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Economic Growth, Renewable Energy and Methane Emissions: Is there an Enviromental Kuznets Curve in Austria?

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ABSTRACT

This paper provides empirical evidence of environmental Kuznets curve for Austria. Using the autoregressive distributed lag method, the relationship between methane emissions (CH_4), gross domestic product, electricity production from renewable energy sources (excluding hydro) and trade openness is analyzed; the variables are used in per capita terms except for trade openness. In the long term, cointegration analysis indicates that the variables have a distribution inverted U-shaped and Granger causality test shows unidirectional causality between CH_4 and the variables involved. Since CH_4 is the second highest greenhouse gas emitted in the world, political and academic implications of this study are relevant to include in planning decisions that aim to mitigate climate change.

Keywords: Methane Emissions, Renewable Energy, Trade Openness
JEL Classifications: C32, O52, Q43, Q54

1. INTRODUCTION

The increase of the greenhouse gases (GHG) concentration in the atmosphere accelerates the global warming. In 2014, the concentration of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) in the atmosphere was 397.7 ppm[1], 1833 ppb[2] and 325.9 ppb respectively (World Meteorological Organization, 2015). On average, the anthropogenic emissions grew 1.3% annual from 1970 to 2000 and 2.2% annual from 2000 to 2010 (IPCC, 2014). The environmental and political interest to mitigate the global warming's effects is growing; the policy makers of many countries have as challenge generate economic growth without compromise the future generations' quality of life.

The environmental KC (EKC) hypothesis describes the relationship between environmental degradation and economic growth with an inverted U-shaped distribution. The hypothesis holds that as a country's economy grows, the emissions of polluting gasses rise until a turning point in which the trend inverts. Grossman and Krueger (1991) were the first to analyze the EKC hypothesis. It is worth say that the EKC hypothesis is an extension of the KC hypothesis, which describes the relationship between income inequality and economic growth (Kuznets, 1955).

The EKC literature is wide and the environmental degradation indicator most used is the carbon dioxide (CO_2). Some studies have included trade openness and urbanization at the analysis the relationship between CO_2 and economic growth, as in the studies for Pakistan and Tunisia (Ahmed and Long, 2012; Farhani and Ozturk, 2015). Others studies have disaggregated the total energy consumption into oil, gas, electricity and coal; these showed the

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[1] ppm: Parts per million (10^6).
[2] ppb: Parts per billion (10^9).

hypothesis EKC for each of these energies (Saboori and Sulaiman, 2013; Ashfaq et al., 2016). On the other hand, some studies have shown that the EKC hypothesis does not hold for some countries, as is the case of Cambodia and Latin America and the Caribbean (Ozturk and Al-Mulali, 2015; Pablo-Romero and De Jesús, 2016).

After carbon dioxide, methane is the second GHG most emitted, its potential to catch heat in the atmosphere is 23 times higher than CO_2 (IPCC, 2001), and so an increase of this gas requires more attention. The EKC literature that it used CH_4 emissions as environmental degradation indicator is limited; the Section 3 cites studies that they have analyzed several GHG including CH_4.

Austria ranks the fifth place between the European Union (EU) countries with greatest renewable energy consumption, although it is not between the ten greatest GHG emitters in EU, it ranks twelfth place in this ranking (European Environmental Agency, EEA Greenhouse Gas - Data Viewer, 2014). This study aims to confirm the existence of EKC for Austria using as Environmental degradation indicator the methane emissions, the interest for analyze the fulfillment of the hypothesis is greater, due to the economic factors this country.

This study applies the autoregressive distributed lag (ARDL) method to demonstrate EKC evidence in Austria. The per capita gross domestic product (GDP), trade openness and electricity production from renewable energy sources (excluding hydroelectric) are relevant variables; at long run, the cointegration analysis supports the hypothesis with an inverted U-shaped distribution, the Granger causality test shows unidirectional causality between the methane emissions and the variables of interest.

This paper is structured as follows: Section 2 describes energy context of Austria; Section 3 shows the literary review; Section 4 describes data and econometric model; Section 5 explains the methodology; Section 6 presents the results and Section 7 concludes.

2. AUSTRIAN CONTEXT

Austria is a country of central Europe which has a population of approximately 8.57 million (WDI, 2015), is part of the EU since 1995 and the Organization for Economic Cooperation and Development (OECD) since 1961. It is ranked no. 23 in the ranking of 188 countries with a high human development index (UNDP, 2015) and about 6.2% of its population lives below the poverty line (Index Mundi, 2012).

Austria is one of the countries with the highest consumption of renewable energy in the EU, exceeded only by Norway, Sweden, Finland and Latvia, with 34% of consumption in 2012; higher than the average of EU and OECD, with a consumption of 14 and 11% respectively (Figure 1) (World Bank, 2012).

In fact, clean energy provides about 70% of electricity consumption in this country (Eurostat, 2014), its main sources are: Hydropower and biomass (European Renewable Energy Council, 2011); becoming the fourth largest producer of hydropower in Europe, making up 60% of total clean energy produced in the region, while biomass production makes up 16.4% of the renewable energy consumed in the country (ABA, 2015).

