EGE AKADEMİK BAKIŞ / EGE ACADEMIC REVIEW

Cilt 17 • Sayı 4 • Ekim 2017
SS. 481 / 492
Doi: 10.21121/eab.2017431297
Başvuru Tarihi: 29.11.2016 • Kabul Tarihi: 22.05.2017

The Role of International Trade and Urbanization on Environmental Technical Efficiency in EU Member and Candidate Countries

Avrupa Birliği Üye ve Aday Ülkelerde Uluslararası Ticaret ve Kentleşmenin Çevresel Teknik Verimlilik Üzerindeki Rolü

Yavuz Selman DUMAN[1], Adnan KASMAN[2]

Abstract

In recent years, global attention has been devoted towards the devastating effects of high carbon emissions on the environment and economy. The Paris Agreement which was accepted by over 190 countries in December 2015 marks the beginning of a new era towards the battle against climate change. The reason for such a collective action towards a renown global phenomenon is to provide a cleaner environment and sustainable economy for the future generations. Understanding environmental efficiency is one of the most significant aspects of this endeavor. This paper uses environmental efficiency scores estimated through a parametric hyperbolic distance function for EU member and candidate countries over the years 1990-2011, and investigates its relationship with per capita income, industrial share of GDP, openness to trade, and urbanization by using a Tobit model. The results suggest that all the variables are significant determinants of environmental technical efficiency. The relation between environmental technical efficiency and economic development shows a U-shaped curve, whereas industrial share of GDP follows an inverse U-shaped curve. There is an inverse relationship between environmental technical efficiency and openness to trade, and a positive relationship with urbanization.

Keywords: Environmental Technical Efficiency, European Union, Determinants of Efficiency, Environmental Kuznets Curve, Urbanization.

Özet

Son yıllarda küresel dikkat, yüksek karbon emisyonlarının çevre ve ekonomi üzerindeki yıkıcı etkileri konusuna ayrılmıştır. Aralık 2015'te 190'dan fazla ülke tarafından kabul edilen Paris Anlaşması iklim değişikliğine karşı savaşta yeni bir dönemin başlamasını işaret ediyor. Kötü şöhretli bir küresel olguya karşı böylesine bir ortak eylemin amacı, gelecek nesiller için daha temiz bir çevre ve sürdürülebilir ekonomi sağlamaktır. Çevre verimliliğini anlamak bu çabanın en önemli yönlerinden biridir. Bu makale, 1990-2011 yılları arasında AB üye ve aday ülkeleri için parametrik hiperbolik bir mesafe fonksiyonu aracılığıyla tahmin edilen çevresel verimlilik puanları ile kişi başına düşen gelir, sanayinin GSYİH içindeki payı, ticarete açıklık ve kentleşme arasındaki ilişkiyi bir Tobit modeli kullanarak araştırmaktadır. Sonuçlar, tüm değişkenlerin çevresel teknik verimliliğin önemli birer belirleyicisi olduğuna işaret etmektedir. Çevresel teknik verimlilik ile ekonomik kalkınma arasındaki ilişki U şeklinde bir eğriyi gösterirken, sanayinin GSYİH payı ters U şeklinde bir eğri izlemektedir. Çevresel teknik verimliliğin ticarette açıklık ile arasında ters, kentleşme ile pozitif bir ilişkisi vardır.

Anahtar Kelimeler:Çevresel Teknik Verimlilik; Avrupa Birliği; Verimlilik Belirleyicileri; Çevresel Kuznet Eğrisi; Kentleşme.

1. Introduction

The adverse effects of global warming have become more evident in the recent years. Rising carbon dioxide (CO_2) emissions, due to excessive use of fossil fuels, is one of the main obstacles for sustainable development and economic growth. Countries concerned about climate change, sustainable development and providing a nurturing environment for

[1]Dr., Yalova Üniversitesi, yavuzselmand@gmail.com
[2]Prof.Dr., Dokuz Eylül Üniversitesi, adnan.kasman@deu.edu.tr

the future generations, joined the United Nations Framework Convention on Climate Change (UNFCCC). The Convention established the Kyoto Protocol in 1997 which set binding targets to reduce carbon emissions. In December 2015, the Paris Agreement, successor to Kyoto Protocol, has been accepted by a large number of countries with the aim of keeping global warming below 2°C, above pre-industrial levels. Maintaining global warming below or at certain levels requires countries to lower their CO_2 emissions, in general, the greenhouse gas (GHG) emissions.

Understanding the various causes and effects of climate change is vital in identifying the problem and coming up with a solution. Climate change policy has three pillars; economic, technological and environmental. Carbon taxes, abatement policies, carbon trading, and energy source diversification are some policies/solutions that can be categorized under the economic pillar, while improving production technology, appliances and vehicles to be more energy efficient are some of many solutions under the technological pillar. Environmental pillar deals with the human factor of the problem and advocates green economy, sustainable development, and green accounting. Targeting one of these pillars can produce a solution towards preventing climate change through decreasing GHG emissions. These policies might vary across countries with diverse technologies, resources and, public opinion towards climate change. Therefore, the cost of each option varies for each country. For developed countries with diversified sources of energy, transforming their energy profile from a carbon intensive to a low carbon mix might not be a cost-effective option while, for developing countries with scarce resources the opposite is true. Similar argument can be made for technological development such that the difference in technological advancement between a developed and developing country will be an issue that would have reflections on the energy intensity of their industry and its productivity.

