

# The Estimation of Environmental Kuznets Curve (EKC) in EU: Do Information Communication Technology (ICT) and E-Commerce Consumption Matter?

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**Abstract:** Environmental Kuznets Curve (EKC) explained the relationship between economic growth and environmental degradation in inverted U-shaped curve but the validity of EKC hypothesis can be affected by additional variable and area of study. This study focused on 27 European Union (EU) countries with consideration of two new variables; information communication technology (ICT) and E-commerce consumption which recently had rapid growth in EU. The data was panel data during 2008–2014 and mainly was from world indicator index (WDI). Fixed effect (FE) and Random effect (RE) approach was considered and FE was selected by Hausman test to analyze the panel data in this study. The results showed that EKC hypothesis was not valid if ICT and e-commerce consumption were not estimated. When, considering ICT and e-commerce consumption as additional variables in EKC model, however, the Environmental Kuznets Curve hypothesis was supported for the selected panels in EU region. Moreover, ICT and E-commerce consumption decreases environmental degradation in the model.

**Keywords:** E-commerce consumption, Economic Growth, Environmental Degradation, Environmental Kuznets Curve (EKC), European Union (EU), Information Communication Technology (ICT).

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## 1. INTRODUCTION

Information communication technology (ICT) is the importance factor which profoundly affecting all businesses. The emergence of the ICT has empowered multiple aspects of companies' operations. The interacting and conducting business activities gain more efficiently through ICT faction such as digital networks of both internal and external communication. For country level, Impact of Information communication technology (ICT) have been studied by many scholars. Previous studies have strong evidence that ICT is an important factor of economic growth [1],[2],[3]. Apart from the effects on economic, the effects on environment cannot be ignored. Climate change is the biggest environmental problem of the world. It is disrupting national economies and affecting people lives. For mitigating the impacts of climate change, decreasing greenhouse gases is important challenge for all countries as well as The European Union (EU). EU is a unique economic and political union between 27 EU countries. EU countries are under the 1997 Kyoto Protocol, which is committed to reduce CO<sub>2</sub> emissions. Moreover, EU is setting target that by 2050, EU will have net zero greenhouse gas emissions [4]. Achieving this goal is required to consider both economic and environment. From a theoretical perspective, scholars used the Environmental Kuznets Curve (EKC) to explain the environmental-economic nexus. EKC hypothesis estimate the relationship between a pollutant which is an environmental factor such as carbon dioxide (CO<sub>2</sub>) and economic factor such as GDP. It shows that economic factor and environmental factor can be reflected through an inverted U-shaped curve. However, the validity of EKC hypothesis has given conflicting results. Previous research stated that contradictory results of the EKC hypothesis in each study related to two reasons [5]. The first reason is related to area of study such as a group of countries or a single country. In a single country such as France [6], Turkey [7], China [8], Thailand [9], (and Pakistan [10] are support EKC hypothesis. While, some countries reject the validity of the hypothesis

such as United State [11] Iran [12] and Vietnam [13]. In the case of group countries, the EKC hypothesis is confirmed by the studies of Farhani et al., [14] for 10 Middle East and North African (MENA) countries. While, the study of West African countries does not support the EKC hypothesis [15]. Other reason that makes conflicting results in validity of ECK hypothesis is the difference of additional variable integrated. Energy consumption is frequently added in EKC hypothesis. Since, the higher of economic growth is required the bigger of energy consumption [7] and energy consumption has positive effects on greenhouse gases [6]. In addition, there are other additional variables which are added in EKC hypothesis such as population [15], financial [16] and trade [13].

However, Information communication technology (ICT) has fairly added in EKC hypothesis. There is a study in Tunisia considered ICT as one of additional variables in EKC hypothesis. The result didn't support validity of EKC as well as it stated that ICT has no effect on carbon emission [5]. On the other hand, in Pakistan, increasing of ICT will decrease carbon emission and there is validity of EKC hypothesis [17]. Although, these two studies considered ICT in EKC but as mention before, the result of the EKC hypothesis validity also depend on area of study. EU which now have 27 countries (excluding UK) considers ICT as the important factor for economic. However, there is no research that test ICT in EKC hypothesis. Thus, the validity of Environmental Kuznets Curve (EKC) hypothesis addressing ICT in 27 EU countries is tested in this article. Additionally, e-commerce consumption which has rapid growth in this area will also be considered in the EKC testing.

