GAZİANTEP UNIVERSITY
JOURNAL OF SOCIAL SCIENCES

Journal homepage: http://dergipark.org.tr/tr/pub/jss

Araştırma Makalesi ● Research Article

Do Technological Development And Clean Energy Effect Environmental Awareness?: An Empirical Analysis for Turkey

Teknolojik Gelişme ve Temiz Enerji Çevresel Farkındalığı Etkiler mi?: Türkiye İçin Ampirik Bir Analiz

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MAKALE BİLGİSİ

Makale Geçmişi:
Başvuru tarihi: 17 Aralık 2019
Kabul tarihi: 19 Haziran 2020

Anahtar Kelimeler:
Teknolojik Gelişme,
Temiz Enerji,
ARDL Sınır Testi

ÖZ

Teknolojik gelişme, çevre açısından hem avantajlı hem de dezavantajlı bir etkiye sahiptir. Teknolojik gelişmenin en önemli etkilerden biri ise temiz enerji bilincidir. Bu doğrultuda çalışmanın amacı, Türkiye'de alternatif ve nükleer enerji ile patent uygulamalarının çevre kirliliği üzerindeki etkilerini araştırmaktır. Buna ek olarak, kişi başına düşen reel GSYİH'nın karbon emisyonu üzerindeki doğrusal etkilerinin yanı sıra, parabolik ilişkiler de 1990-2014 dönemi için test edilmiştir. Bu amaçla ARDL sınır testi uygulanarak değişkenler arasındaki eşbütünleşme ilişkisi araştırılmakta ve VECM Granger nedensellik analizi kullanılarak nedensellik bağı incelenmektedir. ARDL sınır testi yaklaşımından elde edilen ampirik sonuçlar, teknolojik gelişmenin karbon emisyonu ile pozitif ilişkili olduğunu ortaya koymaktadır. Ancak, temiz enerjinin karbon emisyonları ile negatif bir ilişkisi vardır. Yani, temiz enerjinin uzun vadede kişi başına düşen karbon emisyonlarındaki etkisi teknolojik gelişmelerin etkisinden daha fazladır. Öte yandan, teknolojik gelişme ve temiz enerji negatif (sırasıyla -0.114 ve -0.190) ve kısa vadede karbon emisyonu üzerinde istatistiksel olarak % 1 güven düzeyinde anlamlılığa sahiptir. Ayrıca, kısa ve uzun dönem sonuçlarına göre Türkiye'de EKC eğrisinin ampirik varlığı, elde edilen 11.998 (sabit 2010 ABD Doları) olan gelir dönüm noktası ile desteklenmektedir. VECM Granger nedensellik analizi, teknolojik gelişmeden karbon emisyonuna ve kişi başına reel GSYİH'ya kısa dönemde tek yönlü nedensellik ilişkisi olduğunu göstermektedir. Uzun dönemde ise karbon emisyonu başına reel GSYİH'ye, teknolojik gelişmeye ve temiz enerjiye neden olmaktadır.

ARTICLE INFO

Article History:
Received December 17, 2019
Accepted June 19, 2020

Keywords:
Technological Development,
Clean Energy,
ARDL Bounds Test

ABSTRACT

Technological development has both advantages effect and disadvantages effect in terms of environmental. The most important effect is on clean energy awareness. So, the purpose of this study is to analyze the impacts of alternative and nuclear energy and patent applications on pollution in Turkey. In addition, as well as the linear effects of real GDP per capita on carbon emissions, considering the parabolic relations is also tested for the period from 1990-2014. For this purpose, we investigate cointegration by applying ARDL bounds test on parameters and examine the causal link between the series by using Vector Error Correction Model Granger causality analysis. ARDL test empirical results express that technological development is correlated with carbon emissions positively. However, clean energy has a negative relation with carbon emissions. That is, clean energy is more effective than technological development on carbon emissions per capita in long term. On the other hand, technological development and clean energy have negative (-0.114 and -0.190 respectively)and statistically significant impact on carbon emissions in short term. Moreover, the long and short run results supported the empirical presences of EKC curve in Turkey with income turning point at 11.998 (constant 2010 US$), which has been attained. In addition, VECM Granger causality analysis expresses that there is a one-way causality running from technological development to carbon emissions and real GDP per capita in short term. Furthermore, carbon emissions cause real GDP per capita, technological development and clean energy in the long run.