On the other hand, although Austria is not among the ten largest producers of GHG emissions from the EU (ranked twelfth place), the 83.80% of GHG emitted in this country correspond to carbon dioxide (CO_2), followed by methane (CH_4) with 6.96% and nitrogen oxide with 6.88% (United Nations, 2012); where 77.6% of the energy sector causes most of GHG emissions, 20.8% is caused by the transport sector and 10.2% by the agriculture sector (European Environmental Agency, 2014).

CH_4 emissions have been declining at an average rate of 0.27% between 1970 and 2012, while CO_2 emissions have been increasing at an average rate of 0.86% over the same period (Figure 2) (World Bank, 2012).

In addition, The 2010 National Renewable Energy Action Plan has projected that by 2020, the proportion of renewable energy consumption over final energy consumption will reach 34% (European Environmental Agency, 2014).

3. LITERATURE REVIEW

There have been several studies about EKC which have analyzed the relationship between pollution levels and per capita income resulting in a negative quadratic function. Pollution levels are measured through indicators, among which are: Levels of air quality such as CO_2, methane and nitrous oxide, indicators of water quality and quantity of heavy metals or toxic metals per cubic meter and other indicators as urban sanitation, energy use, amount of municipal solid waste, among others (Zambrano-Monserrate et al., 2016). However, the most commonly used indicators are those that measure levels of air quality, such as methane, which is the dependent variable in this study.

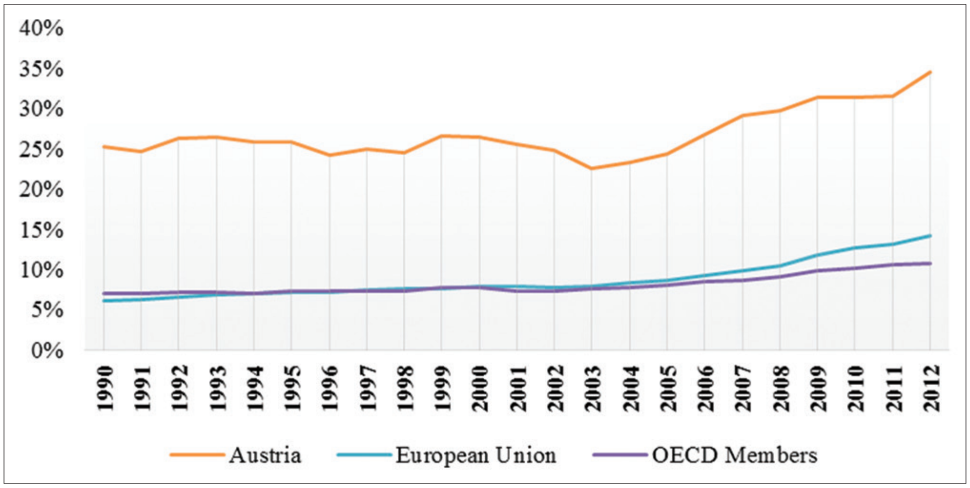
3.1. Electricity Production from Renewable Energy Sources

Molinuevo-Salces et al. (2016) have expressed in their study the need to create alternative sources of energy to prevent methane (CH_4) continue to increase globally, since it is a greenhouse gas usually caused by anaerobic processes that in excessive amounts can cause environmental problems. Biomass could be an alternative, since it is the second renewable energy source most commonly used in Austria, however, the handling of large amounts of waste from agriculture and agro-industry, end up harming the environment even when being generated clean energy (in the case of biofuel). Chun-Min and Shu-Yii (2015) instead, have examined alternative ways of creating biomass through its transformation to biowaste, so that the development of this energy does not generate negative effects that undermine the purpose of such production.

3.2. Economic Growth

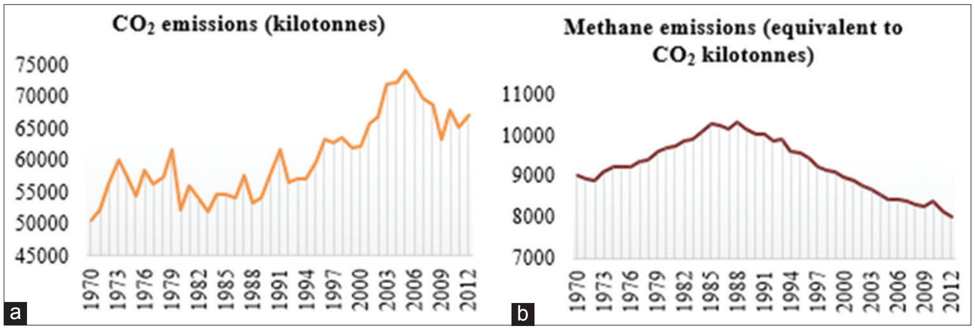
The economic growth indicator most used is the GDP, since it indicates the productive capacity of a country in monetary terms in a defined period. Worldwide, the economic and demographic growth are main causes of CO_2 emissions, the annual anthropogenic

Figure 1: Renewable energy consumption (% of total energy consumption)



Source: World Bank

Figure 2: (a and b) CO_2 and CH_4 emissions from Austria



Source: World Bank

emissions of GHG increased around 10 $GtCO_2$-eq[3] from 2000 to 2010. This increase derives from the following sectors: Energy (47%), industry (30%), transport (11%) and buildings 3% (IPCC, 2014).

