# Impact of green transport technologies on $CO_2$ emissions from the transportation sector

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## Abstract

This study explores the impact of climate change mitigation technologies related to transportation on $CO_2$ emission from 15 European Union countries using an ARDL model. The results from the study take time between 1995 and 2014 and they show that climate change mitigation technologies from transport don't have an impact on carbon emissions and they are not the main asset to reduce them. However, this reduction has its basis on the part of renewable energy in total energy consumption (solar, hydroelectric, geothermal, biomass, and wind) and countries' wealth. For example in France, the employment of energy efficiency on transports and the development of biofuels have shown a reduction in transport emissions (INSEE, 2017). Besides, people's behavior is evolving (supposing more environmentally friendly due to an increase in their richness), thus, adding value as another factor in the diminution of carbon emissions from transport compared to the massive use of green technologies in this sector.

**Keywords:** $CO_2$ emissions, UE-15, Green innovation, Transport sector, ARDL, EKC curve.

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## I. INTRODUCTION

After years of resource exploitation, thinking they were infinite and without caring about the environmental side effects, we are now seeing the side effects of our bad management of the environment. Indeed, half of the human-induced carbon emissions since 1750 occurred in the past 40 years (OECD, 2016). Different conferences and congress about climate change as COP21 were a place where countries accorded some decisions to mitigate and reduce carbon dioxide emissions, which is the principal gas in the global warming issue. One of the principal topics was the agreement between the countries to maintain the margin of global warming below 2 °C (UN FCC, 2015). Although the achievement of this objective is increasingly compromised (UNEP, 2017), it is the responsibility of public decision-makers to implement public policies that favor the transition to a more low-carbon economy that uses natural resources efficiently and promotes social inclusion.

The most important greenhouse gas is $CO_2$ which represents almost 76% of anthropic emission of greenhouse gases (GIEC, 2014). Also, the $CO_2$ emissions come from different sectors where transportation is the producer of almost 25% of the total $CO_2$ emissions (WHO 2016). In EU-18 countries, from a study driven on 2017, they were distributed in the following way, 53,2% for private vehicles, 19,3% for commercial vehicles, 21% for heavyweights, 1,3% for two wheels vehicles and 5,2% for non-road vehicles (air, rail, river and maritime and others) (Commissariat général au DD, 2020).

Regarding these environmental issues, some scholars agreed on one of the solutions which are to develop environmental innovation (Aghion, P; Hemous, D; Veugelers, 2009), or mostly known as eco-innovation. According to (Kemp and Pearson, 2007).

*Eco-innovation is the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives.*

Looking into the different solutions proposed to mitigate the $CO_2$ emissions in these sectors, we find several studies showing the impact of green technologies as a solution against global warming and carbon emission. In consequence, different papers have been published to evaluate the correlation between these technological advances and the $CO_2$ emissions(Akram et al. 2020; Cheng et al. 2019; Cheng, Ren, and Wang 2019; P. Wang et al. 2013; Shahbaz et al. 2020; Gu et al. 2019; Yii and Geetha 2017; Georgatzi, Stamboulis, and Vetsikas 2020; Su and Moaniba 2017).

However, research in this area is still limited and far from reaching a consensus. Indeed, some studies (D. Acemoglu, G. Gancia, 2012; Jaffe, Newell, & Stavins, 2002) admit that the effect of green technologies on CO2 emissions (positive or negative) depends on the level of wealth of the countries and the periodicity of the impact (short term vs long term). The existence of short-term rebound effects[1] (Braungardt, Elsland, & Eichhammer, 2016) is particularly noticeable in general-purpose technologies such as fuels (Font Vivanco, Kemp, & van der Voet, 2016; Herring & Sorrell, 2009; Steve Sorrell, 2007) and this contributes to the debate about the effect of green technologies on $CO_2$ emissions. Similarly, the findings of the Italy-wide study (Weina, Gilli, Mazzanti, & Nicolli, 2016) point to the extent to which environmental innovation increases environmental productivity but does not reduce $CO_2$ emissions.