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GENİŞLETİLMİŞ ÖZET

Birçok ülke, üretim ve ticari faaliyetlerin yoğunlaşması, sanayileşme, kentleşme, ekonomik büyüme, hızlı nüfus artışı ve yaygın teknoloji kullanımı gibi ekonomik faaliyetlerin yoğunlaşması nedeniyle önemli çevresel bozulma sorunlarına maruz kalmaktadır. Bu çevresel bozulmaların temel nedeni artan enerji ihtiyacı ve kullanılan enerjinin türü ile yakından ilgilidir. Ülkelerin artan enerji talebini karşılamak için daha fazla enerji üretmeleri gerekmektedir ve bazen enerji ihtiyacı ithal petrole bağımlılığın artmasına neden olmaktadır. Ancak, enerji ithal eden ülkeler bazı enerji güvenliği sorunları ile karşılaşmaktadır. Özellikle yenilenemeyen enerji kaynaklarının kullanımı artan enerji talebi ile birlikte düşünüldüğünde küresel olarak iklim değişikliğinin ve çevresel bozulmaların geri dönülemez boyutlara ulaşabileceğinin temelini oluşturmaktadır. Yenilenemeyen enerji kaynakları karbon bazlı olarak sınıflandırılan sonlu kaynaklardır ve yenilenemeyen bu enerji kaynakları sera etkisi yaratarak iklim değişikliğine neden olmaktadır. Bu kaynaklara bağımlılığın azaltılması, çevresel kalite ve ekonomik koşullar açısından önemlidir. Dünyadaki fosil yakıt rezervlerinin önümüzdeki 45 yıl içinde tükenmesi beklenmektedir. Bu nedenle, alternatif enerji kaynaklarına yönelmek ve bunların kullanımını sağlamak bir zorunluluk haline gelmiştir. Temiz enerji kaynakları (alternatif ve nükleer enerji gibi) zamanla tüketilen fosil yakıtlara bağımlılığı azaltır. Özellikle 1973 yılında petrol fiyatlarındaki artış ve bunu izleyen petrol krizi dünya genelinde bu konudaki farkındalığı artırmıştır. Öte yandan, yenilenebilir enerji kaynaklarına verilen önem arttıkça teknik ihtiyaçlar ortaya çıkmıştır. Teknik ihtiyaçları karşılamak için teknik çözümler bu alandaki birçok patentin konusu olmuştur ve bu nedenle yenilenebilir ve temiz enerji kaynakları, çevre dostu olması ve tükenmemesi nedeniyle devlet teşvikleri tarafından desteklenmektedir. Bu nedenle, yenilenebilir ve temiz enerji teknolojilerine ilişkin patent başvurularının sayısı sürekli artmakta ve geliştirilen yeni teknolojiler sayesinde patent başvurularının sayısı ve kalitesi artmaktadır.

Çalışma Türkiye özelinde değerlendirildiğinde Türkiye'nin petrol ve gaza olan önemli bir ithalat bağımlılığının bulunması ve bu durumun karbon emisyonlarında 1990'dan bu yana iki kattan fazla artışa neden olması önemlidir. Dünya Bankası Göstergeleri raporu 1969 yılında kişi başına karbon emisyonunun 1,14 metrik ton olduğunu göstermiştir. Karbon emisyonları, 2005 yılında Türkiye'nin Yenilenebilir Enerji Yasası'nı yürürlüğe koymasıyla 3,50 metrik ton olarak gerçekleşmiş, ancak bu rakam 2010 yılında 4,12 metrik tona ve 2014 yılında 4,49 metrik tona yükselmiştir. Kanunun çıkarılmasından bu yana karbon emisyonu % 154 artmıştır. IEA'nın raporuna göre (Uluslararası Enerji Ajansı, 2016) Türkiye ilk kez bir emisyon azaltma hedefi belirlemiş ve temiz teknolojilere yatırım yapmaya, yayılan sera gazını azaltmaya ve yüksek çevresel performans ve güvenlik standartları sağlamak için yasal çerçeveler uygulamaya odaklanmıştır. Bu bağlamda teknolojik gelişmenin artan ekonomik önemi ekonomik büyümeyi sürdürmek, karbon emisyonlarını azaltmak ve temiz enerji kaynaklarının kullanımını artırmak için politika yapılarını etkilemektedir. Teknolojik gelişmenin bir göstergesi olarak patent başvuruları, teknolojik gelişmenin yanı sıra çevresel zorlukların etkilerini kısıtlamada kritik bir rol oynamaktadır. Çevre kalitesini korumak ve hükümet tarafından çevresel yenilikleri teşvik etmek için her yıl patent gibi yüzlerce teşvik verilmektedir. Bu kapsamda mevcut literatür incelendiğinde çalışmaların ağırlıklı olarak Çevresel Kuznets Eğrisinin elde edilmesi üzerine olduğu belirtilebilir. Bununla beraber yenilebilir enerji kaynaklarının çevre üzerindeki etkisini inceleyen çalışmalarda mevcuttur. Bu çalışmalardan elde edilen ampirik bulgular ülkelere, zaman periyoduna ve kullanılan yönteme göre değişmektedir. Ancak ağırlıklı olarak yenilebilir enerji kaynaklarının kullanımının çevresel kalite üzerinde pozitif etki yaptığı sonucu elde edilmektedir.