As result of the activities related the development of a country, the environmental contamination is an inherent effect on the economic system. However, the EKC hypothesis affirms that the GHG emissions increase together to economic growth until to a turning point in which the relationship inverts. Some studies with panel data that they have used as indicators the CO_2 emissions and per capita GDP are Coondoo and Dinda (2002), Acaravci and Ozturk (2010), Kasman and Duman (2015), Apergis and Ozturk (2015).

Given that the anthropogenic activities are link to the methane emissions sources, the economic growth increases the environmental degradation. There are studies that they have used several GHG and they confirmed the existence the EKC for CH_4 emissions, as for 22 OECD countries, this study made a separate analysis for CO_2, CH_4 and N_2O; the results showed a quadratic relationship among GHG and GDP at long run (Cho et al., 2014). Additionally, a study showed that the expected relationship does not comply for CO_2, N_2O and PFC[4]; only to case of CH_4 showed the quadratic relationship with the interest variables (Kubicová, 2014). Fujii and Managi (2015) tried to prove the hypothesis for individual and total industrial sector of 39 countries, with the total data of industry the study showed an inverted U-shaped distribution for CO_2 and N-shaped for CH_4, N_2O, NH_3[5]y NMVOC[6].

3.3. Trade Openness

The effect of trade openness on the climate change is attributed to the impact of GHG emissions, which is caused by the increase the production and energy consumption (WTO, 2016). For Portugal, Shahbaz et al. (2015) showed positive relationship among trade openness and CO_2 emissions. However, Ali and Abdullah (2015) found that the trade openness causes a decrease the environmental degradation in Malaysia.

Given that the activities derivate of production are link to the methane emissions sources (production and transport of coal, nature gas, and oil), an increase in the trade volume tend to rise the CH_4 emissions. Such as the EKC empiric evidence about the relationship among the CO_2 emissions and trade openness, this study shows the relationship between CH_4 emissions and trade openness for Austria.

4. ECONOMETRIC METHOD AND DATA

Following the recent empirical literature such as Ahmad et al. (2016), Onafowora and Owoye (2014) y Zambrano et al. (2016),

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[3] $GtCO_2$-eq: Gigatonnes (1 Gt = 1012 kg = 1 Pg) CO_2-equivalent.

[4] PFC: Perfluorocarbons.

[5] NH_3: Ammonia.

[6] NMVOC: Non-metallic volatile organic compounds.

the log-linear quadratic form is employed to analyze the effects of economic growth and an indicator of environmental contamination. We proposed to analyze the relationship between methane emissions, economic growth and electricity production from renewable energy sources (excluding hydroelectric). In this context Equation 1 determines emissions of methane (CH_4) in Austria depend on the variables mentioned above in per capita terms.

$$CH_{4_t} = f(GDP_t, GDP_t^2, ENER_t, TR_t) \tag{1}$$

We also include trade openness as a controlling variable; we consider all variables in their logarithmic form. The logarithms can interpret elasticities directly and shows more efficient results as compared to the functional form of a simple linear model (Ehrlich, 1996). Then, we apply the following model for empirical analysis presented in Austria:

$$\begin{aligned} LCH_{4t} &= \beta_0 + \beta_{GDP} LGDP_t + \beta_{GDP^2} LGDP_t^2 \\ &\quad + \beta_{ENER} LENER_t + \beta_{TR} LTR_t + \mu_t \end{aligned} \tag{2}$$

Where CH_4 indicates methane emissions per capita (measured in kt of CO_2 equivalents), GDP represents GDP per capita (in constant 2005 US Dollar) this variable is used to represent the income per capita as economic growth. ENER is the production of electricity from renewable energy sources (excluding hydroelectric, measured in kWh per capita), TR represents trade openness (sum of exports and imports as a percentage of GDP) and μ is the residual or error term. All the data mentioned was obtained from the World Development Indicators (World Bank) for Austria over the period between 1970 and 2012.

The EKC hypothesis suggests that the coefficient β_{GDP} is expected to be positive, and $\beta_{GDP}{}^2$ negative. A $\beta_{GDP}>0$ suggests that the higher the economic growth, the higher the CH_4 emissions for Austria. A $\beta_{GDP}{}^2<0$ indicates that there is a turning point where the relation between economic growth and CH_4 is inverted, and a higher economic growth derives into a decrease in CH_4 emissions for Austria, this turning point is calculated as:

$$T^* = \exp\left({}^{-\beta_{GDP}}\!/_{2\beta_{GDP^2}} \right)$$

However, if $\beta_{GDP}{}^2$ is statistically non-significant, methane emissions increase or decrease monotonously regard economic growth. For the expected sign of electricity production based on renewable energy (Arent et al., 2014) and (Lacheheb et al., 2015) argue that the change of primary energy to renewable energy will reduce emissions of GHG proportionally, so it is expected that $\beta_{ENER}<0$; however according to (Jebli et al., 2016) the sign could be positive if the level of renewable energy is low and the technology used for production is polluting. The expected sign of $\beta_{TR}<0$ because as that environmental protection laws in the country are more rigorous, firms will stop producing goods that generate pollution and these will be imported from countries that have more flexible laws (Shahbaz et al., 2015). However, (Halicioglu, 2009) and (affirms that the sign can be positive depending on the behavior of the country's industries, i.e., if these are contaminants in the production of their goods.