Among these papers we don't found a specific study taking the effect of green innovation on carbon emission from transportation, having a gap in the literature. This gap is where we will focus our empirical work. Furthermore, few empirical studies examine the influence of environmental patents on carbon emissions by applying econometric methods (Cheng, Ren, Wang, & Yan, 2019). This study aims to analyze at the European Union level[2] the effect of green transport innovation on $CO_2$ emissions from the transportation sector.

The central hypothesis is based on a working paper made by Mongo (2019) which studied at the European Union level the effect of green technologies on $CO_2$ emissions from an autoregressive distributed lag model (ARDL). The study suggests that in the long-term period there will be a reduction of $CO_2$ emissions but an increase in the short-term period based on the rebound effect (Font et al, 2016; Herring et al, 2009), assuming that this effect is mostly caused by energetic and transport sectors. This empirical work will study the previous hypothesis for the transport sector presenting firstly a literature review, followed by an explanation of the data and the methodology which allow us to estimate at the European Union level the effect of green transport innovations on carbon emissions. Finally, the conclusions and policy recommendations are presented in the last section.

## II. LITERATURE REVIEW

Since the pioneering work of (G. M. Grossman & Krueger, 1991) who postulated the hypothesis of the Kuznets Environmental Curve (KEC)[3] a growing body of work on the determinants of $CO_2$ emissions has developed in recent decades (Lean & Smyth, 2010; Perman & Stern, 2003; Rashid Gill, Viswanathan, & Hassan, 2018; Stokey, 1998; Yang, Sun, Wang, & Li, 2015). In this context, the degree of international openness (G. M. Grossman & Krueger, 1991; Hu, Xie, Fang, & Zhang, 2018; Piaggio, Padilla, & Román, 2017), the rate of urbanization (Wang, Su, Li, & Ponce, 2019), the structure of the productive apparatus (Du, Li, & Yan, 2019), the level of wealth (Dinda & Coondoo, 2006; Esteve & Tamarit, 2012; Kuznet, 1955), innovation technological (Yii & Geetha, 2017) and finally the energy structure (Cheng, Ren, Wang, & Shi, 2018) are the main variables usually used to explain $CO_2$ emissions. This study aims to explore some of these variables.

Carbon emissions are the focus on several projects as they constitute an estimated 75% of global GHG emissions (Ganda 2019). In some empirical works the variable studied was the general carbon emission, showing the impacts of different factors as the energy efficiency, renewable energy production, public-private

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[1] An illustration of the direct rebound effect is given by (Herring & Sorrell, 2009): For example, since fuel-efficient vehicles make travel cheaper, consumers may choose to drive longer and/or more often, thus offsetting some of the energy savings achieved. Similarly, if a plant uses energy more efficiently, it becomes more profitable, which encourages new investment and increased production. This is called the direct rebound effect.

[2] EU-15 in 2004

[3] Which suggests an inverted U-shaped relationship between the pollution indicators of environment and per capita income

investments in energy, energy mitigation technologies and energy consumption in the $CO_2$ emissions (Akram et al. 2020; Cheng et al. 2019; Cheng, Ren, and Wang 2019; P. Wang et al. 2013; Shahbaz et al. 2020; Gu et al. 2019; Yii and Geetha 2017). Many of these works have studied the relationship between the EKC curve and the $CO_2$ emissions. Georgatzi, Stamboulis, and Vetsikas. (2020) define transportation as part of a socio-technical system in transition to sustainability, where changes come from the development of new technologies and new business models. Their study is focused on the analysis of the impact of different factors that can contribute to a low carbon economy in the transport sector. Finally, they conclude remarking that the strict regulation policies and the increase in their strictness are a factor which will decrease the $CO_2$ emissions. We found a lack in the number of papers that analyze the impact of transport sector innovation on $CO_2$ emissions from transportation, and who have done it, concentrate the study on developing countries. For this reason, we will complete the literature evaluating the effect of climate change mitigation technologies on transportation on carbon dioxide emissions from transportation suggesting that an increasing number of patents will decrease carbon emissions.