Belirtilen tüm nedenler göz önüne alındığında, bu çalışma, kişi başına düşen karbon emisyonları üzerindeki kişi başına düşen gerçek GSYİH, alternatif ve nükleer enerji ve patent uygulamalarının doğrusal ve parabolik etkilerini araştırarak literatürde eksik olan bazı bilgileri doldurmaya katkıda bulunmaktadır. Bu nedenle çalışmanın temel amacı, kişi başına düşen karbon emisyonu ile kişi başına düşen GSYİH'nin doğrusal ve parabolik etkileri, alternatif ve nükleer enerji ve Türkiye'deki patent uygulamaları arasındaki ilişkiyi analiz etmektir. Bu kapsamda ARDL Sınır Testi yaklaşımı ve VECM Granger nedensellik yöntemi 1990-2014 dönemi için uygulanmıştır. ARDL testinin sonuçları, teknolojik gelişmenin karbon emisyonları ile pozitif bir korelasyona sahip olduğunu, temiz enerjinin ise karbon emisyonları ile negatif korelasyon gösterdiğini göstermiştir. Yani temiz enerji, uzun vadede karbon emisyonları üzerindeki teknolojik gelişmeden daha etkilidir. Ayrıca, teknolojik gelişme ve temiz enerjinin kısa vadede kirlilik üzerinde olumsuz etkisi vardır. Ayrıca, uzun ve kısa dönem sonuçları, EKC eğrisinin Türkiye'deki ampirik varlıklarını desteklemiştir. VECM Granger nedensellik testinin sonuçları, teknolojik gelişmeden kişi başına karbona ve kişi başına gerçek GSYİH'ye kısa vadede tek yönlü bir nedensellik olduğunu ortaya koymuştur. Buna ek olarak, uzun vadeli sonuçlar, karbon emisyonlarının Türkiye'de kişi başına reel GSYİH, teknolojik gelişme ve temiz enerjiye neden olduğunu göstermiştir. Sonuçlar, temiz enerjinin hem kısa hem de uzun vadede karbon emisyonlarını azalttığını açıkça göstermektedir. Teknolojik gelişme, kısa vadede karbon emisyonlarını da azaltmaktadır. Ayrıca, çevre kirliliği ekonomik büyüme ile birlikte belirli bir gelir düzeyine yükselmekte ve daha sonra, Türkiye'de EKC hipotezini 11.998 (sabit 2010 ABD $) seviyesine ulaşmıştır. Bu nedenle, elde edilen sonuçlara göre, teknolojik gelişme, nükleer, yenilenebilir ve temiz enerji kaynaklarına yönelik projelerin ve yatırımların odaklanabileceği ve Türkiye'de kısa ve uzun vadede yatırımların artırılabileceği söylenebilir. Teknolojik gelişme ve temiz enerji kaynakları çevresel bozulmayı azaltmak için makul bir teklif olabilir. 2023 vizyonu çerçevesinde gerekli maliyet ve fayda analizlerinin yapılması ve temiz enerji politikalarının detaylandırılması önemlidir. Son olarak, bu kapsamda faaliyet gösterecek şirketler için teşvikleri artırmak, gerekli finansman kaynağını sağlamak ve yenilenebilir enerji teknolojisi geliştirmek için sanayi politikalarının çevresel kalite ve dolayısıyla enerji verimliliği üzerinde de etkisi olabilir. Son olarak, temiz enerji alanında faaliyet gösterecek şirketler için teşviklerin artırılması ve gerekli finansman kaynağının sağlanması için sanayi politikalarının oluşturulması ve yenilenebilir enerji teknolojisinin geliştirilmesi de çevresel kalite ve dolayısıyla enerji verimliliği üzerinde etkili olabilir.

Introduction

Many countries have been exposure important environmental degradation problems by increasing in economic activity such as concentration of production and commercial activities, industrialization, urbanization, economic growth, rapid population growth, widespread use of technology in the previous years. These countries need to generate more energy to meet increasing energy demand and sometimes necessity of energy causes increasing dependence on imported oil. However, energy-importing countries encounter with some energy security problems. Import of energy, energy security, increasing greenhouse gas emissions, and environmental degradation force countries to find energy alternatives and make investment in nuclear, renewable and clean energy sources. Using clean energy sources can reduce dependence on energy inputs and environmental problems at the local and global level. Using more renewable energy can lower carbon effect and increase energy diversity and security.

One important issue to be addressed, Turkey has an important import dependency on oil and gas, and this causes increasing in carbon emissions more than doubled since 1990. World Bank Indicators report demonstrated that carbon emission per capita was 1.14 metric tons in 1969. The carbon emissions were 3.50 metric tons in 2005 when Turkey enacted the Renewable Energy Law but the figure increased to 4.12 metric tons in 2010 and raised to 4.49 metric tons in 2014. The carbon brief profile reported that carbon emissions per capita is 5.4 metric tons in 2018 and it increases 154% since the enacted the law. According to the IEA's report (International Energy Agency, 2016), Turkey has determined an emission reduction goal at the first time and focused to investment in clean technologies, reducing greenhouse gas emitted and implementing legal frameworks to provide high standards of environmental performance and safety. On the other hand, global carbon emission has escalated an all-time high in 2018 and estimated that total carbon emission concentrations in atmosphere will reach peak level ever, at 407 parts per million reported by Global Carbon Project (2018). The increased economic importance of technological development gets governments' attention and affects their policy structures to continue economic growth, the decreased of carbon emissions and the increased use of clean energy resources. Patent applications as an indicator of technological development play a critical role in restricting the impacts of environmental difficulties besides technological development. Hundreds of incentives such as patent are granted every year to protect environmental quality and encourage the environmental innovations by government.