Another policy option targets the energy input. Decreasing the use of energy, mostly fossil fuels, without compensating the difference with a cheaper and cleaner alternative, will lead to a reduction in CO_2 emissions however with a cost of economic slowdown. Since alternative and clean energy options are not as efficient as fossil fuel yet, countries become hesitant in employing policies that require energy reduction and, refrain from targeting CO_2 emission reductions. In this context, countries devote their efforts on simultaneously reducing CO_2 emissions and increasing productivity. A growing number of studies have been devoted on the topic of technical, environmental and energy efficiency. Technical efficiency refers to improving production capabilities by enhancing labor and capital while energy efficiency refers to generating more output with the same or lower energy input. Environmental efficiency, on the other hand, is a concept that incorporates both technical and energy efficiency with the addition of reducing the bad output, "CO_2 emissions". It can be denoted as green production or technically efficient if output is increasing and CO_2 emissions are decreasing simultaneously while the inputs are held constant or lowered. When countries target environmental technical efficiency, they conserve energy[1],transform their industry to a less energy intense one, promote green architecture, renewable energy, and green economy. All of which can be categorized under the environmental pillar of climate change policy.

Although it is important to investigate environmental technical efficiency for countries to determine their specific policies, we believe that it is also significant to investigate the determinants of environmental technical efficiency. Accurately identifying the determinants will enable countries to focus more on the right determinant to increase environmental technical efficiency. Hence, the main objective of this paper is to investigate the effects of per capita GDP, openness to trade, and urbanization on environmental technical efficiency for a panel of European Union (EU) member and candidate countries for the 1990-2011 period, using a Tobit model. The environmental technical efficiency scores were calculated using parametric hyperbolic distance functions by Cuesta and Zofío (2005) and Cuesta et al. (2009)[2].

The contribution of our paper to the existing literature is twofold: First, unlike previous body of research, this paper uses environmental technical efficiency scores estimated through a parametric hyperbolic distance function approach and adds urbanization as a new macro-economic variable, which is considered a determinant for environmental technical efficiency. Second, this is the first paper that investigates a relationship between the determinants and environmental technical efficiency for the EU member and candidate countries between 1990-2011.

By way of preview, our main empirical results suggest that the relation between environmental efficiency and economic development shows a U-shaped curve supporting a formulation of the Environmental Kuznets Curve (EKC)[3]. Furthermore, the results also suggest that industrial share of GDP have a positive effect which follows an inverse U-shaped curve suggesting that above a certain threshold level, increasing share of industry negatively effects environmental technical efficiency. Openness to trade is also a significant determinant of environmental efficiency and is inversely correlated with environmental efficiency. Finally, urbanization has a statistically significant positive effect on environmental technical efficiency.

The rest of the paper is organized as follows. Section 2 reviews the previous literature on determinants of environmental efficiency. Section 3 discusses the model of the study and econometric methodology. Section 4 discusses the data and empirical results of the estimations. The paper's concluding remarks are provided in section 5.

2. Literature Review

Global consensus on the correlation between increasing energy consumption and rising GHG emissions has made energy efficiency popular and one of the most debated topics in studies incorporating energy, environment, and efficiency. Although energy efficiency (EE) has the potential to reduce GHG emissions, the argument against it is that it leads to the phenomenon known as 'Jevons' Paradox'. Jevons argued that "it is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to a diminished consumption. The very contrary is the truth" Jevons (1865). What Jevons and a more contemporary study by Khazzoom (1980)observed was that increasing EE led to a higher use of energy, therefore causing GHG emissions to rise even further.

Recent studies, therefore, focus more on environmental efficiency and analyze the effects of various economic variables. Zaim and Taskin (2000) utilized non-parametric techniques to estimate an environmental efficiency index and investigated its relationship with determinants such as per capita GDP, population density, environmental public research and development expenditures, and share of manufacturing in GDP. They observed a typical inverse U-shaped Kuznets curve between environmental efficiency and per capita GDP and significant relationship between population density, R&D, and share of manufacturing in GDP.

Taskin and Zaim (2001)used a DEA model to compute environmental efficiencies and investigated a relationship between trade composition, the share of polluting exports, and openness with environmental efficiency using OLS and found them to be significant determinants. They also found that increasing level of openness above a threshold has a larger effect on high-income countries whereas it does not have a significant effect on low or middle-income countries. Färe et al. (2004) constructed an environmental performance index through a DEA approach using the pollutants CO_2, NO_X (nitrous oxide) and SO_X (sulfur oxide), and further analyzed its relationship with economic development and population. In terms of environmental Kuznets curve, the study found that independently CO_2 is positively related to per capita GDP, however, simultaneously CO_2, NO_X and SO_X do not have a clear relationship with per capita GDP.