It exists a consensus on the impact of energy consumption from renewable energy sources, showing that they tend to decrease the carbon emissions in Europe (Dogan and Seker, 2016; Van den Bergh, Delarue, and D'haeseleer, 2013). However, it could exist a lack of the results regarding different time sets as we will do in this work for the short and the long-term. The study driven by Wang *et al.* (2013) found that energy consumption structure has a significant input on carbon emissions. Its recommendation around energy is based on the development of renewable low-carbon energy sources to decrease $CO_2$ emissions. In the transport sector, we suppose the same behavior considering the significative increase of biofuels' consumption (IFP 2019). From the literature, we will consider that renewable energy consumption will decrease the $CO_2$ emissions in the short and long-term.

Then, the GDP has been included in several works as the main value for carbon emission reduction. Besides, some works talk about the EKC (Kuznet, S, 1995; Grossman and Krueger, 1991) who shows that the developing countries will pollute until they arrive at a certain developed point where the economic power allows mitigating and reducing the pollution, showing a U-shaped inverted curve (Acheampong 2018; Akram et al. 2020; Cheng et al. 2019; Gu et al. 2019; Hashmi and Alam 2019; Khan et al. 2020; Su and Moaniba 2017; W. Wang et al. 2020; S. Wang, Zeng, and Liu 2019; P. Wang et al. 2013). From their study, Akram *et al.* *(*2020) shown a positive impact between carbon emissions and the GDP per capita. Furthermore, they confirm the EKC hypothesis for 66 developing countries showing a decrease in $CO_2$ emissions for the long-term. We suppose as European countries are developed and have a wealth of power, they will start to decrease their pollution thanks to the economic resources. Many works include the GDP per capita as an important factor but the conclusions are given for a general scenario. Besides, the papers whereas transportation is the main topic, the GDP is not included as a variable. We will include the GDP per capita in our empirical analysis to fill this gap and verify if our hypothesis of a GDP per capita increases the $CO_2$ emissions in the short-term but decreases in the long-term is valid.

The urban population plays an important role as some scholars found this variable tends to increase carbon emissions making them increase. Wang *et al.* (2013) suggest that this increase is due to higher economic development and consumption level which rise GHG emissions. For Akram *et al.* (2020), there is an existent link between the urbanization level and the environmental issues as carbon dioxide emissions.

Technological innovation is one of the main bases of our work as some scholars as Georgatzi, Stamboulis, and Vetsikas. (2020) recognize the new technologies as an asset to reach the transition to the sustainability of the transportation sector. Their results present a positive impact from transport innovation technologies on carbon dioxide emissions; indeed, technological innovations have a significant factor for the emissions' reduction (Georgatzi et al, 2020).

## III. DATA AND METHODOLOGY

### A. *DATA*

The period chosen for this empirical study is located between 1995 and 2014, for the 14 principal countries of the European Union. It considers the EU-15 without Portugal due to a lack of the database.

The variable which will be the reference for our study is carbon dioxide emissions and it is defined as the number of tons of $CO_2$ emitted to the atmosphere, per one million units of current USD. The carbon emissions are divided into 5 sectors which are Electricity, Transportation, Industry, Commercial & Residential, and Agriculture. Being more specific, we will focus only on emissions from the transportation sector having as a reference to the empirical study driven by Georgatzi, Stamboulis, and Vetsikas, 2020. The data is provided by the database of the OECD. The different papers which have been evaluated confirm us that the reference variable, carbon emissions from the transport sector, will allow us to fill a gap knowing that not so many studies had focused their results on this factor. Furthermore, as recommended in the literature review, factors as the economic aspects and the technological innovation in the studied field will be included to complete the lack of literature.

Renewable energy consumption is defined as the percentage of total energy consumption by the Word Bank WDI. We will consider that renewable energy consumption will decrease the $CO_2$ emissions in the short and long-term.

The GDP per capita is defined as the sum of gross value added by all resident producers in the economy plus any product taxes and many other subsidies not included in the value of the products (World Bank, 2020), and its expressed in current US$.