The increasing threats of environmental impairment have drawn awareness to the link between clean environment and economic growth. The increase in income experienced in the period when economic development gained speed may slow down the environmental degradation at a certain income level. Thus, environmental quality increases with a certain income level. Accordingly, there is an inverse U-shaped relationship between economic growth and carbon dioxide emissions. This approach is called the Environmental Kuznets Curve (EKC) hypothesis (Shahbaz and Avik, 2018,s.3).

The validity of the hypothesis is examined with different econometric approaches and is currently being discussed for different country groups with the model put forward by Grossman and Krueger (1991). In addition, to date, some researchers have focused on investigating the nexus between real GDP, energy consumption and pollutant emissions. However, the impact of economic growth, clean energy (such as alternative and nuclear energy) and technological development (such as patent applications) on environmental quality have been conspicuous by its absence.

Considering all the reasons mentioned above, this study has a contribution to fill in some piece of information missing in the literature by investigating the linear and parabolic effects of real GDP per capita, alternative and nuclear energy and patent applications nexus on the carbon emissions per capita for the period from 1990-2014 by using ARDL Bounds Test approach and VECM Granger causality for Turkey.

The paper is prepared as following: Section 2 is reviewed the studies and findings on economic growth, patent applications and clean energy in relation to the pollutant emission. Section 3 expresses the model and data sources. The empirical methods and results are given in Section 4. Based on the findings, Section 5 includes conclusions and policy prescriptions.

Literature

There are numerous studies testing the nexus between environmental degradation and economic output under the name of Environmental Kuznets Curve in the environmental economics literature. It can be given examples as follows: Abdou and Atya (2013); Ang (2007); Apergis and Ozturk (2015); Apergis and Payne (2009); Arouri et al. (2014); Aslanidis and Iranzo (2009); Bello and Abimbola (2010); Cole et al. (1997); Day and Grafton (2003); Dinda (2004); Friedl and Getzner (2003); Grossman and Krueger (1995); Jalil and Mahmud (2009);Jalil and Feridun (2011); Halicioglu (2009); Halkos and Tzeremes (2009); Lantz and Feng (2006); Managi and Jena (2008); Marrero (2010); Omisakin (2009); Pao and Tsai (2010); Roca et al. (2001); Shafik and Bandyopadhyay (1992), Suri and Chapman (1998), Vollebergh et al. (2005) and Yaguchi et al. (2007). In addition, Baek (2015); Balsalobre et al. (2015); Cho et al. (2014); Esteve and Tamarit (2012); Gill et al. (2018); Kasman and Duman (2015); Hamit-Haggar (2012); Hussain et al. (2012); Murthy and Gambhir (2018); Özokcu and Özdemir (2017); Shahbaz et al.(2013); Shahbaz et al.(2014); Sinha and Shahbaz (2018) and Sugiawan and Managi (2016) also tested validty of the Environmental Kuznets Curve (EKC) Hypothesis is the most important hypothesis which states the relation between environmental degradation and economic growth.

The EKC is tested empirically on various pollutants such as air pollution, water pollution, carbon dioxide, ecological footprint (Al-Mulali et al., 2015; Aşıcı and Acar, 2016; Charfeddine and Mrabet, 2017; Destek et al. ,2018; Hassan et al. 2018; Aydin et al. 2019), deforestation (Shafik and Bandyopadhyay, 1992; Kaufmann et al., 1998; Stern, 2004; Managi, 2006; Leitao, 2010). However, wide-ranging literatures have focused on carbon emissions as an indicator of environmental pollution. EKC hypothesis gives the different results based on data period, analysis methods, selected countries profile and variables. For instance, Panayotou (1993) and (1997) reported that inverted U-shape in 30 countries during different data period using different variables for each study. Musolesi et al. (2010) estimated validity of EKC hypothesis for 109 countries using Bayesian estimation approach during 1959- 2001. The empirical results depict that EKC association between variables is valid for full sample, G7, OECD, and EU15. By using the panel cointegration model, Mehrara and Ali Rezaei (2013) analyzed the EKC hypothesis in BRICS countries during 1960-1996 and they found the EKC hypothesis is reasonable for BRICS countries. You and Lv (2018) searched the nexus between carbon emissions and income in 83 countries for the years 1985-2013 and reported that there was strong evidence to validity of the EKC. Moreover, the studies by Selden and Song (1994), Stern etc. (1996), Moomaw and Unruh (1997), Agras and Chapman (1999), Heil and Selden (2001), Faiz-Ur-Rekman and Nasir (2007), Fodha and Zaghdoud (2010), Beak and Kim (2013), and Nasreen et al. (2017) found EKC pattern between variables. Destek (2018), between the years 1990-2014 tests the hypothesis with STIRPAT EKC model in Turkey and the study concludes that the EKC hypothesis is supported. Similarly, Danish et al. (2019) find that EKC pattern is valid in BRICS countries in 1990-2015 in other BRICS countries except India. Nguyen et al. (2019) examines the relationship between CO2 emission, financial development index, openness and income between 1996 and 2014 for the 33 developing countries by using STIRPAT model. In this study, carbon emissions are analyzed by sector and U-shaped hypothesis is obtained in construction and public services sector while reverse-U-shaped hypothesis is used in production sector. On the other hand, U-shaped curve was found by Wang etc. (2011) for 28 provinces in China during 1995-2007 and the results showed that there is one-way causality from economic growth to environmental pollution in the long-run. Özcan (2013) also analyzed the EKC pattern for 1990–2008 in case of 12 Middle East countries and the results did not confirm to validity of EKC association in 5 Middle East countries.