Färe et al. (2004) also observed from the environmental performance index, with only CO_2 to account for the bad output, that countries with low environmental performance are dependent on oil whereas those with high environmental performance have the highest dependency on nuclear energy. Ramanathan (2005) also found a similar pattern as Färe et al. (2004) in terms of the relationship between fossil fuel dependency and environmental performance. Kumar (2006) investigated environmentally sensitive total factor productivity for 41 developed and developing countries and examined the impact of openness on conventional and environmentally sensitive productivity. Kumar (2006) also used DEA and directional distance functions to derive the productivity index and found that openness is a significant determinant of environmental efficiency as well.

Zhou et al. (2007)used a non-radial DEA approach to measure environmental performance for OECD countries between 1995-1997. They observed that environmental performance have soared between those years and assert that the change in environmental performance is mainly due to the technological improvements. Kumar and Khanna (2009) measured environmental efficiency and environmental productivity for 38 countries and explained the differences between efficiency and productivity through income levels, share of industrial output, capital per labor, use of commercial energy, and population density in addition to the degree of openness using a Tobit model. Their results are similar to that of Taskin and Zaim (2001) and Kumar (2006) in the sense that both found openness to be a significant determinant of environmental efficiency. Yu-Ying Lin et al. (2013)estimated environmental productivity in 70 countries between the years 1981-2007 through a generalized meta-frontier Malmquist productivity index approach. They also examined the relationship between GDP per capita, capital per labor, use of commercial energy per unit of GDP, and the openness and environmental efficiency. They found that openness is a significant determinant for developed countries whereas failed to observe a significant relationship between openness and environmental efficiency for developing countries. Li and Wang (2014) combined a slacks-based efficiency measure and the meta-frontier to measure environmental efficiency and formulized a Tobit model to study the effects of per capita GDP, energy intensity, industrial structure, foreign direct investment (FDI) and, openness on environmental efficiency. Their results show that there is positive correlation with per capita GDP, U-shaped relation with industrial structure, negative relation with energy intensity and, openness and, no significant relation with FDI.

The studies specify the determinants of environmental efficiency using efficiency scores calculated through non-parametric approaches, mostly using 2-stage DEA. In the second stage analysis, some utilized Tobit methodology (Kumar and Khanna 2009; Li and Wang 2014), whereas others used least squares (Zaim and Taskin 2000; Taskin and Zaim 2001; Kumar 2006). The arguments against these methods are mainly directed towards the efficiency scores that are estimated by DEA. There are major limitations of the DEA methodology. Simar and Wilson (2007) state that in all the two-stage DEA studies, the major problem with the estimated efficiency scores are that they are serially correlated. Similar discussions against the use of DEA to measure efficiencies and the problems it creates are also argued by McDonald (2009) and Simar and Wilson (2011) Cuesta et al. (2009) also added that the DEA approach is non-linear except under the assumption of constant returns to scale. DEA and non-parametric approaches has been studied by numerous researchers, those notable are reviewed by Ang and Zhang (2000) and Zhou et al. (2008).

The contribution of this paper to the related literature is that by using environmental technical efficiency scores calculated through a parametric hyperbolic distance function approach, we eliminated the limitations of the DEA approach. The arguments towards using least squares or Tobit analysis to test for exogenous variables' effects on environmental efficiency are related to DEA and this study stays above that argument in terms of its efficiency scores.

3. Model and Methodology

3.1. Determinant Analysis

As summarized in the previous section, numerous variables have been used in the process of analyzing the factors influencing the environmental efficiency. In addition to the common variables such as per capita GDP, industrial share, trade openness we have included the ratio of urban population to total population into the analysis. One other common variable is the energy intensity however we have discarded it in our analysis. Energy intensity is defined as the ratio between energy use and GDP, identifying the amount of energy used to produce one unit of output. The energy intensity indicator has been criticized by several scholars on the grounds that it was misleading and it failed to explain phenomenon of climate change. Since the denominator is GDP and at times of economic growth GDP increases faster than energy use, energy intensity will decrease. However, this decrease does not translate into lower carbon emissions or higher efficiency. In the reverse case, during economic recessions GDP drops faster than energy use, hence energy intensity will rise nevertheless, that does not refer to decreasing energy or environmental efficiency. This can easily be observed by looking at the trend of energy intensity and carbon emissions throughout the years. Figure 1 shows a comparison of energy intensity and CO_2 emissions of the World. Although energy intensity has decreased through the years, CO_2 has increased continuously.

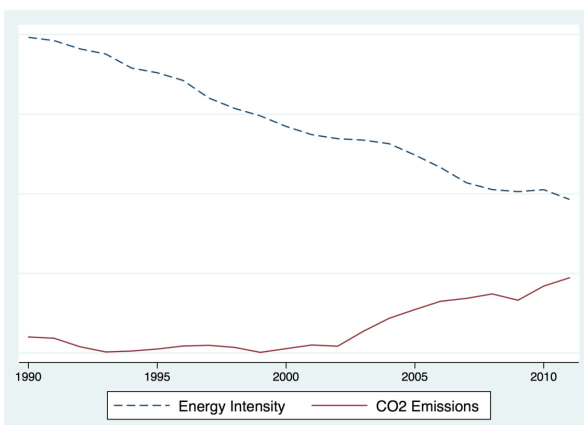

Figure 1: Energy Intensity and CO2 Emissions for the World between 1990-2011

Other factors can also affect energy intensity such as, population, natural resources, type of primary energy source, transformation of the industry from heavy machinery to electronics and, transferring energy intensive production to other countries. Hence, the overall evaluation of the energy, emissions, and environmental efficiency analysis without taking these shifts into consideration will be misleading.