The urban population is defined as the part of the population living in urban areas and it is represented by the percentage of the total population (World Bank, 2020).

The climate change mitigation technologies related to transportation represent the number of inventions developed by the country's inventor, independent of the jurisdiction where patent protection is sought (OECD, 2020). The variables, sources, and literature supports are shown in Table.1.

***Table 1.***
*Variable definitions*

| Variable | Definition | Units of measurement | Source | Related studies |
|---|---|---|---|---|
| $TCO_2$ | CO2 emissions from transport | Tonnes per one million units of the current USD GDP | OECD | (Georgatzi, Stamboulis, and Vetsikas, 2020); (Khan et al. 2020); (Su and Moaniba 2017) |
| ENR | Renewable energy consumption | % of total energy consumption | WB | (Akram et al. 2020; Allard et al. 2018; Cheng et al. 2019; Dong, Sun, and Dong 2018; Cheng, Ren, and Wang 2019; Paramati, Mo, and Gupta 2017) |
| GDP | Gross domestic product per capita | Dollar (current values) | WB | (Acheampong 2018; Akram et al. 2020; Cheng et al. 2019; Gu et al. 2019; Hashmi and Alam 2019; Khan et al. 2020; Su and Moaniba 2017; W. Wang et al. 2020; S. Wang, Zeng, and Liu 2019; P. Wang et al. 2013) |
| URB | Urban population | % of the total population | WB | (P. Wang et al. 2013; Akram et al. 2020; Hashmi and Alam 2019; Kahouli 2018) |
| PAT | Climate change mitigation technologies related to transportation | Number of patents | OECD | (Georgatzi, Stamboulis, and Vetsikas, 2020); (Cheng, Ren, and Wang 2019); (Cheng et al. 2019) |

## B. *ARDL MODEL*

The model presents the following structure.

$$TCO2 = f(PAT, GDP, URB, ENR) \quad \mathbf{(1)}$$

Where $CO_2$ emissions in the transport sector represent TCO2 emissions and it is a function of four variables, including green patents in transport (PAT), GDP per capita (GDP), the rate of urbanization (URB), and finally the consumption of ENR (ENR). The statistics of the model and the variables are presented in Table.2 in the annexes section.

The Eq. (1) can be rewritten in a logarithmic form with a time series and panel form specification as follows:

$$LogTCO2_{it} = \alpha_0 + \alpha_1 LogTCO2_{it} + \alpha_2 LogPAT_{it} + \alpha_3 LogGDP_{it} + \alpha_4 LogURB_{it} + \alpha_5 LogENR_{it} + \varepsilon_{it} \tag{2}$$

Where the subscript i (i = 1, ..., N) denotes the country i in our sample, N being equal to 14. t (t = 1, ..., T) indicates the period. Our panel has 14 countries and 20 years, so it has more years (T) than countries (N). The variables are not stationary at I (0) but they are probably at I (1). This means that the model is dynamic and suppose an inclusion of lagged dependent variables as a regressor. In this case, a panel ARDL model as proposed by (Pesaran & Smith, 1995) is more appropriate. According to these authors, the advantages over other dynamic model methods, such as fixed effects, instrumental variables, or GMM estimators proposed by (Anderson & Hsiao, 1981, 1982, Arellano, 1989, Arellano & Bover, 1995) is that these methods can produce inconsistent estimates of the average value of the parameters unless the coefficients are identical across countries. On the other hand, the ARDL model is relatively more efficient in the case of small and finite sample data sizes.

The model estimated has a form of an ARDL (p, q, q….q) model:

$$\Delta LogTCO2_{it} = \Phi_i \left( LogTCO2_{i,t-1} - \beta'_i X_{i,t} \right) + \sum_{j=1}^{p-1} \alpha_{ij}\, \Delta LogTCO2_{i,t-j} + \sum_{j=0}^{q-1} \delta'_{ij}\, \Delta X_{i,t-j} + \mu_i + \varepsilon_{it} \tag{3}$$

Where, $X$ is the vector of explanatory variables; $\Phi_i$ is the group-specific speed of adjustment coefficient (expected that $\Phi_i < 0$); $\beta'_i$ are our vector of interest, which measures the long-run impact of the explanatory variables on the CO2 emissions; ECT = $[LogTCO2_{i,t-1} - \beta'_i X_{i,t}]$ is the error correction term; $\alpha_{ij}$, $\delta'_{ij}$ are the short-run dynamic coefficients; $p$ and $q$ are optimal lag orders. $\mu_i$ is the constant.