Holtz-Eakin and Selden (1995) employed panel data analysis to investigate the relation among environmental degradation and economic growth and the results specify that there is a monotonic relation among series for the years 1951-1986. Mikayilov etc. (2018) reported that EKC hypothesis was invalid in Azerbaijan for the period 1992-2013 and found monotonically increasing among carbon emissions and income. On the other hand, Friedl and Getzner (2003) investigated the validity of the linear effects and non-linear effects of economic development on carbon emissions for Austria during 1960-1999 and found a cubic (N-shaped curve) relations among series. Similarly, Galeotti and Lanza (2005) searched linear effect of economic growth on carbon emissions as well as parabolic and cubic effects and found N-shaped curve for 108 countries spanning from 1971 to 1995. Moreover, Grossman and Krueger (1991) and Poudel etc. (2009) revealed that N-shape relationship in NAFTA and 15 Latin American countries using described variable sulfur dioxide and carbon, respectively. Similarly, Sinha et al. (2017) found N-shaped curve in N11 countries during 1990-2014. Moreover, Álvarez-Herránz et al. (2017) reported the same findings in 28 OECD countries for the years 1990- 2014. On the other hand, Yaduma et al. (2015) found inverted N-shaped for world, OECD, non-OECD and west during 1960-2007. In addition, Nasr et al. (2015), and Moghamad and Dehbeashi (2018) also researched cubic effects and found inverted U-shaped.

According to EKC, environmental pollution increases to a certain level of income with economic growth and then begins to fall. That is, while pre-industrial societies make their livelihood based on agriculture, no industrial pollution is encountered in this period. The use of natural resources in the transition to industrial society starts to increase, and environmental pollution is rapidly increasing with the use of technologies that cause environmental pollution. In the later stages of economic development, societies begin to spend their income in this direction in order to increase the quality of the environment by becoming aware of the habitable environment (Cialani, 2007, s. 568-577). However, the increase in income is not the only indicator for improving the environmental quality. The roles of patent applications and alternative energy that are accepted as a tool of environmental quality and accepted as one of the crucial indicators to access high-cost clean energy technologies and one of the key strategies to addressed sustainable development have mostly ignored. Lanjouw and Mody (1996) examined the relation among pollution expenditure and patent activity as well as composition of innovation for US, Japan, and Germany using patent data from 1972 to 1986 and found that environmental innovation increases pollution subsiding cost expenditures in a country. Brunnermeier and Cohen (2003) investigated the determinants of environmental innovations during 1983-1992 periods in US using patent applications and concluded that a positive relationship existed between pollution abatement expenditures and environmental patents. Popp (2006) investigated the innovation and spreading of air pollution control technologies using patent data with NO_2 and SO_2 variables for United States, Japan and Germany. The results of the study represented the little increase in foreign patents increased domestic emissions for variable of NO_2 and SO_2 except Japan. Finally,

Objectives

The main aim of the study is to research the effect of alternative and nuclear energy with patent applications on carbon emissions. This relation examines with ARDL test approach over the short and long run for the years 1990-2014. Moreover, we investigate considering possible parabolic effects as well as linear effects of real GDP per capita on carbon emissions per capita for testing EKC pattern. In addition, we analyze the direction of causality between real GDP per capita, alternative and nuclear energy, patent applications and carbon emissions using VECM Granger causality method in Turkey.

Non-renewable energy sources are finite resources classified as carbon based and these non-renewable energy sources cause climate changes by creating greenhouse effect. Reducing the dependence on these resources is important in terms of environmental quality and economic conditions. Fossil fuel reserves in the world are expected to be depleted in the next 45 years. Therefore, it has become a necessity to turn to alternative energy sources and ensure their use. Clean energy sources (such as alternative and nuclear energy) reduce dependence on fossil fuels that are depleted over time. Particularly, the increase in oil prices and the subsequent oil crisis in 1973 raised the awareness on this issue worldwide. On the other hand, with the increasing importance given to renewable energy sources, technical needs have emerged. Technical solutions to meet the technical needs have been the subject of many patents in this field and so renewable and clean energy resources are supported by government incentives due to environmentally friendly and not exhausted. For this reason, the numbers of patent applications regarding renewable and clean energy technologies are consistently increasing and the number and quality of patent applications have increased thanks to new technologies developed.

Turkey, due to its geographical location and natural resources a country has a high potential renewable energy production. From this point of view, it is aimed to examine the extent of technological development and the effective use of clean energy resources in Turkey. This study makes four contributions to the literature: i) this is the first study to examine the impacts of clean energy and technological development on environmental quality in Turkey. ii) although studies on the effects of real GDP per capita on environmental pollution have been widely reported in the literature, this study investigates the validity of EKC pattern using also alternative and nuclear energy and patent applications. iii) this study also employs the ARDL approach that consider the short and long run link between variables. iv) the findings obtained in this study would be an important contribution in the field of clean energy and technological development for Turkey.