## 2. LITERATURE REVIEW

### 2.1 Environmental Kuznets Curve (EKC)

Initially, Environmental Kuznets Curve (EKC) hypothesis estimate the relationship between carbon emission and economic growth. It shows that economic growth and carbon emissions can be reflected through an inverted U-shaped curve. The EKC shows that in the initial stages of economic growth. Economic growth has positive effect on carbon emissions. However, after a certain threshold level, carbon emission will decrease when there is increasing of economic growth then environmental quality improves [18]. Then, EKC has been tested by many researchers. For economic growth, most researches use gross domestic product (GDP) present this sector. There are few studies use productivity represent economic growth. Carbon emission or carbon dioxide is normally represented environmental pollutant in EKC model. Then, it is extended by using other environmental pollutants. For example, Carbon monoxide (CO), Sulphur dioxide (SO<sub>2</sub>) and total suspended particulate matter (TSP)<sup>2</sup> are chosen as some environmental indicators in EKC model for the study in Canada during 1974–1997 but this study did not support EKC hypothesis [19]. While, EKC hypothesis is validated when replaced carbon dioxide emission in EKC model with suspended particulate matter (SPM) in the atmosphere in 26 countries [20]. In the same way, Ozone (O<sub>3</sub>), Sulphur dioxide (SO<sub>2</sub>) and Nitrogen oxides (NO<sub>x</sub>) include nitric oxide (NO) and nitrogen dioxide (NO<sub>2</sub>) were used for testing EKC hypothesis in UK during 1991–2009. This study gave different result depend on the approach. Fixed effects approach shows that there is no evidence of EKC hypothesis while Arellano–Bond GMM result the validity of EKC as well as Logit model's results with fixed effect approach supported EKC hypothesis.

There are various of methodology of testing Environmental Kuznets Curve (EKC) hypothesis. Fixed effect is one approach which is frequently used in literature. Grossman and Krueger [18] which is initial research of EKC used fixed effect approach, random effect approach and OLS approach for examining. While, Shafik and Bandyopadhyay [21] analysed EKC by using solely fixed effect. As same as, recent study, fixed effect and random effect were used in the testing of EKC hypothesis in AEAN countries in the period of 1993–2014 [22]. Moreover, Autoregressive Distributed Lag (ARDL) bounds testing has been used in numerous papers. For instance, during 1971–2007, ARDL bounds testing approach confirmed that EKC hypothesis is validated in Korea [23]. In the same way, ARDL bounds testing approach has tested EKC hypothesis in Turkey [24], Pakistan [25], ASEAN [26]. In addition, there are many other approaches can be used to test EKC hypothesis such as random effect, OLS, Cross section analysis, Johansen cointegration, Granger causality, VECM Granger causality, Panel VAR and impulse-response function analysis, Toda-Yamamoto causality test and FMOLS.

Moreover, EKC hypothesis has been extended by adding additional variables or control variables. Energy consumption is frequently added in EKC hypothesis. For instance, energy consumption was added in EKC model testing in 19 European countries by Acaravci and Ozturk [27]. While, Baek and Kim [23] tested EKC hypothesis in Korea by adding energy

consumption. Plus, this study also adding electric production included fossil fuel and nuclear energy. Foreign direct investment (FDI) was added in the study of EKC in MIKTA countries [28]. Additionally, trade openness, population and energy intensity were added for testing EKC hypothesis in 13 Asian [29]. In addition, EKC hypothesis has been conducted in different countries and different regions as well as different period of time. For example, the study of EKC in 19 European countries between 1960 to 2005 using ARDL approach. It showed that EKC is valid in Denmark and Italy but the rest on other countries did not support the exist of EKC [27]. While, France supported validity of EKC in period of 1960–2000 using VECM method [6].