5. METHODOLOGY

5.1. Cointegration Method

For cointegration analysis, we use the ARDL bounds testing approach developed by Pesaran et al. (2001). The ARDL examines the long-run relationships between CH_4 emissions, economic growth, electricity production from renewable energy sources (excluding hydroelectric) and trade openness in Austria.

The main advantage of this method is that it allows to estimate the long-term relationship regardless of the order of integration for each series and has better properties for short sample data sets as the ARDL model allows regressors to be stationary in different levels (Haug, 2002); unlike other traditional methods like the residues based approach (Engle and Granger, 1987), the maximum likelihood method (Johansen and Juselius, 1990) and the modified ordinary least squares (Phillips and Hansen, 1990).

The ARDL methodology can be made in two steps. First, the ARDL unrestricted model is estimated, as we show in Equation 3:

$$\begin{aligned} \Delta LCH_{4t} &= \beta_0 + \beta_{GDP} LGDP_{t-1} + \beta_{GDP^2} LGDP^2{}_{t-1} \\ &\quad + \beta_{ENER} LENER_{t-1} + \beta_{TR} LTR_{t-1} + \sum\nolimits_{i=1}^{p} \beta_{1i} \Delta LCH_{4t-i} \\ &\quad + \sum\nolimits_{j=0}^{q} \beta_{2j} \Delta LGDP_{t-j} + \sum\nolimits_{k=0}^{m} \beta_{3k} \Delta LGDP^2{}_{t-k} \\ &\quad + \sum\nolimits_{l=0}^{n} \beta_{4l} \Delta LENER_{t-1} + \sum\nolimits_{r=0}^{o} \beta_{5r} \Delta TR_{t-r} + \mu_t \end{aligned} \tag{3}$$

The null hypothesis representing no cointegration is $\beta_{CH4}=\beta_{PIB}=\beta_{PIB}{}^2=\beta_{ENER}=\beta_{AC}=0$, and the alternative hypothesis representing cointegration is that at least one β_k is not zero ($\beta_k \neq 0$). The calculated F-statistics value is compared with lower critical bound and higher critical bounds from Narayan (2005) for small sample higher than thirty values. If the F-statistic calculated is greater than the critical value, then there is statistical evidence of cointegration in the relationship of the variables. If the F-statistic calculated is less than the critical value we cannot reject the null hypothesis of no cointegration. The selection of the optimal lag is analyzed with Schwarz information criterion (SIC). If there is cointegration, the next step is to define the relationship of short and long run. For the short run, the ARDL model includes error correction term (ECT_{t-1}), as we show in Equation 4:

$$\begin{aligned} \Delta LCH_{4t} &= \alpha_0 + \sum\nolimits_{i=1}^{p} \alpha_{1i} LCH_{4t-i} + \sum\nolimits_{j=0}^{q} \alpha_{2j} \Delta LGDP_{t-j} \\ &\quad + \sum\nolimits_{k=0}^{m} \alpha_{3k} \Delta LGDP^2{}_{t-k} + \sum\nolimits_{l=0}^{n} \alpha_{4l} \Delta LENER_{t-1} \\ &\quad + \sum\nolimits_{r=0}^{o} \alpha_{5r} \Delta TR_{t-r} + \lambda ECT_{t-1} + \varepsilon_t \end{aligned} \tag{4}$$

The ECT coefficient (γ) in Equation 4 is the adjustment parameter and represents the speed of the model achieves a long run equilibrium. This coefficient is expected to be negative and statistically significant.

Finally, additional diagnostics tests must be applied to verify correct specification of the model, such as the Jarque-Bera normality test, Breusch-Godfrey serial correlation Lagrange multiplier test, autoregressive conditional heteroskedasticity

(ARCH) test, Ramsey RESET test and stability tests (CUSUM/CUSUMSQ).

5.2. Granger Causality

The ARDL model does not determine the direction of causality among the variables; thus it is necessary to specify a vector error correction model (VECM) to analyze cointegrated variables. We test Granger-causality following two-step procedure of Engle and Granger (1987). First, we estimated the residuals of the long run model (Equation 2) as a proxy of the error correction term. The last step consists on estimating the VECM as we show in Equation 5.

$$\begin{bmatrix} \Delta LCH_{4t} \\ \Delta LGDP_t \\ \Delta LGDP^2_t \\ \Delta LENER_t \\ \Delta LTR_t \end{bmatrix} = \begin{bmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \\ \phi_4 \\ \phi_5 \end{bmatrix} + \begin{bmatrix} \phi_{11,1} & \phi_{12,1} & \phi_{13,1} & \phi_{14,1} & \phi_{15,1} \\ \phi_{21,1} & \phi_{22,1} & \phi_{23,1} & \phi_{24,1} & \phi_{25,1} \\ \phi_{31,1} & \phi_{32,1} & \phi_{33,1} & \phi_{34,1} & \phi_{35,1} \\ \phi_{41,1} & \phi_{42,1} & \phi_{43,1} & \phi_{44,1} & \phi_{45,1} \\ \phi_{51,1} & \phi_{52,1} & \phi_{53,1} & \phi_{54,1} & \phi_{55,1} \end{bmatrix}$$