Model and Data

In order to analyze the nexus with carbon emissions (per capita), linear and parabolic effects of real GDP (per capita), alternative and nuclear energy and patent applications, the annual date from 1990 to 2014 is examined in Turkey. The most important constraint in the paper is the time period. The time period should have been selected the years 1990-2014 because of restricted data of carbon emissions and the energy data for Turkey.

Many of the studies investigating the validity of the EKC hypothesis included the square of the income variable in the model. In this way, long-term effect of income and whether it is quadratic is investigated. Those paper use common characteristics of model specification (Shahbaz and Avik, 2018). Therefore, the model is established the following,

$$InCO_{2t} = \delta_0 + \delta_1 InY_t + \delta_2 InY^2{}_t + \delta_3 P_t + \delta_4 ALT_t + \mu_t (1)$$

Where $InCO_t$ represents natural log of carbon emissions per capita, InY_t and InY_t^2 represent natural log of real GDP per capita and square of real GDP, respectively. InP_t is patent applications and $InALT_t$ is alternative and nuclear energy. Logarithmic form is applied to all variables. To calculate the existence of EKC curve in Turkey, the turning point of EKC is computed by $\hat{\tau} = \exp\left(-\frac{0.5\hat{\alpha}_1}{\hat{\alpha}_2}\right)$. In this study, we utilized with patent applications as an indicator of technological development and alternative and nuclear energy as an indicator of clean energy. The data of carbon emissions (metric tons per capita), real GDP per capita and square of real GDP per capita (constant 2010 US$), patent applications (residents) and alternative and nuclear energy (% of total energy use) are obtained from World Development Data Bases.

Methodology and Empirical Findings

In this paper, we utilized the Phillips-Perron (PP) unit root test to inquire into the stationary of variables. In addition, cointegration analysis and VECM Granger causality test are used to examine nexus between GDP per capita, carbon emissions per capita, square of GDP per capita, alternative and nuclear energy and patent applications. In first step, we research the stationary properties of the variables using with PP unit root test. The results of PP unit root test are shown in Table 1. The results of the unit root test indicate that all series appear to be non-stationary in level. All variables are stationary in first differences.

Table 1: Unit Root Test Results

Variables	Phillips-Perron (PP) Test			
	Level		First differences	
	Constant	Constant & Trend	Constant	Constant& Trend
InCO_2	-1.867 (0.343)	-2.614 (0.277)	-6.516 (0.000)	-6.716 (0.000)
lnY	0.490 (0.984)	-2.342 (0.401)	-6.094 (0.000)	-6.209 (0.000)
InY^2	0.664 (0.990)	-2.177 (0.486)	-5.996 (0.000)	-6.140 (0.000)
InP	1.552 (0.999)	-1.226 (0.889)	-5.631 (0.000)	-6.784 (0.000)
lnALT	-1.993 (0.318)	-3.070 (0.130)	-8.328 (0.000)	-8.161 (0.000)

Note:Numbers in brackets are p-values.

In this stage, we utilize cointegration analysis to test the existing of long-run relationship between carbon emissions, linear and parabolic effects of real GDP, patent applications and alternative energy. We utilized ARDL approach developed by Peseran et al. (2001). ARDL estimation method is appropriate procedure to enable the examination of the long-term relations between the different levels of integrated series. This involves the variables to be integrated at I(0) or I(1) or I(0)-I(1). The other main advantage of ARDL approach allows analyzing short and long run relations between variables (Pesaran and Shin, 1998). Additionally, the ARDL model, which is suggested by Pesaran and Shin (1999) to provide consistent results against the problems of autocorrelation and endogeneity, is as follows:

$$dlnCO_{2t} = c_0 + \sum_{i=1}^{n} \beta_{0,i}\, InCO_{2,t-i} + \sum_{i=1}^{n} \beta_{1,i}\, dInY_{t-i} + \sum_{i=1}^{n} \beta_{2,i}\, dInY^2{}_{t-i} + \sum_{i=1}^{n} \beta_{3,i}\, dInP_{t-i} + \sum_{i=1}^{n} \beta_{4,i}\, dInALT_{t-i} + \delta_0 InCO_{2,t-1} + \delta_1 InY_{t-1} + \delta_2 InY^2{}_{t-1} + \delta_3 InP_{t-1} + \delta_4 InALT_{t-1} + \mu_t (2)$$

The difference operator is shown by d and n refers number of delays. In order to test common significance with $\delta_0, \delta_1, \delta_2, \delta_3, \delta_4$, F statistics is calculated to determine the upper and lower limits. As a result of the analysis, diagnostic tests are very important for obtaining consistent results. For this reason, diagnostic tests such as CUSUM, CUSUMQ, ARCH, Ramsey-Reset are applied in this study. Schwardz Bayesian Criteria is state the suitable lag of ARDL model for specification implies that $CO_t = f(Y_t, Y^2{}_t, P_t, ALT_t)$ and F-statistic is shown in Table 2.

