 and 0 and significant. We test for heteroscedasticity, normality and autocorrelation of the residuals using regular diagnostic tests, and we use the Ramsey reset test to ensure that no relevant variable is excluded. The stability of the parameters is checked using the recursive estimation Cumulative Sum test (CUSUM) and Cumulative Sum of Squares test (CUSUMQ).

5. EMPIRICAL RESULTS

Table 2 presents the main descriptive statistics for the variables used in the analysis (before applying the logarithmic transformation), while Figure 1 shows the evolution of the variables during the period of analysis (1971-2014).

It can be observed that EF has decreased over the period while GDPpc, FDI, and Energy have increased. For the same period, the world average EF was 2.707, while it was 2.831 for South America, with the highest value corresponding to Uruguay and the lowest to Ecuador (1.850). The fact that Uruguay exhibits the highest EF in South America highlights the need for studying the factors affecting EF in this country.

Since our main objective is the study of the nexus between EF and GDP, we plot the relationship between these two variables in Figure 2. Figures 1 and 2 suggest that after the GDPpc reached a certain point, EF started to decline, suggesting the existence of EKC in Uruguay for the years under study.

Table 3 shows the results of the unit root tests applied to the logarithm of the variables in level and difference forms. The majority of the tests suggest that the series under study are integrated of order 1. Exceptions are the results of the PP test for the variable *lnEF* and *lnFDI* that indicate that the variables are stationary (or integrated of order 0), and the Dickey-Fuller-GLS test for the variable *lnEnergyUse* that tells us that the variable is integrated of order 2. Since the majority of the tests indicate that the variables are I(1), we can continue with the ARDL model.

The results of the ARDL bound test of cointegration that explores the existence of a long-run relationship between EF and its determinants are shown in Table 4. The lag length of the ARDL model is determined using the Akaike Information Criterion (AIC) as (1, 4, 2, 4, 3) for the function $f\left(lnGDP_t, lnGDP_t^2, lnFDI_t, lnEnergy_t\right)$. The F-statistic and the t-statistic values are 5.487 and −5.223 respectively. Both values are larger than the upper bounds at 5% and 1% level of significance, respectively, leading us to the rejection of the null hypothesis of no cointegration. As a result, we find a long-run relationship between Ecological Footprint, GDPpc, FDI, and energy use per capita over the study period of 1971-2014 in Uruguay.

The long-run and short-run effects of economic growth, foreign direct investment, and energy consumption on Ecological Footprint are presented in Table 5. The upper panel indicates that all the long-run

Table 2: Descriptive statistics

Statistic	Ecological footprint of consumption per capita (gha/person)	GDP per capita (constant 2010 US$)	Foreign direct investment, net inflows (% of GDP)	Energy use (kg of oil equivalent per capita)
Mean	4.548	8172.112	2.057	902.130
Median	4.594	7648.306	0.746	865.971
Minimum	2.696	5558.678	-0.167	663.306
Maximum	6.618	13856.700	11.790	1378.274
SD	0.885	2229.136	2.674	191.552
Skewness	−0.068	1.015	1.694	1.298
Kurtosis	2.361	3.240	5.563	3.756
SK test	0.830	7.220	17.320	10.560
P-value	0.660	0.027	0.000	0.005
Observations	44	44	44	44