Since the preliminary study by Kraft and Kraft (1978) which investigated the relationship between energy and GNP (Gross National Product), and the vast literature preceding it, there is no doubt to the existence of the correlation between energy and economic growth. In the recent years with phenomena such as global warming and climate change, the focus has been on the relationship between the environment and economy. The commonly known theory is pinned as the Environmental Kuznets Curve, asserting that in the first stages of economic development, as per capita income increases, the environment deteriorates until a threshold. At that point, people prefer environmental quality along with higher economic development hence the effects on environment relaxes as per capita income increases. This is mostly illustrated by an inverse U-shaped curve which is called the EKC. By using the per capita GDP and its quadratic form, our objective is to test the existence of the EKC for environmental technical efficiency.

One other variable we have chosen as a determinant of environmental technical efficiency is the industrial structure. Industrial transformation in countries mostly follows a similar pattern, starting with primary heavy industry mostly focused on iron, steel and machinery which are mostly energy intensive. In the secondary stage, the focus is on division of labor or technical efficiency and, mass production which requires the improvement of production technologies and the primary industrial structure. Following is the tertiary industry which emphasizes on information technologies (IT), electronics and, automated production. As the industrial structure moves forward through these stages, each predecessor loses demand and the successors' proportion increases. With the improving technology, output and technical efficiency, the environmental impact decreases.

Our third variable as a determinant of environmental efficiency is trade openness. Studies (e.g., Taskin and Zaim 2001; Dean 2002) have shown that openness has a significant impact on the environmental performance through terms of trade and export structure. International trade determines industrial structure of a country. Countries, with loose environmental regulations and a focus on primary industries will become offshore production centers for polluting industries. On the contrary, countries that have a comparative advantage in terms of tertiary industries and strict environmental regulations will reach higher environmental efficiency.

The last variable we have chosen as a determinant is the urban population ratio or most commonly known as urbanization. Urbanization's impact on the environment is analogous to positive externality through economies of scale. The general idea behind economies of scale is that, agglomeration of industries drives innovation, increases know-how, improves the region and, overall improves the economy. Necessity is the mother of innovation\invention and, necessity arises when larger populations of people live in the same area. Necessities such as transportation, architecture, machines, vehicles, education, healthcare, housing and, better food; create incentives to improve these aspects of life. In the long run, healthy environment becomes a necessity and it highlights the significance of sustainable development and green technologies.

Highly populated cities increase the compactness of daily life such as commuting and public transportation. For example, in highly populated cities, people prefer walking, cycling or public transportation which increases transportation efficiency, reduces the use of energy and eventually enhances the environmental performance. Green architecture is another positive impact of urbanization that benefits the environment. Buildings that generate its own electricity, refine rain water, and use solar panels, host populations as many as a small village therefore expands coverage of such utilities to higher populations while saving extra infrastructure cost. Providing efficient infrastructure and public services to a larger population in clusters is relatively cheaper and easier to manage in every aspect of housing from construction to waste management, and water sanitation compared to dispersed settlements. Urbanization, through dispersing the cost to many, makes environmental friendly goods and services accessible and affordable to a larger population.

Finally, urbanization brings a higher standard of living in every aspect of life which in a sense leads to the EKC. With rising standards of living, the necessities or priorities of life eventually shift from food, housing, health and, education to environment. Urbanization speeds up the process of change in priorities of life.

3.2. Empirical Analysis

The regression model we used in this paper is the Tobit model (Tobin,1958) also known as the censored regression. The simplest Tobit model can be formulized as follows;

$$y_t^* = \beta_0 + X_t^{'}\beta + \varepsilon_t, \; t = 1,2,...,n \qquad (1)$$

$$y_t = \begin{cases} y_t^* & if \quad y_t^* > 0 \\ 0 & if \quad y_t^* \leq 0 \end{cases} \qquad (2)$$

where $\varepsilon_t \left| X_t \; is \; N(0, \sigma_0^2) \right.$ and $\{y_t, x_t\}$ is i.i.d. X_t is a vector of determinants and β is a vector to be estimated. Another formulation of the Tobit model is $y_t = \max\{0, x_t^{'}\beta + \varepsilon_t\}$. Tobit (censored) Model is different from the conventional regressions in the sense that the dependent variable is censored which means the observations are constraint to a specific range, such as the environmental technical efficiency scores that range between 0 and 1.

Based on the theoretical foundation and, equation (1) and (2) when we take into consideration the environmental technical efficiency $EE \in (0,1)$ and construct a Tobit model, the equation will be as follows;

$$EE_{i,t} = \beta_0 + \beta_1 pGDP_{i,t} + \beta_2 (pGDP_{i,t})^2 + \beta_3 IND_{i,t} + \beta_4 (IND_{i,t})^2 + \beta_5 T0_{i,t} + \beta_6 UR_{i,t} + \varepsilon_{i,t} \qquad (3)$$

where, pGDP, IND, TO and UR denote economic development level, industrial share of GDP, trade openness and share of urban population, respectively.