## 2.2 Information Communications Technology (ICT)

Information Communications Technology (ICT) is a technology innovation. It defines as a concept that include computers and other information equipment as well as computer software, communications equipment, and instruments [30]. ICT has various form. However, in literature, most scholars used number of fixed telephones, Mobile cellular and Internet users as ICT proxies as well as, in recent studies, Fixed broadband is also used as one of ICT proxy [31],[32]. Information and Communications Technology (ICT) has rapid growth in the past decades all over the world. Regarding the growing importance of ICT, many academicians and researchers have focused on studying the impact of ICT on various field especially in economic growth. Lee et al, [33] investigated the effect of ICT on Economic growth in 9 ASEN countries and the result showed that increasing of ICT will rise the economic growth. In the same way, ICT has positive effect on economic growth in G20 countries [34]. For environmental degradation, some scholars have conducted papers about the impact of ICT on carbon emission but the studies have given the mixed result. In ASEAN, showed that increasing of ICT will rise carbon emission [33]. As same as in G20, carbon emission will increase if ICT increase [34]. While, there is a study stated that ICT has no significant on carbon emission [35]. However, recent studies support the positive role of ICT in mitigating greenhouse gas emissions. The rise of Information of communication technology (ICT) deceases carbon emission in many regions such as 20 emerging economies [36] and Pakistan [17].

## 2.3 E-commerce consumption

E-commerce consumption is a consumption that involves electronic commerce or e-commerce. While, E-commerce is one of the advanced ICT systems and be generally defined as commercial transactions conducted electronically on the internet. WTO, [37] stated that e-commerce is the use of the Internet to conduct business transactions nationally or internationally. It can happen in the pattern of buying and selling goods or services using the internet as well as the transferring of money and data to execute these transactions. Therefore, definition of e-commerce consumption is not only the consuming of online physical products but e-commerce consumption also includes any kind of commercial transaction that is facilitated through the internet. For example, the trade of physical product requires inventory to be replenished and orders to be physically shipped to customers as sales are made. Moreover, e-commerce covers the transection of digital products such as downloadable digital goods, templates, and courses that must be purchased for consumption or licensed for use. Plus, e-commerce consumption can be in the form of retail, wholesale, drop shipping, crowdfunding and subscription. Since, any consumption is going to have an impact on economic. The rapid consumption in e-commerce at the present day will surely has an effect on economic. E-commerce offers the convenience in transection. It is easy for making a consumption thought this channel. Even, seller and consumer are in difference part of the world but the transection can be occurred in any second. Previous study investigated about inputs and development of electronic commerce and economic growth, declaring that e-commerce increased profits for firms and led to the economic development of countries. Moreover, the increasing of demand will increase supply of e-commerce good and service [38]. Except from economic, e-commerce consumption might either has impact on environment. Although, the studies about impacts of e-commerce consumption on environment are limited. However, it is well-known that e-commerce consumption in tangible goods needs to be delivered to customer. The becoming of e-commerce made change in freight transport. In the traditional distribution system, manufactures, wholesalers and retailers make big-lot deal and the volume of freight transport between them is thick, resulting efficient utilization of trucks and other resources. The last-mile transport is conducted by consumers' passenger trips with the purpose of shopping, although there are emerging concerns that older people without a driving capability cannot go shopping. In the case of e-commerce, however, thick freight transport is used in a limited way while direct delivery to consumers covers all the other parts. Usually small-lot orders are consolidated by the parcel delivery companies. The thick inter-city freight transport is de-consolidated at their terminals, and last-mile transport is conducted by light vehicle [39]. According to, Hidayatno et al,[40], the increasing of

E-commerce consumption will rise B2C and C2C. Then it will lead to high delivery (light vehicle transportation) which finally result in increasing of carbon emission. In the other hand, the rise of E-commerce consumption will decrease the shops which decrease the use of heavy vehicle to transport the goods then carbon emission will down. As well as it will decrease transportation to shops of customer. So, the carbon emission will decrease. Although, there is no previous study that add e-commerce consumption in EKC model. Thought, according to association of e-commerce consumption on both economic and environment, there is ability that e-commerce consumption will influence the validity of EKC hypothesis.

### 3. DATA AND METHODOLOGY

#### 3.1 Research Model

Dietz and Rosa (1997) developed Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model to get rid of the limitations in IPAT. Recent research used STIRPAT model to test the validity of EKC hypothesis by adding square of per capita GDP ( $GDP^2$ ) in the model [41]. In addition, the newest variables which has rapid growth and literature shows tendency of e-commerce consumption affecting both environmental degradation and economic growth. Whereas, it has never been added in EKC model before. The extended STIRPAT version was shown in eq. (1)

$$\ln CO_{2it} = \alpha_{it} + \beta_1 \ln GDP_{it} + \beta_2 \ln GDP_{it}^2 + \beta_3 \ln POP_{it} + \beta_4 \ln EC_{it} + \beta_5 \ln REC_{it} + \beta_6 \ln ICT_{it} + \beta_7 \ln E\_COM_{it} + \varepsilon_{it} \quad \text{eq. (1)}$$