Figure 1: Evolution of the variables over time

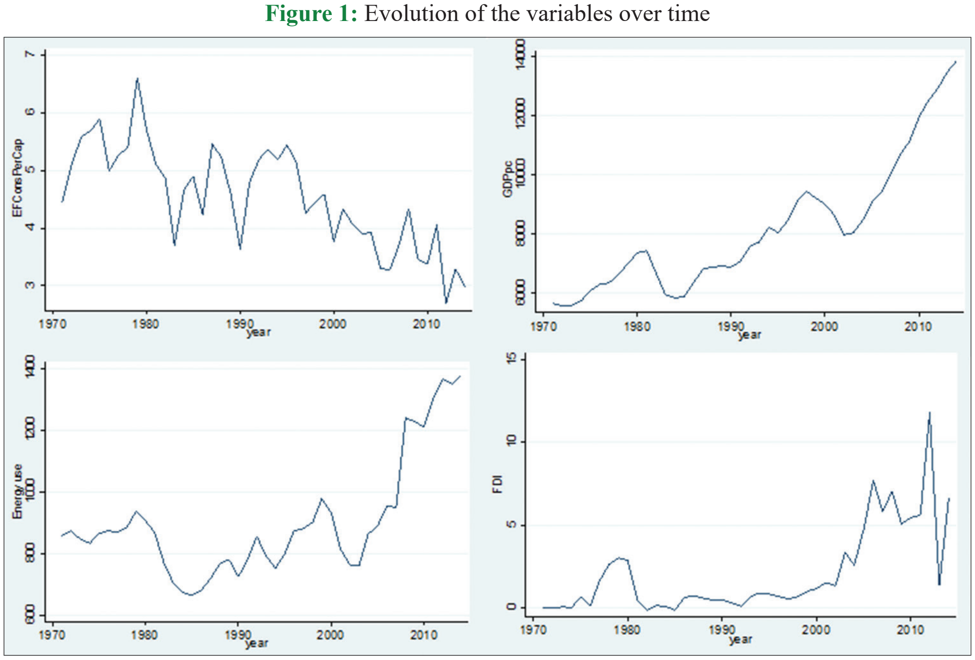


Table 3: Unit root tests

	Augmented Dickey-Fuller		Phillips-Perron		Dickey-Fuller-GLS		Kwiatkowski–Phillips–Schmidt–Shin	
	Statistic	Decision	Statistic	Decision	Statistic	Decision	Statistic	Decision
lnEF	−2.864 [3]	I(1)	−4.862 [3]***	I(0)	−2.252 [2]	I(1)	0.149 [2]**	I(1)
ΔlnEF	−4.761 [2]***		−9.860 [2]***		−3.973 [2] ***		0.038 [2]	
lnGPDpc	−1.668 [3]	I(1)	−1.762 [3]	I(1)	−2.300 [2]	I(1)	0.179 [2]**	I(1)
ΔlnGDPpc	−4.019 [2]**		−3.641 [2]**		−3.999 [2]***		0.049 [2]	
lnFDI	−2.875 [3]	I(1)	−4.654 [3]***	I(0)	−2.289 [2]	I(1)	0.119 [2]*	I(1)
ΔlnFDI	−4.037 [2]**		−10.515 [2]***		−3.957 [2]***		0.042 [2]	
lnEnergy	−1.579 [1]	I(1)	−1.323 [1]	I(1)	−1.504 [1]	I(2)	0.315 [2]***	I(1)
ΔlnEnergy	−5.565 [0]***		−5.565 [0]***		−2.693 [3]		0.042 [2]	

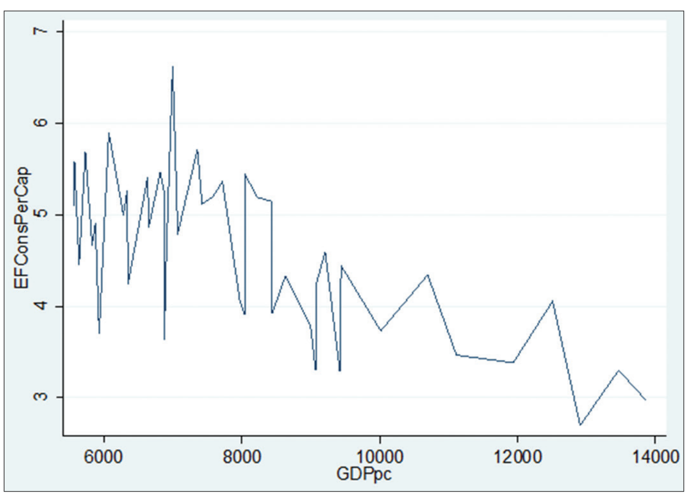
1: *Significant at 10% level, **significant at 5% level, ***significant at 1% level. 2: In KPSS test: H0 Series is I(0), for the other tests: H0 Series is I(1). 3: The Akaike Information Criterion (AIC) is used to choose the optimal lag length (which is presented in square brackets)

Table 4: ARDL bound test of cointegration

Estimated equation	$lnEF_t = f\left(lnGDP_t, lnGDP_t^2, lnFDI_t, lnEnergy_t\right)$	
Lag length	(1, 4, 2, 4, 3)	
F-statistic	5.487**	
t-statistic	−5.223***	
	Critical values for F-statistic (T=40)	
Significance level (%)	Lower bound, I(0)	Upper bound, I(1)
10	2.561	4.026
5	3.147	4.844
1	4.589	6.840
	Critical values for t-statistic (T=40)	
Significant level	Lower bound, I(0)	Upper bound, I(1)
10	−2.429	−3.548
5	−2.812	−4.001
1	−3.602	−4.932

*Significant at 10% level, **significant at 5% level, ***significant at 1% level

Figure 2: Relationship between EF and GDP



coefficients are statistically significant. The estimated coefficients of *lnGDPpc* and *lnGDPpc²* indicate that *GDPpc* and *GDPpc* squared have a negative and positive effect on Ecological Footprint, respectively. This finding suggests the existence of an inverted U relationship between EF and *GDPpc*, validating the EKC hypothesis for Uruguay over the period of analysis. This result is in line with other single country studies using EF such as Mrabet and Alsamara (2017), Hassan et al. (2018), and Sarkodie and Strezov (2018).