$$+ \begin{bmatrix} \Delta LCH_{4t-1} \\ \Delta LGDP_{t-1} \\ \Delta LGDP^2_{t-1} \\ \Delta LENER_{t-1} \\ \Delta LTR_{t-1} \end{bmatrix} + \begin{bmatrix} \phi_{11,k} & \phi_{12,k} & \phi_{13,k} & \phi_{14,k} & \phi_{15,k} \\ \phi_{21,k} & \phi_{22,k} & \phi_{23,k} & \phi_{24,k} & \phi_{25,k} \\ \phi_{31,k} & \phi_{32,k} & \phi_{33,k} & \phi_{34,k} & \phi_{35,k} \\ \phi_{41,k} & \phi_{42,k} & \phi_{43,k} & \phi_{44,k} & \phi_{45,k} \\ \phi_{51,k} & \phi_{52,k} & \phi_{53,k} & \phi_{54,k} & \phi_{55,k} \end{bmatrix}$$

$$+ \begin{bmatrix} LCH_{4t-k} \\ LGDP_{t-1} \\ LGDP^2_{t-1} \\ LENER_{t-1} \\ LTR_{t-1} \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \varphi_{1t} \\ \varphi_{2t} \\ \varphi_{3t} \\ \varphi_{4t} \\ \varphi_{5t} \end{bmatrix} \quad (5)$$

Where the vector of φ_t is white noise, and the ECT_{t-1} is the error correction term lagged one period. The vector of δ_k are interpreted as the speed of adjustment of the dependent variable to deviations from the long-run equilibrium.

6. EMPIRICAL RESULTS

6.1. Stationarity Test

An assumption of ARDL methodology is that all variables are to a maximum order of integration I (1). Therefore, it is important to prove that all variables are of order I (0) or I (1), the Dickey-Fuller applies to prove that the variables are as integrated of order I (1) at most. The results of Table 1 suggest that all variables have unit root level, but they are stationary in first difference, i.e., I (1).

6.2. Cointegration Test

The next step, it is necessary to use the ARDL bound test to verify the long-term relationship between the variables. The test results are sensitive to the choice of the order of lags. To do this, SIC was used to choose the maximum number for each variable lag. Table 2 presents a set of combinations including the chosen model (12202).

Based on the best model selected, it is verified that the variables are cointegrated; in that sense, the F-statistic must be calculated using the Wald test using the ARDL unrestricted model; as indicated by Equation 2. Table 2 shows the results where the F-statistic calculated is 4,873, this value is compared with the critical values proposed by (Narayan, 2005) in the case II without trend and intercept restricted. The lower limit of the table is 3.967, it shows that the F-statistic calculated is greater than the critical value, 1% significance; therefore, we can say that the variables are cointegrated of order I (0). Furthermore, we have conducted diagnostic tests in order to verify the model specification such as Breusch-Godfrey serial correlation test, Ramsey RESET test, Jarque-Bera normality test, ARCH test and CUSUM and CUSUMSQ stability parameters test; as shown in Figure 3 and Table 3.

Table 1: ADF test for stationarity of variables (with intercept and trend)

Variable	Ho: No unit root	
Level	**T-statistics**	**Critical value**
LCH_4	−0.955864	−3.191277
LGDP	−2.477680	−3.191277
$LGDP^2$	−2.449504	−3.191277
LENER	−2.267249	−3.191277
LTR	−2.921473	−3.188259
1^{ST} difference		
ΔLCH_4	−3.935030	−3.526609**
ΔLGDP	−5.688785	−4.205004*
Δ $LGDP^2$	−5.683818	−4.205004*
ΔLENER	−7.449998	−3.600987*[1]
ΔLTR	−6.266287	−4.192337*

*,**1%, 5%, 10% level of significance; McKinnon (1996) one side values, [1]The variable ΔLENER the test it was conducted only with intercept. ADF: Augmented Dickey–Fuller

Table 2: Lag Length selection criteria

Lag combination	SIC	F-statistics	P value
(2,2,2,2,2)	−5.25	2.79	0.05
(2,2,2,0,2)	−5.41	3.83	0.01
(2,0,0,0,1)	−5.42	2.67	0.04
(1,2,2,1,2)	−5.43	4.38	0.01
(1,2,2,0,2)	−5.51	4.88*	0.00
(1,2,0,0,2)	−5.47	4.25	0.01
(1,1,2,0,2)	−5.41	3.69	0.01
(1,0,0,0,1)	−5.49	3.43	0.01
(1,0,0,0,0)	−5.45	3.00	0.03

SIC: Schwarz information criterion, *1% significance level

Table 3: Cointegration tests results

Bounds testing to cointegration	
Estimated equation	$CH_{4t}=f(GDP_t, GDP_t^2, ENER_t, TR_t)$
Optimal lag structure	(1,2,2,0,2)
F-statistics	−5.507932*
Diagnostic check (F-statistics)	
R^2	0.784458
Adjusted-R^2	0.634515
F-statistics	5.231728
J-B normality test	2.178478
Breusch-Godfrey LM test	1.250538
ARCH LM test	0.187158
Ramsey RESET	0.183571
CUSUM	Stable
CUSUMSQ	Stable

*Significant at 1%

6.3. Estimated Long-run Model

The long-run estimates are reported in Table 4. The variables are significant at 1%, except LTR. However, the model presents problems of serial correlation; for this reason, standard errors have been estimated using a robust method proposed by Newey and West (1987). This ensures the consistence of the estimated standard errors in the presence of both autocorrelation and heteroscedasticity. In addition, Figure 4 shows the CUSUM and CUSUMSQ tests; the results suggest that the parameters are stable. The sign of the linear term of GDP is positive while the sign of the nonlinear term is negative and both are significant to 1%. The results suggest the inverted U relationship between economic growth and emissions of methane, therefore, can be interpreted as an increase of 1% in per capita GDP will increase methane emissions by 27% approximately, ceteris paribus.

