yönetim ve ekonomi araştırmaları dergisi
journal of management and economics research

Cilt/Volume: 17 Sayı/Issue: 4 Aralık/December 2019 ss./pp. 1-16
D. Güvercin Doi: http://dx.doi.org/10.11611/yead.497559

THE NEXUS BETWEEN FINANCIAL DEVELOPMENT AND CARBON EMISSION: SYSTEM GMM APPROACH

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ABSTRACT

The study examines empirically the nexus between financial development and carbon emission by giving particular emphasis on non-linear relations between financial development and carbon emission. To this purpose we used data for 52 countries over the period 2001-2014 and estimated the empirical model with System GMM method. The results indicate the validity of environmental Kuznets curve, and the positive significant effect of urban population and electric consumption on the carbon emission. Results indicate that there is U shaped relation between financial development and carbon emission indicating that at higher stages of financial development carbon emission increases by increasing rates. Moreover, the interaction variable between financial development and GDP per capita is positive significant.

Key Words: *Financial Development, Carbon Emission, System GMM, Environmental Kuznets curve, Non-linear Relations.*

JEL Codes: *O16, E44, Q56.*

FİNANSAL GELİŞME VE KARBON SALINIMI İLİŞKİSİ: SİSTEM GMM YAKLAŞIMI

ÖZET

Bu çalışma finansal gelişme ve karbon salınımı arasındaki ilişkiyi özellikle bu değişkenlerin arasındaki doğrusal olmayan ilişkiye yer vererek uygulamalı olarak incelemeyi amaçlamaktadır. Bu amaca uygun olarak belirlenen ekonometrik model 52 ülke ve 2001-2014 dönemi verisi kullanılarak, Sistem GMM yaklaşımı ile tahmin edilmiştir. Sonuçlar, çevresel Kuznets eğrisinin varlığını ve şehirsel nüfusun ve elektrik tüketiminin karbon salınımı üzerine pozitif etkileri olduğunu göstermiştir. Sonuçlar, finansal gelişme ve karbon salınımı arasında U-biçiminde bir ilişkinin olduğunu ve finansal gelişmenin ileri aşamalarında karbon salınımın yüksek derecelerde arttığını göstermiştir. İlaveten, kişi başına Gayrisafi Yurtiçi Hasıla ve finansal gelişme arasındaki etkileşimin katsayısının pozitif olduğu bulunmuştur.

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Makale Geçmişi/Article History

Başvuru Tarihi / Date of Application : 14 Aralık / December 2018
Düzeltme Tarihi / Revision Date : 5 Eylül / September 2019
Kabul Tarihi / Acceptance Date : 30 Kasım / November 2019

Araştırma Makalesi/Research Article

Anahtar Kelimeler: *Finansal Gelişme, Karbon Salınımı, Sistem GMM, Çevresel Kuznets Eğirisi, Doğrusal Olmayan İlişkiler.*

JEL Kodları: *O16, E44, Q56.*

1. INTRODUCTION

Since seminal work of Grossman and Krueger (1993;1995) there are several empirical researches conducted to show the inverted-U shaped relation between per capita income and carbon emission named as Environmental Kuznets Curve (EKC). These studies put significant emphasis on the state of the environmental degradation along the economic development path of the economy. Namely, these studies seek to answer whether environmental degradation at the initial phases of economic development decays steadily over time. The presence of EKC implicitly implies that institutions and public awareness about environment is endogenous to per capita income levels. In other words, high income countries would have stricter environmental regulations and more aware about environmental degradation resulting from economic activities.

However, focusing on growth in GDP per capita and not on development of financial markets, would not be describe the evolution path of the environmental degradation caused by economic factors in the country. The analysis should include the level of financial development in the country which mobilizes and channels savings to the most efficient investments (Greenwood, Sanchez and Wang, 2010; Levine, 1999), reduce transaction costs and enhance innovation activities (Aghion, Howitt and Mayer-Foulkes, 2005) and enable high-return, technological and risky, investments through risk sharing (Acemoğlu and Zilibotti, 1997; Greenwood and Jovanovic, 1990). On the other hand, financial development might increase consumption of goods and services as automobiles, air conditioners (Sadorsky, 2010) with high carbon footprints.