4. Data and Empirical Results

4.1. Data

To investigate the determinants of environmental technical efficiency, this paper uses the panel environmental technical efficiency data of EU member and candidate countries from 1990 to 2011. The efficiency scores have been estimated through a parametric hyperbolic distance function approach following Cuesta and Zofío (2005) and Cuesta et al. (2009). Per capita GDP has been used as a proxy for economic development level, industry value added (% of GDP), trade percent of GDP is used to determine level of openness and percent of urban population is used for urbanization. Data is compiled from World Bank Development Indicators (WDI) between the years 1990-2011. The definitions of the variables are presented in Table 1. Summary statistics for the calculated efficiency scores, however, are given in the Appendix Table A1.

Table 1: Data Sources and Descriptions

Variable	Indicator	Units	Source
Efficiency	(EE) Environmental Technical Efficiency	EE ∈ (0,1)	Calculated with parametric hyperbolic distance function
Economic Development	(pGDP) per Capita Gross Domestic Product	Constant 2005 US$	World Bank (WDI)
Industrial Structure	(IND) Industry value added % of GDP	100%	World Bank (WDI)
Trade Openness	(TO) International Trade % of GDP	100%	World Bank (WDI)
Urbanization	(UR) Urban Population % of Total Population	100%	World Bank (WDI)

4.2. Empirical Results

The Tobit analysis results, summarized in Table 2, indicate that economic development level, industrial structure have significant effects ($p < 0.01$ $\forall$t tests) on environmental technical efficiency regardless of other determinants, openness and urbanization. On the other hand, openness to trade and urbanization are also statistically significant determinants of environmental technical efficiency.

In all four of the models, the effect of per capita income on efficiency is negative and significant. However, its quadratic term is statistically positive, suggesting that there is a U-shaped relationship between economic development and environmental technical efficiency. This suggests that as the per capita income increases at the initial stage of economic development, environmental technical efficiency will decrease (by -0.144e-04 for model 4) which will also increase environmental degradation. Once a threshold level of per capita income is reached, the environmental efficiency will start to increase with rising per capita income. Along with increasing environmental efficiency, environmental degradation will start to decrease. The overall relationship between environmental technical efficiency and per capita income therefore, supports the EKC hypothesis.

Table 2: Empirical Estimation Results

	Model 1	Model 2	Model 3	Model 4
	w/o TO and UR	*with TO w/o UR*	*with UR w/o TO*	*with TO and UR*
$pGDP$	-0.109e-04*** (7.61e-07)	-0.129e-04*** (7.89e-07)	-0.118e-04*** (8.58e-07)	-0.144e-04*** (8.97e-07)
$pGDP^2$	1.10e-10*** (1.24e-11)	1.61e-10*** (1.41e-11)	1.16e-10*** (1.27e-11)	1.75e-10*** (1.46e-11)
IND	46.653*** (4.292)	43.007*** (4.177)	48.204*** (4.340)	45.132*** (4.187)
IND^2	-705.07*** (66.87)	-626.39*** (65.559)	-733.27*** (67.96)	-664.00*** (65.91)
TO		-0.846*** (0.124)		-0.916*** (0.125)
UR			0.980** (0.467)	1.531*** (0.455)
C	0.070 (0.066)	0.189 (0.066)	0.004 (0.075)	0.082 (0.073)
X^2	365.40***	409.84***	369.77***	421.02***
Log Likelihood	469.03	491.2	471.2	496.84

(*, **, ***, statistically significant at 10%, 5%, 1% levels, respectively, the values in parenthesis indicates the standard errors, pGDP, IND, TO and UR denote; economic development level, industrial share of GDP, trade openness and share of urban population respectively, C denotes the constant, w/o=without)

Industrial share of GDP, based on the results of all four models, is also a statistically significant determinant of environmental technical efficiency. Unlike per capita income, the relation between industrial structure and environmental technical efficiency follows an inverse U-shaped curve. As the industrial share of GDP increases, environmental technical efficiency increases however, once a threshold of industrialization is reached, environmental technical efficiency starts to decrease. The inverse U-shaped relationship indicates that there is some diminishing marginal returns in terms of environmental efficiency. The more industrialized a country becomes, at one point, the less energy efficient it will end up being.

The results from model 2 and 4 indicate that openness to trade is another statistically significant determinant of environmental technical efficiency. Free trade has been studied in numerous studies as a significant source of economic growth, and economic growth is significantly correlated with environmental degradation which was pointed out by Grossman and Krueger (1991, 1995). Therefore, it is logical that increasing openness to trade negatively impacts the environment. Apart from the relation between trade and economic growth, and its reflection on the environment, there are other aspects of free trade causing the negative impact on environment. Ekins et al. (1994) asserted that transportation is a necessity of free trade and with increasing transportation, the use of fossil fuels increases. Increasing use of fossil fuels, releases more CO2 into the atmosphere which in return exacerbates global warming.

Urban population share of total population is also a statistically significant and positive coefficient, indicating that environmental efficiency increases with the increase in the share of urban population. As previously stated, urbanization provides compactness to life in many aspects from health, access to clean water, transportation, and education. The compactness of urban life improves the possibility to increase energy efficiency which in return can enhance environmental efficiency. For example, in rural areas it requires more energy and infrastructure to provide essential requirements of housing to smaller populations whereas in urban areas where population is dense, similar investments serve a higher population. Economies of scale also improve environmental efficiency through positive externalities such as agglomeration of industries in certain regions which increases both productivity and efficiency through division of labor and specialization.