The coefficient of production of electricity from renewable sources (ENER) is positive and significant. Therefore, a 1% increase in electricity production from renewable energy raises methane emissions by 0.03%, ceteris paribus.

The long-term elasticity between methane emissions and trade openness (TR) is 0.11%. The results indicate that a 1% increase in international trade in Austria, CH_4 emissions will increase by 0.11%, ceteris paribus.

6.4. Estimated Short-run Model

Short-term estimates are reported in Table 5, the sign of GDP and GDP^2 is negative and positive, respectively; and both are significant at 10%, which shows the relationship in the U form. In other words, in the short term, methane emissions decrease with economic growth to a turning point where CH_4 emissions start to increase as the economy grows Austria.

The short-run elasticity between methane emissions and electricity production from renewable sources is 0.02%. The results suggest that an increase of 1% of electricity production from renewable sources, leads CH_4 emissions increase by 0.02%, ceteris paribus.

The coefficient of trade openness is negative and significant. Interpreting this, in the short term, an increase of 1% of

Table 4: Long-run estimates

Dependent variable		LCH_{4t}	
Independent variable	**Coefficient**	**t-statistic**	**P value**
C	−143.1546	−24.97230	0.0000
$LGDP_t$	27.04480	24.17739	0.0000
$LGDP_t^2$	−1.134559	−24.10028	0.0000
$LENER_t$	0.036369	4.289262	0.0001
LTR_t	0.114790	2.428046	0.0203
$ECM(-1)_t$	0.622266	6.058135	0.0000
Diagnostic check (F-statistics)			
R^2	0.981411		
Akaike info criterion	−5.376563		
Schwarz criterion	−5.128324		
F-statistics	380.1208		
P (F-statistics)	0.000000		
J-B Normality test	0.447724		
Breusch-Godfrey LM test	0.298760		
ARCH LM test	0.033792		
Ramsey RESET test	0.165591		
CUSUM	Stable		
CUSUMSQ	Stable		

Figure 3: (a and b) Chart of CUSUM and CUSUMQ test (cointegration model). The straight lines represent critical bounds at 5% significance level

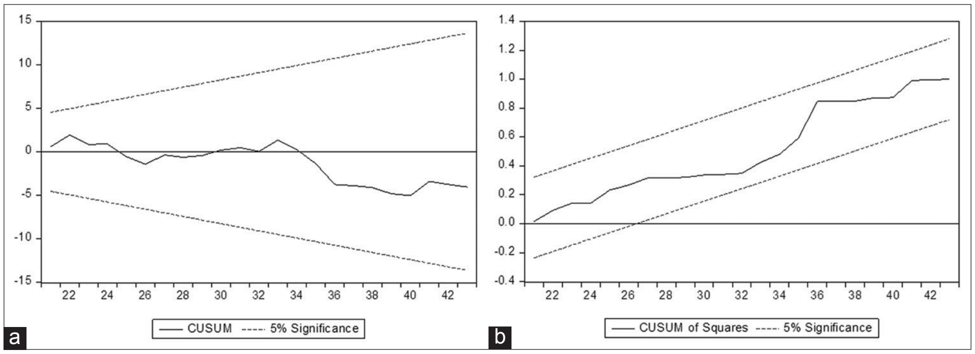
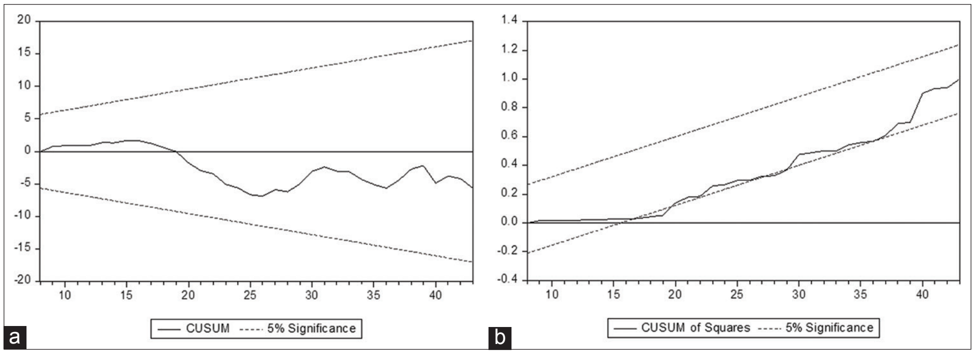


Figure 4: (a and b) Chart of CUSUM and CUSUMQ test (long-run model). The straight lines represent critical bounds at 5% significance level



international trade in Austria, CH_4 emissions decreased by 0.08%, ceteris paribus.

The ECM is negative and significant at 1%, confirming the existence of cointegration equation; this means that deviations from equilibrium methane are corrected by 29.5% within one year.

Finally, and CUSUMSQ CUSUM test are shown in Figure 5, and concludes that the parameters are stable.