Transportation (29 % of carbon emission worldwide), electricity (28 % of carbon emission worldwide) and industry sectors (22 % of carbon emission worldwide) generate considerable amount of carbon emission (EPA, 2019). Therefore, indigenous firms targeting larger production units in these sectors by raising funds through financial markets in the early phases of industrialization might irrevocably harm the environment (Zhang, 2011; Sadorsky, 2010).

Developed countries become more service oriented and dependent on manufactured goods import from developing countries which leads to relocation of carbon intensive production from developed to developing countries (Li and Hewitt, 2008; Ahmad and Wyckoff, 2003). Therefore, financial development which mobilizes and channels savings for investments would result in expansion of export sector and environmental degradation in developing countries.

Moreover, Pollution Haven Hypothesis (PHH) argue that production of carbon intensive goods would relocate to locations with lax environmental regulations. There are several empirical papers on

the PHH confirming the international relocation of production of carbon intensive goods (Sun, Zhang and Xu, 2017; Tang, 2015; Grether and Mathys, 2010; Wagner and Timmins, 2009; Cole, 2004) Therefore, countries, mostly developing countries, which are at the climbing side of the EKC, with lax environmental laws might experience increase in export of carbon intensive goods. Financial development in the country might boost the expansion of export sector and worsen environmental degradation.

EKC argues that environmental degradation decreases at the later phases of economic development due to rising environmental concerns leading to more stringent environmental laws and regulations. Therefore, environmental laws and regulations might be endogenous (Millimet and Roy, 2011). Therefore, at the initial phase of economic development the environmental rules and regulations are less stringent. Moreover, Race to the Bottom Hypothesis (RBH) argues that in particular developing countries adopt less stringent environmental standards to attract foreign investments (Frankel and Rose, 2002).

Developing countries which are at the initial phases of economic development, would have limited financial capacity to channel savings into investments, thus, foreign firms flowing into country due to lax environmental laws and regulations would ease domestic credit constraints (Harrison and McMillan, 2003). Foreign firm entrance would, then, enhance financial development which would lead to expansion of production units engaging with carbon intensive goods and services that might contribute to environmental degradation.

On the other hand, financial development might lead to increase the number of investment projects aiming to lower the environmental degradation in the country. Even though, cost effective renewable energy technologies lowering the dependency of production on fossil fuels are expensive to install, funds can be raised through through financial markets (Painuly, 2001). Moreover, financial markets might ease the usage of high cost abatement technologies that are hard to finance without functioning credit markets.

The transformation of industry based economy to service based economy might be led by the capital accumulation boosted by financial development (Larrain, 2010). If such a transformation occurs, there would be lower demand for fossil fuel energy due to nature of production in services versus industry resulting in lower greenhouse gas emissions.

Additionally, financial markets might reward/punish the firms according to their environmental recognition. Lanoie, Laplante and Roy (1998) showed that capital markets reward firms according to their environmental performance. Dasgupta., Laplante and Mamingi (2001) showed the presence of channel, “news about environmental reputation”, through which financial markets impact environmental degradation. They argue that pollutant firms would be punished and the firms with superior environmental performance would be rewarded through capital markets. Capelle - Blancard

and Laguna (2010) uses data for 64 chemical explosions in chemical plants for the period of 1990-2005 and show that firms causing environmental degradation experience significant loss in market shares in following days.

The current study seeks to uncover non-linear relation present in the nexus between financial development and carbon emission. The present paper has contributions to the relevant literature in two folds. First, it contributes to the growing body of empirical literature on the issue. Second, it contributes to the relevant literature by providing evidence on the relation between financial development and carbon emission for the sample used in the study that differs from the findings in the relevant literature.

The structure of the paper is as follows. The next section refers about studies in the relevant literature which is followed by the section that discusses the non-linear relation between financial development and carbon emission. The third section is on the data followed by the section on the econometric methodology and estimation results. The conclusion section wraps up the findings of the paper.