Table 2. ARDL Models Results

Estimated models	Optimal lag length	F-statistic
$CO_{2_t} = (Y_t Y_t^2 PAT_t ALT_t)$	2, 0, 0, 3, 2	3.484*
	Critical values	
Lower bounds I_0		*Upper bounds* I_1
%10: 2.2		%10: 3.09
%5 : 2.56		%5 : 3.49
%1 : 3.29		%1 : 4.37

Note: ∗, ∗∗ and ∗∗∗ show 10%, 5% and 1% levels significance respectively.

Appropriate ARDL model for Turkey is (2,0,0,3,2) when carbon is dependent variable and F-statistic is 3.484 which is greater than upper critical bound value at ten percent level. This finding means the null hypothesis is rejected and this indicates that all variables are cointegrated in long run.

Table 3. Results of Long and Short run

Dependent variable: CO_2 Variables	Coefficient	t-statistic
Long run results		
Constant	-112.462***	-10.506
$\boldsymbol{InYt}$	24.245***	10.151
$\boldsymbol{InY^2t}$	-1.291***	-9.627
$\boldsymbol{InP_t}$	0.059***	2.840
$\boldsymbol{InALT_t}$	-0.170***	-2.814
Short run results		
$\Delta\boldsymbol{InY_t}$	24.136***	7.355
$\Delta\boldsymbol{InY^2_t}$	-1.285***	-7.092
$\Delta\boldsymbol{InP_t}$	-0.114***	-4.181
$\Delta\boldsymbol{InALT_t}$	-0.190***	-7.874
ECM(-1)	-0.881***	-6.173
Diagnostic tests	F-statistic	Probability
Serial	0.992	0.390
ARCH	0.042	0.838
Normality	3.977	0.137
RAMSEY	0.596	0.450
CUSUM	Stable	
CUSUMQ	Stable	

Note: ∗, ∗∗ and ∗∗∗show 10%, 5% and 1% levels significance respectively.

The diagnostic tests are also important subject to get consistent results. In case of the diagnostic tests results, as a seen in Table 3, Breusch-Godfrey LM Test indicates that serial correlation for the equations does not exist. The results of ARCH test indicate that residuals are homoscedastic in case of Turkey. Further, in order to investigate the normality of the error process, Jarque-Berra statistic has been estimated. The result of Jarque-Berra statistic indicates that there is a normality behavior. In addition, the results of Ramsey-Reset test support the correct functional form.

The long run coefficient of variables is reported in Table 3. According to results, the coefficient of real GDP per capita is positively significant while the coefficient of square of real GDP per capita is negatively. These findings support of EKC pattern in case of Turkey. In long run, firstly the level of carbon emissions increases with income until mature, then becomes stabilizes, and last turn decreasing. Additionally, there is a positive correlation among technological development and carbon emissions. However, clean energy is correlated with carbon emissions negatively. The result suggests that an increase in clean energy leads to decreased in carbon emissions in Turkey. It means that clean energy is more effective than technological development on carbon emissions in long term.

In Table 3, the short run parameters indicate that carbon emission is positively affected by real GDP per capita. That is, a 1% increases in GDP per capita increases emissions per capita by 24.1%. The coefficient of square of real GDP per capita is negatively significant with carbon emissions and the results of the short run also supported the empirical presences of EKC curve in Turkey. In addition, the results state the existence of inverted U-shaped curve among variables with a turning point at 11.998 (constant 2010 US$). According to the results, technological development and clean energy have negative and statistically significant impact on pollution in short term. Our empirical exercise indicates that the long run influence of technological development and clean energy are more effective than the results of short run. The estimate of ECM_{t-1} term is -0.881. It is negative as expected and significant statistically at 1% level. It shows that the shock in CO2 is vanished by 88.1% each year. It is refer that the speed and remarkable regulation process for Turkey economy in presence of any shock to the model.

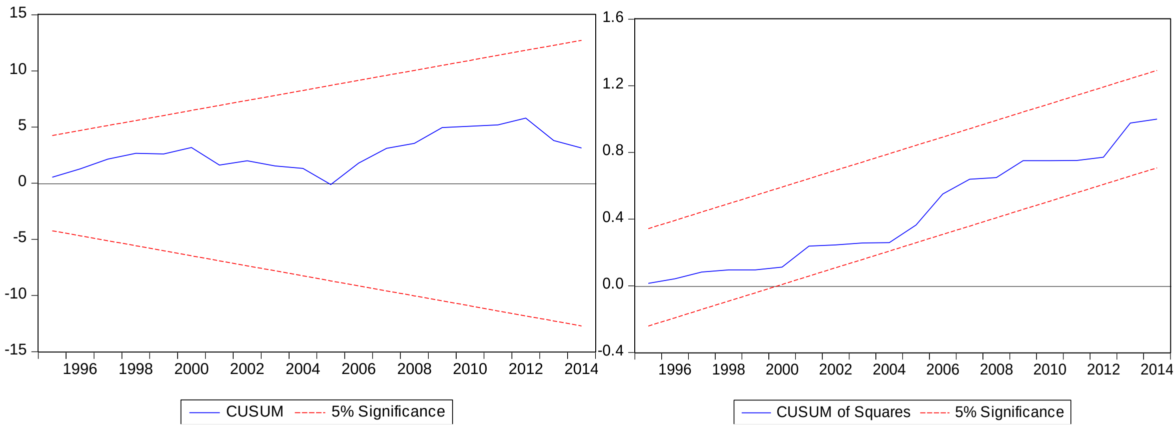

Fig. 1. Plot ofCUSUM and CUSUMQ tests

CUSUM and CUSUMQ tests and displayed in figure 1. These tests are expressed the stability properties. Tests are significant at 5 % and the results represent that both tests are inside the critical bounds at 5 % level of significance.