6.5. Granger-causality Test

Table 6 shows the results of granger-causality test. There exist unidirectional long-run causal relationship from GDP, GDP^2, ENER and TR to CH_4 emissions. Furthermore, there exist a unidirectional relationship from GDP, GDP^2 and TR to ENER. This results confirms the hypothesis of the existence of EKC in the case of Austria. This can be seen in Table 7, where is reported the variance decomposition and indicates that a change in the standard deviation of GDP represents a shock of 19.63% in CH_4 emissions. Since this shock is greater if it were otherwise (19.63% > 11.17%), then there is a unidirectional Granger causality from GDP to CH_4. In addition, a change of one standard deviation of GDP^2 represents a shock of 5.01% in CH_4 emissions. Since this shock is less than if it were otherwise (5.01% < 11.70%), then there is a unidirectional Granger causality CH_4 to GDP_2.

7. CONCLUSIONS AND POLICY IMPLICATIONS

The aim of this paper was to analyze the existence of EKC theory in the economy of Austria. The ARDL developed by (Pesaran et al., 2001) was chosen to analyze a short and long term relationship between methane emissions, economic growth, electricity production from renewable sources and trade openness; in the period 1970-2012. The positive and negative sign of the coefficients of GDP and GDP^2 respectively justify an inverted U-shape relationship in the long run between economic growth and methane emissions.

The results of short-term model show that the sign of GDP and GDP^2 is negative and positive respectively, so that a U-shaped relationship exists in the short term, but in the long run there is evidence to say that the hypothesis of EKC is fulfilled as it can corroborate the Granger causality analysis that economic growth causes methane emissions. This confirms that in the long-run, there will come a point where as increase the country's economic growth, CH_4 emissions will decrease.

This turning point is $-\beta_{PIB}/2\beta_{PIB^2} \cong \$150,037.38$, however this point is out of the sample observed in this period, which means that it has not yet reached the tipping point. In other words, the variable GDP can be used to predict methane emissions.

Table 5: Short-run estimates

Dependent variable		LCH_{4t}	
Independent variable	**Coefficient**	**t-statistic**	**P value**
C	−0.014502	−3.117367	0.0043
$LGDP_t$	−6.718845	−1.925569	0.0648
$LGDP_t^2$	0.346605	1.999569	0.0557
$LENER_t$	0.021577	1.911612	0.0666
LTR_t	−0.076265	−1.640143	0.1126
$ECM(-1)_t$	−0.299803	−2.968740	0.0062
Diagnostic check (F-statistics)			
R^2	0.665276		
Akaike info criterion	−5.985557		
Schwarz criterion	−5.436671		
F-statistics	4.471962		
P (F-statistics)	0.000598		
J-B Normality test	3.084575		
Breusch-Godfrey LM test	1.512420		
ARCH LM test	0.412071		
Ramsey RESET test	0.046917		
CUSUM	Stable		
CUSUMSQ	Stable		

Table 6: Granger causality test results

Null Hypothesis	F-statistic	P value
$LGDP_t$ does not Granger cause LCH_{4t}	8.58376	0.0009
LCH_{4t} does not Granger cause $LGDP_t$	0.61088	0.5484
$LGDP_{2t}$ does not Granger cause LCH_{4t}	8.65189	0.0009
LCH_{4t} does not Granger cause $LGDP^2_t$	0.53134	0.5924
$LENER_t$ does not Granger cause LCH_{4t}	4.88941	0.0132
LCH_{4t} does not Granger cause $LENER_t$	0.08318	0.9204
LTR_t does not Granger cause LCH_{4t}	4.74437	0.0148
LCH_{4t} does not Granger cause LTR_t	1.56144	0.2237
LCH_{4t} does not Granger cause ECT_{t-1}	1.19157	0.3158
ECT_{t-1} does not Granger cause LCH_{4t}	0.74046	0.4842
$LGDP_t$ does not Granger cause $LENER_t$	2.50304	0.0960
$LGDP^2_t$ does not Granger cause $LENER_t$	2.47433	0.0984
LTR_t does not Granger cause $LENER_t$	2.57493	0.0901

Figure 5: (a and b) Chart of CUSUM and CUSUMQ test (short-run model). The straight lines represent critical bounds at 5% significance level