The next section will present first, the stationarity tests of the variables, then the existence of cointegration, and finally, the panel estimator.

## C. UNIT ROOT TEST

To test for unit roots (or stationary), we use the tests of (Dickey & Fuller, 2006), (Andrew Levin, Lin, & Chu, 2002) and (Im, Pesaran, & Shin, 2003). In these tests, the null hypothesis is that all the panels contain a unit root and alternative null is not true. Table (2) presents the results of the unit root tests.

*Table 2.*
*Unit roots*

| | ADF | | LLC | | IPS | |
|---|---|---|---|---|---|---|
| Variabl | Level | 1st.Dif. | Level | 1st.Dif. | Level | 1st.Dif. |
| logTCO | 4,64147 | 76,4387*** | 0,76655 | -8,29034*** | 3,68830 | -5,24991*** |
| logPAT | 23,8909 | 119,282*** | -2,26587*** | -7,12819*** | 0,31678 | -8,13025*** |
| logGDP | 8,38456 | 77,6201*** | -0,80000 | -7,98573*** | 2,39876 | -5,32952*** |
| logENR | 6,52812 | 70,4741*** | 1,61693 | -4,13805*** | 5,57407 | -4,65619*** |
| logURB | 14,5801 | 47,5301*** | -2,41053*** | -3,48606*** | 3,50671 | -1,52803** |

**Notes:**
*** significance at 1% level.
** significance at 5% level.
* significance at 10% level.

From the obtained results from the previous tests, we found that our data is integrated on I (0) and I (1). More precisely, in level, the results of the unit root test (LLC) obtained have shown that logPAT and logURB are stationary in I (0). The unit root test of ADF, LLC, and IPS on the first difference showed that the variables are integrated on I (1). The variables statistics are significant on the 1% level. This allows us to reject the null hypotheses (H0), considering these variables are stationary on the first difference. Besides, The used variables in the model are a mix of I (1) and I (0), which is necessary to estimate an ARDL model.

## D. COINTEGRATION TEST

We tested the data with (Pedroni, 1999, 2004) tests. The approach is based on examining residues. If the variables are co-integrated, the residuals must be stationary. The null hypothesis proposes the absence of co-integration, in which the residues $\varepsilon_{it}$ will be I (1). The result of the co-integration test of Pedroni is shown in table 3.

*Table 3.*
*Cointegration test*

*Pedroni Residual Cointegration test*

**Alternative hypothesis: common AR coefs. (within-dimension)**

| | Statistic | Prob | Weighted Statistic | Prob |
|---|---|---|---|---|
| Panel v-Statistic | -0,028727 | 0,5115 | -0,820736 | 0,7941 |
| Panel rho-Statistic | 1,881334 | 0,9700 | 2,159370 | 0,9846 |
| Panel PP-Statistic | -0,050853 | 0,4797 | -0,925984 | 0,1772 |
| Panel ADF-Statistic | -0,752215 | 0,2260 | -3,707328*** | 0,0001 |

**Alternative hypothesis: individual AR coefs. (between-dimension)**

| | Statistic | Prob |
|---|---|---|
| Group rho-Statistic | 3,730474 | 0,9999 |
| Group PP-Statistic | -3,231574*** | 0,0006 |
| Group ADF-Statistic | -2,332796*** | 0,0098 |

**Notes:**
*** significance at p<0,01
** significance at p<0,05
* significance at p<0,1

Fisher's and KAO's tests were used to confirm these results. We have identified a cointegration between the variables for Panel ADF-Statistics and Group PP-Statistics, and Group ADF-statistics. The outcomes are confirmed with Fishers' and KAO's tests. The results of the cointegration test confirm the existence of a cointegration relationship between the series under study, which gives the possibility of estimating the long-term effects of LogPAT, LogGDP, LogURB, and LogENR on LogTCO2.