Industrial revolution was probably the single most effective cause of the increase in urban population, and was also the breaking point at which CO2 emission started to increase rapidly. However, the devastating environmental impact of this process of high industrialization and urbanization was not as prevalent as it is today. In this regard, promoting urbanization will not necessarily promote environmental efficiency; if not supported by environmental regulations, infrastructure, public awareness against emissions, credible zoning for industries and businesses, and clean transportation. Without the accompanying environmental policies and education, increasing urban population, will negatively affect environmental technical efficiency.

5. Conclusion

This paper introduces a new perspective on the determinant analysis of environmental technical efficiency by using efficiency scores estimated via a parametric hyperbolic distance function, and formulates a Tobit model to investigate the relationship between efficiency and its determinants. Apart from the most commonly used variables, per capita income, international trade, industrial structure we have introduced a new determinant, urbanization. Our sample consisted of the EU member and candidate countries over the years between 1990 and 2011. The empirical results suggested that per capita income, industrial share of GDP, openness to trade, and urbanization are all statistically significant determinants of environmental technical efficiency.

Regarding policy implications, the results suggest that targeting all or one of these determinants would have a significant impact on environmental technical efficiency. Although encouraging economic growth at first will not have a positive impact on the environment, sustainable growth after a threshold level of per capita income will increase environmental efficiency. However, as Arrow et al. (1995) suggest, policies that target economic growth are not substitutes for environmental policies. They also argue that economic growth policies must be accompanied by strict environment policies as well. Based on the values of the coefficients of both the per capita income and its quadratic form, targeting only economic growth will have a relatively small effect on environmental efficiency if not supported by environmental policies as well.

Another policy target could be to increase the industrial share of GDP which will highly affect environmental efficiency initially until a level of industrial share is reached. After that level, industrial share of GDP starts to affect environmental efficiency negatively due to diminishing marginal returns. Increasing the share of industry may not be sustainable if it is not supported by policies that also improve production technologies towards green and carbon free production. Therefore, it is a more suitable policy to improve both the industrial share and its structure which means growth policy must be supported by an environmental policy for sustainable development.

For all the developing countries, and economies, the world is becoming smaller and the borders becoming less explicit, which inescapably have effects on the environment. Our results suggested a negative coefficient for trade openness, to which the logical policy implication would be is to control the amount of international trade. In the case of EU, this means controlling the carbon intense new members. The new members in the last decade consist of the Central East European (CEE) countries also known as the transition (from planned to market economy) economies. Planned economies are known to be more energy and carbon intensive compared to the market economies hence them becoming a member and opening more and more to international trade, negatively affected the environmental efficiency during their period of transition. Therefore, in the case of EU, it would be a better policy option to target the energy composition and industrial structure of these countries towards a less carbon and energy intensive, instead of international trade.

Environmental awareness, and climate action are significantly high in EU which is a contributing factor towards the positive correlation between urbanization and environmental efficiency. Countries become a part of a set of environmental policies and regulations as soon as they become a candidate and a member to the EU. In 1973, Environment Directorate General of the European Commission ('DG Environment') was set to preserve, protect and improve EU's environment through policies and legislations. These policies cover a large area of subjects from nature and biodiversity, urban environment, water to chemicals, land, and industry.

On the other hand, projects such as the Odyssee/Mure Project which compiles detailed data on energy efficiency, and CO_2 indicators provide sufficient data, and policy implications for the members. At the end, it boils down to the simple fact that economic, industrial, international trade, and urban policies must be supported by environmental policies to promote environmental efficiency.

6. END NOTES

i. A common misconception that should be addressed is that conservation of energy is not the same concept as energy efficiency. The former means using a constant service less while the latter means using less energy for that constant service. For example, improving a car technology to require less energy will improve its energy efficiency, whereas using that car less refers to conserving energy.
ii. A brief summary of the empirical model used to estimate environmental technical efficiency scores is given in the Appendix.
iii. Environmental Kuznets curve stated by (Grossman and Krueger 1995) refers to the increasing environmental degradation during the initial, lower income levels followed by a decrease once a threshold of per capita income is reached. Therefore, it is represented with an inverse U-type curve.
iv. see Edwards (1993) for a survey of related literature

References

Ang BW, Zhang FQ (2000) A survey of index decomposition analysis in energy and environmental studies. Energy 25:1149–1176.

Arrow K, Bolin B, Costanza R, et al (1995) Economic growth, carrying capacity, and the environment. Ecol Econ 15:91–95.

Cuesta RA, Lovell CAK, Zofío JL (2009) Environmental efficiency measurement with translog distance functions: A parametric approach. Ecol Econ 68:2232–2242.

Cuesta RA, Zofío JL (2005) Hyperbolic Efficiency and Parametric Distance Functions: With Application to Spanish Savings Banks. J Product Anal 24:31–48.

Dean JM (2002) Does trade liberalization harm the environment? A new test. Can J Econ Can d`Economique 35:819–842.