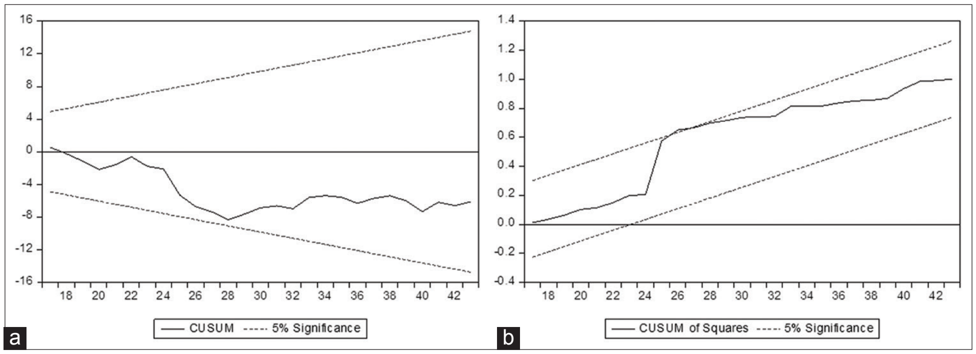


Table 7: Variance decomposition method

Variance decomposition for LCH_4						
Period	**S.E.**	**LCH_4**	**LGDP**	**$LGDP^2$**	**LENER**	**LTR**
1	0.011158	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.015761	87.12997	7.861043	4.183515	0.229145	0.596326
3	0.019768	78.01848	11.08383	5.487368	0.200262	5.210062
4	0.023978	70.75512	12.70953	5.482093	0.176912	10.87635
5	0.028023	65.24140	14.21545	5.479678	0.130007	14.93346
6	0.031667	60.87497	15.61484	5.473151	0.115667	17.92137
7	0.034900	57.47102	16.77783	5.394118	0.150570	20.20645
8	0.037741	54.78457	17.80138	5.276930	0.251721	21.88540
9	0.040215	52.60170	18.74811	5.147396	0.427754	23.07504
10	0.042362	50.78130	19.63391	5.011252	0.678288	23.89525
Variance decomposition for LGDP						
1	0.017561	0.016360	99.98364	0.000000	0.000000	0.000000
2	0.023533	1.494567	95.42470	0.900649	1.431965	0.748117
3	0.027629	3.374458	91.08872	0.657574	2.355035	2.524215
4	0.031016	6.005787	85.14913	0.530314	3.247574	5.067199
5	0.034135	8.114136	79.87961	0.448502	4.129691	7.428062
6	0.036952	9.539788	75.66197	0.386336	4.995243	9.416668
7	0.039470	10.40998	72.40458	0.340439	5.873981	10.97102
8	0.041699	10.89927	69.91189	0.306253	6.794768	12.08782
9	0.043658	11.12309	68.01081	0.280766	7.762170	12.82317
10	0.045377	11.17267	66.54179	0.262112	8.764556	13.25887
Variance decomposition for $LGDP^2$						
1	0.361491	0.031725	99.91403	0.052982	0.001262	0.000000
2	0.486342	1.521348	95.13384	1.129961	1.513238	0.701609
3	0.570877	3.491128	90.77655	0.838298	2.472086	2.421943
4	0.640995	6.225376	84.80555	0.666969	3.382322	4.919782
5	0.705789	8.430778	79.48444	0.554481	4.263785	7.266511
6	0.764576	9.930847	75.21555	0.473351	5.116410	9.263839
7	0.817332	10.85629	71.91353	0.414465	5.974649	10.84107
8	0.864178	11.38519	69.38560	0.370862	6.870780	11.98757
9	0.905495	11.63671	67.45883	0.338014	7.811641	12.75480
10	0.941839	11.70505	65.97291	0.313137	8.787350	13.22155
Variance decomposition for LENER						
1	0.157950	1.480312	0.088179	0.000000	98.43151	0.000000
2	0.205322	0.924400	0.140665	0.001157	90.60398	8.329802
3	0.238528	2.093546	0.167064	0.001678	86.18605	11.55166
4	0.259272	2.277103	0.174532	0.057312	84.01028	13.48077
5	0.274795	2.198829	0.356382	0.088752	82.59154	14.76450
6	0.286079	2.062997	0.709455	0.100617	81.64527	15.48167
7	0.294192	1.951932	1.216271	0.108107	81.05796	15.66573
8	0.300349	1.935320	1.877262	0.110669	80.58191	15.49484
9	0.305492	2.052636	2.700043	0.108885	80.01159	15.12684
10	0.310209	2.307622	3.660102	0.105636	79.24005	14.68659
Variance decomposition for LTR						
1	0.050232	1.986951	37.04279	9.198558	4.842736	46.92897
2	0.058994	6.072011	34.35959	9.150746	4.283939	46.13371
3	0.059900	5.901667	34.53348	8.889409	4.211828	46.46362
4	0.060827	7.043560	34.73665	8.621855	4.241136	45.35680
5	0.062067	8.714006	35.20909	8.321766	4.190759	43.56438
6	0.063625	10.64398	35.43106	7.985029	4.039766	41.90016
7	0.065607	12.70740	35.32326	7.592838	3.846138	40.53036
8	0.067848	14.54850	35.12077	7.211204	3.665525	39.45399
9	0.070148	16.00077	34.93512	6.868996	3.531697	38.66342
10	0.072381	17.08934	34.79518	6.567190	3.463910	38.08438

The coefficient of electricity production from renewable sources (excluding hydropower) in the long term is positive and statistically significant (0.03%). In the short-term, it remains the same sign and statistically significant (0.02%). Furthermore, the results of the Granger causality indicate that exists long-run relationship from production of electricity from renewable sources to methane emissions.

The coefficient of trade openness in the long term is positive and statistically significant (0.11%). However, in the short-term sign is negative and statistically significant (0.07%) in this context, we interpret that in the short term, trade openness in Austria decreased methane emissions. Furthermore, the results of the Granger causality demonstrate that exists long-run relationship from trade openness to methane emissions.

For policymakers in Austria, the results imply the importance of economic growth to control methane emissions. Despite the fact that there is no evidence to justify a permanent positive relationship between economic growth and environmental degradation in no way be interpreted these results favor the liberal conception of "economic growth" (Zambrano et al., 2016). In addition, for renewable sources contribute to the reduction of methane emissions, it's necessary to design policies where firms have incentives to use clean production processes that do not cause adverse effects in the environment.

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