## IV. RESULTS AND DISCUSSION

The ARDL model gives the following results. For the long-term period, we have identified that technological innovation related to transportation does not affect $CO_2$ emissions. The GDP has a negative effect on carbon emissions. We obtained that an increase of 1% on GDP will decrease in 0,92% of the $CO_2$ emissions. While the energy consumption of energy from renewable sources has also a negative effect on carbon dioxide emissions. However, urbanization has a very important impact on carbon emissions showing an increase of 47,13% of CO2 emissions for a growth of 1% of the urban population.

For the short-term we could see that the GDP and the ENR tend to decrease the $CO_2$ emissions in the short-term, being the GDP factor the biggest with an increase of 0,82% of CO2 against 0,12% for the ENR, each of this for an increase of 1% on them. We have also found that technological innovation on transportation doesn't have an impact on carbon emissions in the short-term.

A recapitulative results table is presented in the Annexes section (Table.5) showing the results for the short and long-term.

## V. CONCLUSIONS AND POLICY RECOMMENDATIONS

After the results, we have concluded that the analysis of the carbon emissions from transportation is more complex than it seems. We have discovered that the technological innovation on transportation doesn't represent an impact on CO2 emissions which doesn't confirm our main hypothesis. Technological innovation in transportation doesn't increase or decrease carbon emissions which let us know that technological innovation is not the only solution to decrease carbon emissions in the transport sector. This result doesn’t allow us to confirm the rebound effect theory proposed by Mongo (2019) which supposed that this effect could be caused by the green innovation from the transport sector. However, in the best case, the technological innovation on transportation doesn't impact carbon emission in the short-term but, for a worst scenario, it could be the source of rebound effect as it was explained in Mongo, 2019.

Only renewable energy consumption and increasing GDP tend to decrease $CO_2$ emissions from transportation. Whilst the urban population increases the carbon emission, mostly in the short-term. The obtained results from the ENR confirms our hypothesis and the supports we had from the literature (Akram et al. 2020; Allard et al. 2018; Cheng et al. 2019; Dong, Sun, and Dong 2018; Cheng, Ren, and Wang 2019; Paramati, Mo, and Gupta 2017). Besides, from the transportation sector, these results have coherence with the stylized facts we have described below above where there are some goals stipulated for several EU counties as the development of new green energy sources and the diversification of the energy mix with new renewable sources of energy to carry out the goals of COP21. Besides, we can zoom in France where the development of transports' energy efficiency and biofuels incorporation have significantly reduced carbon emissions (INSEE 2017; IFP 2019).

For the GDP, we confirm our hypothesis which says that a richness increasing tends to improve the environment quality based on people's behavior. Thanks to wealth, people will change the way of consuming, thus helping our impact on the environment. We find that not just technological innovation is important to decrease the CO2 emissions but there are other clues maybe stronger which could be the economic and social renovations coming from the development of countries' wealth.

The results obtained for the urban population confirm our hypothesis which is also based on some scholars' works (P. Wang et al. 2013; Akram et al. 2020; Hashmi and Alam 2019; Kahouli 2018), it has a positive impact for the short and the long-term.

In conclusion, technological innovation in transportation doesn't show up as a main or important variable to study the dynamic of $CO_2$ emissions. However, the GDP, renewable energy consumption, and urban population have an impact on carbon emissions. Finally, one variable dismissed in this study was the infrastructure investments for road, railway, and inland waterway due to its high correlation with other variables. We consider this variable could have also an impact on carbon emission dynamics increasing the $CO_2$ emissions from transportation.

We suggest governments increase the development of renewable sources of energy as they have shown a negative impact on carbon emissions. Knowing that energetic mixed vary among countries we could merge the EU ambitions as the goals from Germany or Belgium from 2030-2050. Furthermore, governments should continue encouraging the consumption and production of biofuels as they are having a good impact on $CO_2$ emissions. These encouragements could be supported by subventions to support the producers or even policies to encourage their consumption and penalizing those who use the more pollutant.