2. LITERATURE REVIEW

This section is on the empirical studies on the nexus between financial development and carbon emission. Some studies do not account the non-linear relation between financial development and carbon emission while some studies account it. The literature accounting only linear relation between variables find inconclusive results. Some studies show the financial development decreases environmental degradation while some show it increases environmental degradation.

Jalil and Feridun (2011) using data for China for the period 1953-2006 argue that financial development decreases environmental degradation. Salahuddin, Gow and Ozturk (2015) using data for Gulf countries for the period 1980-2012 argued that there is negative relation between financial development and carbon emission. Shahbaz, Solarin, Mahmood and Arouri (2013) examined the impact of financial development on carbon emission in Malaysia and show that there is positive significant relation between variables. They argue that as the financial development result in capital inflows, industrialization would follow up leading to increase in carbon emission.

Shahbaz, Shahzad, Ahmad and Alam (2016) used data for the Pakistan over the period 1985Q1-2014Q4 and argue that improvements in banking sector leads to increase in carbon emission. Tamazian, Chousa and Vadlamannati (2009) using data for BRIC countries over the period 1992-2004 argue that financial development leads to increase in R&D related foreign direct investment projects leading to reduction in carbon emission.

Tamazian and Rao (2010), Frankel and Rose (2005), associate the financial development and carbon emission relation with the quality of embedded institutions in the country in the way that if the quality of institutions is high then financial development leads to carbon emission reductions through

market mechanisms as well as environmental regulations imposed by the government. This particular emphasis is critical from the view of this paper as it raises the issue of non-linearity present in the impact of financial development on carbon emission.

Some of the empirical studies accounting the non-linear relation between the financial development and the carbon emission is as follows. Shahbaz et al. (2013) and Charfeddine and Khediri (2016) argue that financial development leads to environment degradation at the initial stages of financial development which decays steadily over time. Chang (2015) uses data for 53 countries for the period of 1999-2008 to examine the non-linear relation between financial development and energy consumption and reports that energy consumption increases with financial development at later stages of financial development. Yuxiang and Chen (2010) argue that at advanced financial development stages, industries adopt more advanced technologies that are less carbon intensive leading to inverted U-shaped relation between the financial development and carbon emission. Shabbaz et al. (2013) and Charfeddine and Khediri (2016) argue that the relation between financial development and carbon emission is inverted U-shaped.

3. FINANCIAL DEVELOPMENT AND ENVIRONMENTAL DEGRADATION: NONLINEARITIES

There are few studies in the literature on the nexus between financial development and carbon emission accounting the non-linear relation compared to studies accounting only linear relation. The current study, thus, contributes to the relevant literature by providing evidence about the presence of non-linear relation between financial development and carbon emission.

The level of financial development in the country and rate of increase in the financial development might explain environmental degradation. The current study aims to unravel the shape of the curvature defining the non-linear relation between financial development and carbon emission by employing suitable empirical methodology. Additionally, the study aims to unravel whether climbing side of the curve defining the relation between financial development and carbon emission is at the right (convex) or at the left (concave), if the non-linear relation is present.

On the other hand, the present paper argues that since the level of financial development positively affects the number of risky projects particularly in technology intensive production (Acemoğlu and Zilibotti, 1997; Greenwood and Jovanovic, 1990), the risk diversification would entail the demand for more conventional and less risky projects. Therefore, financial development and sophistication of the financial contracts emerging at the later stages of development (Blackburn and Varvarigos, 2005) might

lead to demand for projects in more traditional and fusel fuel consuming sectors such as construction, transportation, manufacturing[1].

In other words, since financial development co-evolves with economic development (Bencivenga and Smith, 1998; Boyd and Smith, 1996) firms would easily raise funds and invest in high technology industries including industry on renewable energy technology but they also make an investment in manufacturing, construction etc. industries generating high carbon emissions to spread risks. The reasoning of this behavior is related to fact that industries' response to aggregate volatility would differ even the aggregate pool of investment does not respond to aggregate volatility (Imbs, 2004). Therefore, we argue that as the level of financial development rises the new technology particularly in clean energy sectors would be more popular but there would be also demand for other sectors using traditional energy sources that might result in high carbon emissions.