Edwards S (1993) Openness, Trade Liberalization, and Growth in Developing Countries. J Econ Lit 31:1358–1393.

Ekins P, Folke C, Costanza R (1994) Trade, Environment and Development - the Issues in Perspective. Ecol Econ 9:1–12.

Färe R, Grosskopf S, Hernandez-Sancho F (2004) Environmental performance: An index number approach. Resour Energy Econ 26:343–352.

Grossman GM, Krueger AB (1995) Economic growth and the environment. Q J Econ 110:353–377.

Grossman GM, Krueger AB (1991) Environmental Impacts of a North American Free Trade Agreement. Natl Bur Econ Res Work Pap Ser No. 3914:1–57.

Jevons WS (1865) The Coal Question; An Inquiry concerning the Progress of the Nation, and the Probable Exhaustion of our Coal-mines.

Khazzoom JD (1980) Economic Implications of Mandated Efficiency in Standards for Household Appliances. Source Energy J 1:21–40.

Kraft A, Kraft J (1978) On the relationship between energy and GNP. J Energy Dev 3:401–403.

Kumar S (2006) Environmentally sensitive productivity growth: A global analysis using Malmquist–Luenberger index. Ecol Econ 56:280–293.

Kumar S, Khanna M (2009) Measurement of environmental efficiency and productivity: a cross-country analysis. Environ Dev Econ 14:473.

Li M, Wang Q (2014) International environmental efficiency differences and their determinants. Energy 78:411–420.

McDonald J (2009) Using least squares and tobit in second stage DEA efficiency analyses. Eur J Oper Res 197:792–798.

Ramanathan R (2005) An analysis of energy consumption and carbon dioxide emissions in countries of the Middle East and North Africa. Energy 30:2831–2842.

Simar L, Wilson PW (2011) Two-stage DEA: Caveat emptor. J Product Anal 36:205–218.

Simar L, Wilson PW (2007) Estimation and inference in two-stage, semi-parametric models of production processes. J Econom 136:31–64.

Taskin F, Zaim O (2001) The role of international trade on environmental efficiency: A DEA approach. Econ Model 18:1–17.

Tobin J (1958) Estimation of Relationships for Limited Dependent Variables. Source Econom 26:24–36.

Yu-Ying Lin E, Chen PY, Chen CC (2013) Measuring green productivity of country: A generlized metafrontier Malmquist productivity index approach. Energy 55:340–353.

Zaim O, Taskin F (2000) A Kuznets curve in environmental efficiency: An application on OECD countries. Environ Resour Econ 17:21–36.

Zhou P, Ang BW, Poh KL (2008) A survey of data envelopment analysis in energy and environmental studies. Eur J Oper Res 189:1–18.

Zhou P, Poh KL, Ang BW (2007) A non-radial DEA approach to measuring environmental performance. Eur J Oper Res 178:1–9.

7. APPENDIX

Enhanced Hyperbolic Distance Function

Following (Cuesta and Zofío 2005)and(Cuesta et al. 2009)the hyperbolic distance function $D_H : \Re_K^+ \times \Re_M^+ \times \Re_J^+ \rightarrow \Re^+ U \left\{+\infty\right\}$ is defined as;

$$D_H\left(x,y,b\right) = \inf\left\{\theta > 0 : (x, y/\theta, b\theta) \in T\right\} \quad \text{(A.1)}$$

where $0 < \mathrm{D_H}(\mathrm{x},\mathrm{y},\mathrm{b}) \leq 1$.

(A.1) is called the hyperbolic distance function and has the feature of treating the desirable and undesirable outputs asymmetrically. It allows a simultaneous increase in production while a decrease in bad output. There are couple of reasons as to why enhanced hyperbolic distance function is employed in this study instead of the commonly used non-parametric techniques and Data Envelopment Analysis (DEA). Efficiencies estimated through DEA does not consider standard noise therefore are lower compared to stochastic frontier analysis, the program is non-linear except under constant returns to scale therefore the efficiency estimates are under-estimated (Cuesta et al. 2009), and DEA "efficiency estimates are serially correlated" (Simar and Wilson 2007). $D_H(x,y,b)$ is almost homogenous of degrees k_1, k_2, k_3 and k_4 if, $D_H\left(\mu^{k1}x, \mu^{k2}y, \mu^{k3}b\right) = \mu^{k4} D_H(x,y,b), \forall \mu > 0$

Translog specification of $D_H(x,y,b)$ following(Cuesta et al. 2009)takes the form;

$$\begin{aligned} lnD &= \alpha_0 + \sum_{p=1}^{P} \alpha_p lnx_{pi} + \frac{1}{2}\sum_{p=1}^{P}\sum_{l=1}^{P} \alpha_{pl} lnx_{pi} lnx_{li} \\ &+ \sum_{q=1}^{Q} \beta_q lny_{qi} + \frac{1}{2}\sum_{q=1}^{Q}\sum_{m=1}^{Q} \beta_{qm} lny_{qi} lny_{mi} \\ &+ \sum_{r=1}^{R} \theta_r lnb_{ri} + \frac{1}{2}\sum_{r=1}^{R}\sum_{n=1}^{R} \theta_{rn} lnb_{ri} lnb_{ni} + \sum_{p=1}^{P}\sum_{q=1}^{Q} \omega_{pq} lnx_{pi} lny_{qi} \\ &+ \sum_{p=1}^{P}\sum_{r=1}^{R} \psi_{pr} lnx_{pi} lnb_{ri} + \sum_{q=1}^{Q}\sum_{r=1}^{R} \varphi_{qr} lny_{qi} lnb_{ri} \; (i = 1,2,\ldots,N) \end{aligned} \quad \text{(A.2)}$$