When  $\varepsilon$  is the error term and  $CO_2$  represent the environmental degradation. GDP is Gross Domestic Product per capita (current US dollar).  $GDP^2$  is square of per capita GDP. Plus, POP refer to population size (measured as total person), EC refers to energy consumptions (kg of oil equivalent per capita. REC is renewable energy consumption (percent of total final energy consumption) and ICT represents individual using internet (measure as % of population). E-commerce consumption (E\_COM). It is represented in unit of present of individuals who used internet.

#### 3.2 Data and Descriptive Statistics

In this study, the data which is used is panel data or longitudinal data. It is balanced panel means there is no missing observational data. This panel data is a data which pooling of observations on a cross-sectional 27 countries of European Union (EU) and over 7 time periods during 2008 to 2014. Since, the unit (N) is 27 and time (T) is 7. There are (N) more than (T). so, this panel data is micro panel data. In addition, the data of most variables are from the World Development Indicators includes GDP, population, carbon emissions, energy consumption, renewable energy consumption and ICT. While E-commerce consumption data is accessed via Eurostat. Totally, this study has 7 variables and has 189 observation for each variable. There are 3 variables that unit in percent including REC, ICT and E\_COM. While,  $CO_2$ , GDP, POP and EC have specific unit as shown in TABLE 1.

TABLE 1: DESCRIPTIVE STATISTICS

Variable	Definition	Unit	Observation	Mean	STD	Min	Max
CO2	CO2 emission	metric tons per capita	189	6.861257	3.436654	3.37649	22.38547
GDP	GDP per capita	current US\$	189	1.97E+11	8.93E+11	8.7E+09	3.88E+12
POP	population size	total person	189	7282664.6	21490954.7	409379	82110097
EC	Energy use	kg of oil equivalent per capita	189	3159.63	1447.186	1591.668	8612.234
REC	Renewable energy consumption	% of total final energy consumption	189	13.60518	11.52953	0.250048	49.94855
ICT	Individuals using the Internet	% of population	189	68.24881	14.6029	32.42	95.99
E_COM	e-commerce consumption	% of individuals who used internet within the last year	189	6.887755	9.467083	1	34

### 3.3 Random Effect, Fixed Effects and Hausman Test

Since, there is ability that differences across entities have some influence on dependent variable which is carbon emission in this research. It is suggested to use random effect (RE). As well as, the fixed effect assumes time-invariant characteristics of person or entity dummies. Thus, the retinoate behind the assumption of the correlation between entity's error term and predictor variables. It is designed to study the course of change within a person or entity. Therefore, both random effect and fixed effect has been tested. Then, the Hausman test is used to choose the consistent model.

The result of random effect test show that  $\rho$  is approximately 0.97 while  $\rho$  of fixed effect is around 1 (0.998) which is increase when comparing to RE model (see in Fig. 1). In addition, FE model report F test that all  $u_i = 0$ . P-value equal 0.000. This indicates that there is significant difference between at least some individuals which means each country is difference. Hausman test analysis is perform after the test of RE and FE. the null hypothesis of Hausman test is RE is consistent or the preferred model is RE model; the alternative hypothesis is that the FE model is consistent. As the result in Fig. 3, it shows the null hypothesis is rejected (0.0012). It means panel data in this research model fit with the fixed effect (FE).

Inco2	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
lngdp	26.27071	42.93626	0.61	0.542	-58.54504	111.0865
lngdp2	-52.44093	85.87619	-0.61	0.542	-222.0797	117.1978
lnint	-.1961431	.0540095	-3.63	0.000	-.3028327	-.0894535
inpop	-.8153401	.2039468	-4.00	0.000	-1.218214	-.4124663
lnec	1.002399	.0715393	14.01	0.000	.8610811	1.143717
lnrec	.0037376	.0151937	0.25	0.806	-.0262759	.0337511
lne_com	-.0056828	.0105986	-0.54	0.593	-.0266191	.0152535
_cons	6.255198	3.531776	1.77	0.079	-.7214266	13.23182
sigma_u	1.0217968					
sigma_e	.0375347					
rho	.99865243	(fraction of variance due to u_i)				