The estimated coefficient for *lnFDI* suggests that if FDI increases by 1%, then EF will decrease by 0.15%. This result points to the positive effect of FDI on the environment. Our results confirm the Pollution Halo hypothesis and are in line with Merican et al. (2007) findings for Indonesia, Al-Mulali and Tang (2013), Mert and Bölük (2016), Paramati et al. (2017) for developing G20 countries, and Solarin and Al-Mulali (2018) for France, Japan, and Korea.

Regarding energy, we find that a 1% increase in energy usage per capita increases EF by 1.48%, evidencing the negative effect energy consumption has on the environment. Such a negative impact of energy consumption on EF has also been found by Al-Mulali and Ozturk (2015), Al-Mulali et al. (2015b), Charfeddine and Mrabet (2017), Destek and Sarkodie (2019), Imamoglu (2018), and Sarkodie (2018).

The lower panel of Table 5 shows the short-run estimations. In this case, GDPpc is not found to have a significant impact on EF, indicating that the EKC is not verified in the short-run. Our finding suggests, as pointed out by Ali et al. (2017) who test the EKC hypothesis for CO_2 emissions in Malaysia, that the EKC is a long-run phenomenon.

Moreover, *FDI* and *Energy* have the opposite effect on EF in the short-run to the one they have in the long-run which is similar to

Table 5: Error correction model

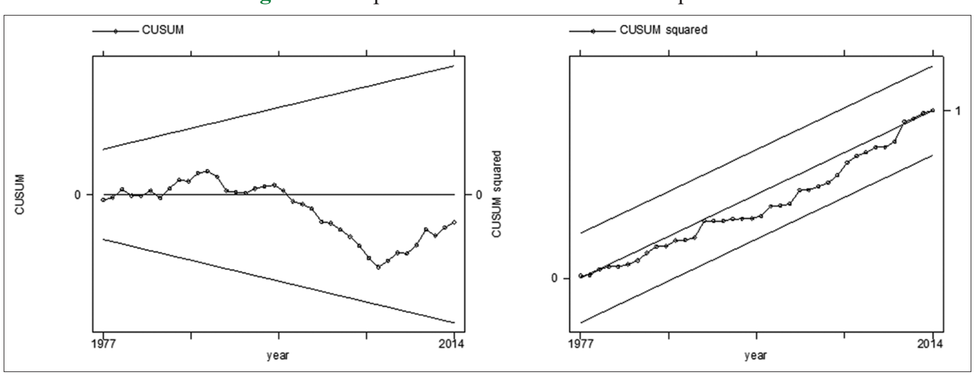
Long-run relationship			
Variable	**Coefficient**	**t-statistic**	**P-value**
lnGPDpc	47.9390	3.68	0.001
$lnGPDpc^2$	−2.6999	−3.72	0.001
lnFDI	−0.1511	−3.04	0.006
lnEnergy	1.4765	3.29	0.003
Short-run relationship			
Variable	**Coefficient**	**t-statistic**	**P-value**
ΔlnGPDpc	−28.4179	−0.71	0.483
$\Delta lnGPDpc^2$	1.6919	0.76	0.456
ΔlnFDI	0.1110	2.13	0.045
ΔlnEnergy	−1.1290	−2.07	0.051
ECT (−1)	−0.9864	−5.22	0.000
Diagnostic tests		**Statistics (P-value)**	
R^2		0.7611	
Adjusted R^2		0.5562	
Durbin-Watson		2.0784	
ARCH LM		0.957 (0.3279)	
Breusch-Godfrey LM		0.349 (0.5544)	
White’s		40.00 (0.4256)	
Ramsey RESET		2.22 (0.1214)	
Shapiro-Wilk W		0.9707 (0.3777)	
Skewness/Kurtosis		0.9767 (0.4192)	

Table 6: Granger causality tests

Dependent variable	Short-run Granger causality - Wald statistics				Long-run Granger causality
	ΔlnEF	ΔlnGPDpc	ΔlnFDI	ΔlnEnergy	ECT_{t-1}
ΔlnEF		6.72***	4.00**	6.56**	−0.549***
ΔlnGPDp	0.83		0.34	2.59	−0.101**
ΔlnFDI	0.00	0.00		0.02	−0.767
ΔlnEnergy	4.56**	8.68***	0.02		−0.182**

*Significant at 10% level, **significant at 5% level, ***significant at 1% level

Figure 3: Graphs of CUSUM and CUSUM squared



Source: Each graph includes a 95% confidence band.

the relationship between financial development and CO_2 emissions found by Ali et al. (2017).