Setting GDP, as the normalizing variable, $\mu = 1/y$. The distance function becomes;

$$D_{H,it}\left(x, \frac{y}{y}, b * y\right) = \frac{D_{H,it}(x,y,b)}{y} \quad (A.3)$$

and (A.2) becomes;

$$\begin{aligned} ln(\frac{D_{H,it}}{y_{Q,it}}) &= \alpha_0 + \sum_{p=1}^{P} \alpha_p lnx_{pi} + \frac{1}{2}\sum_{p=1}^{P}\sum_{l=1}^{P} \alpha_{pl} lnx_{pi} lnx_{li} \\ &+ \sum_{q=1}^{Q-1} \beta_q lny^*_{qi} + \frac{1}{2}\sum_{q=1}^{Q-1}\sum_{m=1}^{Q-1} \beta_{qm} lny^*_{qi} lny^*_{mi} \\ &+ \sum_{r=1}^{R} \theta_r lnb^*_{ri} + \frac{1}{2}\sum_{r=1}^{R}\sum_{n=1}^{R} \theta_{rn} lnb^*_{ri} lnb^*_{ni} + \sum_{p=1}^{P}\sum_{q=1}^{Q-1} \omega_{pq} lnx_{pi} lny^*_{qi} \\ &+ \sum_{p=1}^{P}\sum_{r=1}^{R} \psi_{pr} lnx_{pi} lnb^*_{ri} + \sum_{q=1}^{Q-1}\sum_{r=1}^{R} \varphi_{qr} lny^*_{qi} lnb^*_{ri} \; (i = 1,2,\dots,N) \end{aligned} \quad (A.4)$$

Transforming (A.4) gives us the hyperbolic distance function,

$$- ln(GDP_{it}) = T\left(K_{it}, L_{it}, E_{it}, GDP^*_{it}, t_{it}, CO^*_{2,it}\right) + v_{it} - ln(D_{H,it}) \quad (A.5)$$

The enhanced hyperbolic distance function enables further reductions in all inputs therefore (A.5) becomes;

$$-In(GDP_{it}) = T(K^*_{it}L^*_{it}E^*_{it}t_{it}, CO^*_{2,it}) + v_{it} + u_{it} \quad (A.6)$$

where K, L and E represent capital, labor and energy respectively. $CO^*_{2,it} = CO_{2,it} \times GDP_{it}$, $K^*_{it} = K_{it} \times GDP_{it}, L^*_{it} = L_{it} \times GDP_{it}$ and $E^*_{it} = E_{it} \times GDP_{it}.u_{it} = -ln(D_{H,it})$ is the term, representing the inefficiency in the composed error term structure of the stochastic frontier analysis. v_{it} is the random error term, $v_{it} \sim N(0,\sigma^2_v)$.

Table A1: Summary Statistics for Environmental Technical Efficiency

Country	Obs.	Mean	Std. Dev.	Min	Max
Austria	22	0.554	0.026	0.512	0.595
Belgium	22	0.580	0.025	0.539	0.619
Denmark	22	0.497	0.027	0.452	0.540
Finland	22	0.642	0.022	0.605	0.677
France	22	0.605	0.024	0.565	0.643
Germany	21	0.613	0.022	0.576	0.648
Greece	22	0.584	0.025	0.544	0.623
Ireland	22	0.456	0.028	0.411	0.501
Italy	22	0.568	0.025	0.527	0.608
Luxembourg	22	0.422	0.029	0.375	0.468
Netherlands	22	0.575	0.025	0.534	0.614
Portugal	22	0.619	0.023	0.580	0.655
Spain	22	0.623	0.023	0.585	0.660
Sweden	22	0.660	0.021	0.625	0.694

UK	22	0.592	0.024	0.551	0.630
Bulgaria	22	0.983	0.001	0.981	0.985
Croatia	17	0.637	0.017	0.609	0.665
Cyprus	22	0.460	0.028	0.415	0.505
Czech Rep.	20	0.829	0.011	0.810	0.846
Estonia	17	0.725	0.014	0.702	0.747
Hungary	21	0.731	0.017	0.703	0.758
Latvia	17	0.701	0.015	0.677	0.725
Malta	22	0.388	0.029	0.341	0.434
Poland	22	0.959	0.003	0.954	0.964
Romania	22	0.989	0.001	0.988	0.991
Slovakia	20	0.776	0.014	0.753	0.798
Slovenia	17	0.627	0.018	0.598	0.655
Albania	22	0.566	0.025	0.524	0.606
Macedonia	20	0.624	0.021	0.589	0.657
Montenegro	7	0.592	0.008	0.581	0.604
Serbia	6	0.930	0.001	0.928	0.932
Turkey	22	0.751	0.017	0.723	0.777