Fig 1. The result of fixed effect with ICT and E-commerce consumption

Inco2	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
lngdp	-13.59399	43.33757	-0.31	0.754	-99.1939	72.00592
lngdp2	27.3113	86.6773	0.32	0.753	-143.8928	198.5154
inpop	-.5552932	.2001498	-2.77	0.006	-.950627	-.1599594
lnec	1.156288	.0602959	19.18	0.000	1.037192	1.275383
lnrec	-.0291646	.0130137	-2.24	0.026	-.0548691	-.00346
_cons	-.144329	3.221647	-0.04	0.964	-6.507691	6.219034
sigma_u	.69168953					
sigma_e	.03904713					
rho	.99682332	(fraction of variance due to u_i)				

Fig.2 The result of fixed effect without ICT and E-commerce consumption

	---- Coefficients ----		(b-B) Difference	sqrt(diag(V_b-v_B)) S.E.
	(b) fe	(B) re		
lngdp	26.27071	.0423282	26.22838	42.93625
lnint	-.1961431	-.1695	-.0266431	.0261463
inpop	-.8153401	-.1102582	-.7050819	.1971778
lnec	1.002399	1.002917	-.0005185	.0338788
lnrec	.0037376	-.019593	.0233306	.0050491
lne_com	-.0056828	-.005754	.0000712	.

b = consistent under Ho and Ha; obtained from xtreg  
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(4) = (b-B)'[(V\_b-v\_B)^(-1)](b-B)  
= 18.04  
Prob>chi2 = 0.0012  
(V\_b-v\_B is not positive definite)

Fig.3 the result of Hausman test

According to Hausman test, the fixed effect (FE) is being used for EKC hypothesis testing. The testing of validity of EKC hypothesis in 27EU countries during 2008-2014. According to the inverted u-shape of EKC, therefore, the testing result in this study expected positive sign of GDP and the negative sign of GDP<sup>2</sup>. The result show that EKC model which include ICT and E-commerce consumption valid in 27EU countries during 2008-2014 which is shown in Fig.1. However, to test the influence of ICT and E-commerce consumption in EKC model. EKC model without ICT and E-commerce consumption is tested and shows the result in Fig.2. It provided difference result of EKC validity. The coefficient of GDP and GDP<sup>2</sup> do not indicate the inverted U-shape coefficient. GDP<sup>2</sup> gave positive sign while negative sign is presented in coefficient of GDP which mean the EKC is invalid without ICT and E-commerce consumption. When focus on the effect of ICT and E-commerce consumption, it showed the coefficients of both variables were negative which mean the increasing of ICT and E-commerce consumption in EU will decrease environmental degradation. In addition, population has negative sign but energy consumption has positive sign. While, renewable energy consumption has positive sign in model with ICT and E\_COM but without ICT and E\_COM model show negative sign.

#### 4. CONCLUSION

European Union (EU) has target of net zero greenhouse gas emissions by 2050 [4]. Achieving this goal is required to consider both economic and environment. While, Environmental Kuznets Curve (EKC) explain that economic growth and environmental degradation can be reflected through an inverted U-shape. However, the validity of EKC hypothesis can be affected by additional variable and area of study. Since, Information communication technology (ICT) and E-commerce consumption have rapid growth in EU and the literature shows that ICT and E-commerce consumption has effect on both economic and environment. Therefore, the purpose of this study is the investigating impacts of ICT as well as E-commerce consumption in EKC model in a panel of 27 European Union (EU) during 2008–2014. This paper extended STIRPAT model which include population, energy consumption and renewable energy consumption as additional variable in EKC model. Fixed effect (FE) approach was selected to analyse the model. The result shows EKC hypothesis in this area study is not valid when EKC model not consider ICT and e-commerce consumption. However, when the model includes ICT and e-commerce consumption, there are validity of EKC hypothesis 27 European Union (EU) countries during 2008–2014. In addition, the model showed that ICT and e-commerce consumption decrease environmental degradation. Some policy implications are put forward according to the empirical analysis that it is important to enhance Information communication technology (ICT) and E-commerce consumption in 27 EU countries for reaching zero greenhouse gas emissions because ICT and E-commerce consumption decrease carbon emission and play important role in EKC model.

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