The error correction term, *ECT (−1)*, shows the rate at which the short-run disequilibrium is eliminated in a year. In our case, almost 99% of the disequilibrium in 1 year is eliminated the following year.

The diagnostic tests suggest that no serial correlation and autoregressive conditional or White heteroscedasticity are present, that the error term is normally distributed, and the model is well specified (no important variables are omitted). The stability of the coefficients is tested with the CUSUM and CUSUM squared shown in Figure 3. The graphs indicate that the coefficients are stable since they fall within the confidence band (dotted lines in the figures).

Each graph includes a 95% confidence band

The presence of a long-run relationship between the variables may indicate the existence of either bidirectional or unidirectional causality relationships between the variables under study. The Granger causality test in the context of a vector error correction (VEC) model is applied to detect the causality between the variables. We present the results in Table 6. When the coefficient of ECT_{t-1} is significant it means that there exists a causal relationship in the long-run running from the independent to the dependent variable. This is the case for the EF, GDPpc, and energy consumption. Therefore, we observe bidirectional causality relationships between EF and GDPpc, between EF and energy usage, and between GDPpc and energy usage. Moreover, the results imply the presence of unidirectional causality from FDI to EF in the long run.

In the short run, we observe unidirectional causality running from GDPpc and FDI towards EF, and from GDPpc towards energy consumption. Moreover, we find a bidirectional causality between energy consumption and EF.

6. CONCLUSIONS AND POLICY RECOMMENDATIONS

In this paper, using data for the time span 1971-2014, we investigated the relationship between the EF and income per capita, FDI, and energy usage per capita in Uruguay. Our methodology consisted of several steps. The first step was to study the level of integration of the series used in the analysis. As unit root tests, we used the augmented Dickey-Fuller, Dickey-Fuller Generalized Least Squares, and KPSS tests. The second step was to investigate if the variables were cointegrated. To that end, we used the Autoregressive Distributed Lag bounds test. The long-run and short-run effects of economic growth, foreign direct investment, and energy consumption on Ecological Footprint were analyzed through an Error Correction Model. Finally, we applied the Granger causality test in the context of a VEC model to detect the causality between the variables under study.

We validate the EKC Hypothesis in Uruguay, i.e. there exists an inverse U-shaped relationship between the EF and GDPpc. Moreover, the turning point of the relationship is at $7171 indicating that Uruguay is already located at the downward sloping portion of the curve, i.e. an increase in income per capita would lead to a further decrease in the EF.

Moreover, we found that there is a positive nexus between energy use per capita and the EF while an increase in foreign direct investments leads to a decrease in the EF of Uruguay.

Although a higher energy usage per capita increases the environmental degradation, simply decreasing energy usage certainly cannot be recommended as this would lead to a decline in the economic growth reflected by a bi-directional positive causality between energy use per capita and economic growth. Rather, the implementation of policies leading to more energy saving and more efficient use of energy are recommended. In particular, increasing public awareness about the usage of more energy efficient devices, providing information about how energy can be used in a more efficient way, and providing incentives to households for the usage of more efficient devices and means of transportation would help. Moreover, investing in cleaner and more efficient technologies is also recommended.

There has been an increment in the share of renewables in the energy consumption of Uruguay (from 44.8% in 2001 to 58% in 2015; WDI, 2019). This increase may also be one of the explanations of why the EKC hypothesis is verified in Uruguay (Al-Mulali, 2015a). Policies that would facilitate an increment in the share of renewables in energy consumption would help to reduce environmental degradation. Uruguay is producing a very large share of its electricity from renewable sources, 88.6% in 2015 (WDI, 2019), mainly from hydroelectric sources. This share, however, has been decreasing from 95% in 2001, due to an increase in the demand for electricity coupled with the fact that the country has almost exhausted the possibility of constructing new major power stations for hydroelectric sources (CEPAL, 2010). Therefore, given the potential of the country, increasing the share of other modern renewable energy sources such as wind and solar is recommended.

The negative relationship between FDI and environmental degradation suggests that policies attracting more FDI, especially into the renewable energy and cleaner technology sectors, would help to reduce environmental degradation.

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