Even if they were some limits present during the development of this empirical study as the lack of data, the statistical interference between variables to choose the right model, the discard of some variables due to their pertinence, and finally the global analysis knowing that it could exist a specificity by country. The results show sight of the dynamics and the work to do.

We consider this work can be completed by doing an analysis using the infrastructure investment or even studying the countries on an independent way to find different perspectives which could be shown in the current work. Finally, the number of environmental policies could be studied to see their relation to carbon emissions.

## ANNEXES

***Table 4.***
*Statistics of variables*

| | LOGTCO2 | LOGPAT | LOGGDP | LOGENR | LOGURB |
|---|---|---|---|---|---|
| Mean | 1,842119 | 1,515535 | 4,547336 | 0,890905 | 1,887571 |
| Median | 1,83442 | 1,520153 | 4,546569 | 0,909539 | 1,894468 |
| Maximum | 2,383456 | 3,549994 | 5,074903 | 1,698523 | 1,990485 |
| Minimum | 1,515874 | -0,30103 | 4,080733 | -0,069118 | 1,75675 |
| Std. Dev | 0,178516 | 0,851744 | 0,184146 | 0,45829 | 0,058787 |
| Skewness | 0,54605 | 0,172404 | 0,117397 | -0,15233 | -0,587866 |
| Kurtosis | 3,030276 | 2,544866 | 3,43452 | 2,157933 | 2,823092 |
| Jarque-Bera | 13,92531 | 3,803802 | 2,845914 | 9,355433 | 16,4925 |
| Probability | 0,000947 | 0,149285 | 0,241 | 0,0093 | 0,000262 |
| Sum | 515,7932 | 424,3497 | 1273,254 | 249,4534 | 528,52 |
| Sum Sq. Dev | 8,89119 | 202,4057 | 9,46084 | 58,5982 | 0,964202 |
| Observations | 280 | 280 | 280 | 280 | 280 |

***Table 5.***
*Johansen cointegration test*

*Johansen Fisher Panel Cointegration test*

**Unrestricted Cointegration Rank Test (Trace and Maximum Eigenvalue)**

| Hypothesized No. of CE(s) | Fisher Stat* (from trace test) | Prob. | Fisher Stat* (from max-eigen test) | Prob. |
|---|---|---|---|---|
| None | 571.2 | 0.0000 | 352.9 | 0.0000 |
| At most 1 | 321.8 | 0.0000 | 172.5 | 0.0000 |
| At most 2 | 181.8 | 0.0000 | 97.14 | 0.0000 |
| At most 3 | 117.9 | 0.0000 | 84.67 | 0.0000 |
| At most 4 | 85.08 | 0.0000 | 85.08 | 0.0000 |

***Table 6.***
*KAO Cointegration test*

*KAO Residual Cointegration test*

| | t-Statistic | Prob. |
|---|---|---|
| ADF | 5.6610 | 0.0000 |

***Table 5.***
*Model Results*

| Variable | Coeff. | t-Statistic | P-value |
|---|---|---|---|
| Long Run Equation | | | |
| logPAT | -0,018027 | -0,319779 | 0,7495 |
| logGDP | -0,923561$^{***}$ | -10,40218 | 0,0000 |
| logENR | -0,21677$^{***}$ | -2,870518 | 0,0046 |
| logURB | 47,13126 | 1,693635 | 0,092 |
| Short Run Equation | | | |
| *ECT* | *-0,030472* | *-0,801245* | *0,4240* |
| logPAT | 0,002462 | 0,328700 | 0,7427 |
| logGDP | -0,821431$^{***}$ | -17,89986 | 0,0000 |
| logENR | 0,126289$^{***}$ | -20,462736 | 0,0147 |
| logURB | 3,942589 | 0,364439 | 0,7159 |
| *Constant* | *-2,714343* | *-0,818926* | *0,4138* |

**Notes:**
*** significance at 1% level.
** significance at 5% level.
* significance at 10% level.

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