Finally, the short and long-term causality link is analyzed with VECM. The VECM Granger causality model is as follows:

$$(1-L)\begin{bmatrix} InCO_2 \\ InY_t \\ InY^2{}_t \\ InP_t \\ InALT_t \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{bmatrix} + \sum_{i=1}^{p}(1-L)\begin{bmatrix} b_{11i} & b_{12i} & b_{13i}b_{14i} & b_{15i} \\ b_{21i} & b_{22i} & b_{23i}b_{24i} & b_{25i} \\ b_{31i} & b_{32i} & b_{33i}b_{34i} & b_{35i} \\ b_{41i} & b_{42i} & b_{43i}b_{44i} & b_{45i} \\ b_{51i} & b_{52i} & b_{53i}b_{54i} & b_{55i} \end{bmatrix} \times \begin{bmatrix} InCO_{2_{t-1}} \\ InY_{t-1} \\ InY^2{}_{t-1} \\ InP_{t-1} \\ InALT_{t-1} \end{bmatrix} + \begin{bmatrix} \alpha \\ \beta \\ \delta \\ \vartheta \\ \gamma \end{bmatrix} ECM_{t-1} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \end{bmatrix} \quad (3)$$

$(1-L)$ represents the difference processor, also ECM_{t-1} refers lagged residual term caused by long run association while assuming error terms $(\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t})$ are constant and normally distributed with mean zero and restricted covariance matrix.

Table 4: The results of VECM Granger Causality Test

	Short Run				Long Run
	InCO_2	InY	InP	InALT	ECT (-1)
InCO_2	-	1.961 (0.161)	6.399** (0.011)	0.063 (0.801)	-0.106***[-3.086]
InY	1.928 (0.165)	-	6.222** (0.012)	0.566 (0.452)	-0.081***[-2.501]
InP	0.036 (0.848)	0.001 (0.992)	-	0.882 (0.348)	0.285** [2.074]
InALT	0.091 (0.762)	0.324 (0.569)	0.072 (0.788)	-	0.264** [2.037]

Note: ∗, ∗∗ and ∗∗∗ show 10%, 5% and 1% levels significance respectively. Numbers in parentheses are p-value while numbers in brackets indicate t-statistics.

Finally, the existence of cointegration in long run between carbon emissions per capita, technological development, economic growth and clean energy leads to apply the VECM Granger causality in order to examine the direction of causality among series. The results of Granger causality test illustrates in Table 4. The results of the short run causality test show that the one-way causality relationship from technological development to carbon per capita. The one-way causality also exists from technological development to economic growth. In addition, the neutral effect appears between carbon emissions, clean energy and economic growth.

Concluding Remarks

In order to implement better energy policies in the future and to have a clean environment, it is important to determine the energy demand and increase the use of clean energy. For this reason, the main goal of this study is to analyze the nexus between carbon emissions per capita, the linear and parabolic effects of real GDP per capita, alternative and nuclear energy and patent applications in Turkey. Thus, the ARDL Bounds Test approach and VECM Granger causality method were implemented taking the period 1990-2014. The results of the ARDL test indicated that technological development has a positive correlation with carbon emissions while clean energy is negatively correlated with carbon emissions. That is, clean energy is more effective than technological development on carbon emissions in long term. Moreover, technological development and clean energy have negative effect on pollution in short term. Furthermore, the results of the long and short run supported the empirical presences of EKC curve in Turkey. The results of the of VECM Granger causality test revealed that there is an one way causality coming from technological development to carbon per capita and real GDP per capita in short term. In addition, the long run results illustrated that carbon emissions cause real GDP per capita, technological development and clean energy in Turkey.

The results clearly show that clean energy decreases carbon emissions in both the short and long-run. The technological development also decreases carbon emissions in short-run. Moreover, environmental pollution increases to a certain income level with economic growth and then reverses and accepts the EKC hypothesis in Turkey with income turning point at 11.998 (constant 2010 US$), which has been attained. Therefore, according to obtained results, it can be suggested that projects and investment in technological development, nuclear, renewable and clean energy sources can be focused, and investment can be increased in both the short and long run in Turkey. Technological development and clean energy sources can be a reasonable proposal to decrease the environmental degradation.

According to the findings obtained as a result of the study, it indicates that the clean energy resources' investments on environmental quality can be increased. It is considered important to carry out the necessary cost and benefit analyzes and to detail clean energy policies within the framework of the 2023 vision. Finally, industrial policies to increase incentives for companies that will operate within this scope, to provide the necessary financing source and to develop renewable energy technology can also have an impact on environmental quality and therefore energy efficiency. Finally, increasing incentives and establishing industrial policies for providing the necessary financing source for companies that will operate in the field of clean energy, and developing renewable energy technology can also have an impact on environmental quality and therefore energy efficiency.

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