On the other hand, at the initial stages of the financial development due to credit constraints and minimum size requirements (Acemoğlu and Zilibotti, 1997) large scale or high technology projects would not be undertaken that would include renewable energy investments as well. Therefore, investments in renewable energy technologies and clean energy technologies would be become feasible with financial development.

One another point explored in the study is on the impact of interaction between financial development and GDP per capita since financial development might have various effects on environmental degradation depending on GDP levels. Financial development at high GDP levels would lead to greater size of investment leading to higher carbon emissions if these investments are used in fusel fuel energy consuming industries. Additionally, the size of the investment would be larger as the market expands that would lead to increase in investment in all industries of the economy including industries demanding fossil fuel energy sources. We argue that even the EKC implies the endogeneity of institutions, laws and regulations protecting environment, financial development might lead to increase in large scale projects in sectors with high carbon emissions.

[1] There are different views in the literature regarding the economic diversification. Matsuyama (2000), Acemoglu and Zilibotti (1997) argue that the number of sectors rises as economy develops while Imbs and Wacziarg (2003) argues that after certain threshold level the number of sectors decreases. Therefore, according to Imbs and Wacziarg (2003) the relative importance of tradition sectors first decreases and then increases , or the rate of decrease decreases.

4. DATA

The study uses annual data of 52 developed/developing countries over the period 2001-2014. The variables we used for the empirical estimation and the source of data is displayed at Table 1 below.

Table 1. Variables and Source

Variable	Source
Carbon Emission , (CO2, Metric tons per capita)	World Development Indicators
GDPPC (GDP per capita Constant $, 2010)	World Development Indicators
FINDEV (Financial Development, Domestic credit to Private Sector % of GDP)	World Development Indicators
Trade (Sum of Export and Import as a % of GDP)	World Development Indicators
ELECTRIC (Electric Power Consumption , kWh per capita)	World Development Indicators
URBAN (Urban Population % of Population)	World Development Indicators

Trade variable used in the study measuring the level of openness in the country is the ratio of the sum of export and import to GDP. Financial development variable measuring the level of financial development (financial depth) in the country is the ratio of domestic credit to GDP in percentage terms. It shows the financial resources provided to the private sector by financial intermediaries (monetary authorities, deposit money banks, finance and leasing companies, insurance companies, pension funds etc.) through loans, purchases of non-equity securities, trade credits and other accounts receivable. The present study uses the indicator because it is the most used indicator in the relevant literature to measure financial depth, financial development (Cihak, Demirgüč-Kunt, Feyen and Levine, 2013). Moreover, since the study does not focus on exposure to environmental degradation by stock market development versus banking sector development or by other financial institutions, the variable used highly in the relevant literature to measure financial depth is used. Carbon emission (CO_2) variable shows the carbon dioxide emissions coming from the burning of fossil fuels and the manufacture of cement.

Table 2. Summary Statistics

Variable	Observation	Mean	Std. Dev.	Minimum	Maximum
CO_2	728	5.45	4.4	.01	19.6
GDPPC	728	19631	19890.6	262.9	76420.8
FINDEV	728	357.5	210.2	1	721
TRADE	728	81.6	55.11	19.8	441.6
ELECTRIC	728	4948.7	6546.8	61.4	54779.2
URBAN	728	66.1	19.1	22.7	100

The summary statistics for variables are displayed at Table 2. Table 2 displays that the size of the sample is 728 where the number of countries are 52 and the number of years is 14. The minimum and maximum, mean and variance values for financial development, electric use, GDP per capita and CO_2 emission indicate that there are significant variations across countries in the sample in terms of GDP per capita, financial development, energy demand and carbon emission.

5. EMPIRICAL MODEL AND ESTIMATIONS

The purpose of the empirical part of the current paper is to seek the causality running from financial development to carbon emission. However, because there is possibility of reverse causality, and unobserved country fixed effects the estimation might suffer from bias. In other words, there might be omitted time invariant factors that affect both carbon emission and financial development over time such as culture, preferences, efficiency, formal and informal institutions that are difficult to measure leading to biased estimates.

GMM estimator methodology is designed to eliminate the time invariant fixed effects (country specific effects) and dynamic endogeneity that would result in violation of moment conditions and biased estimates. The GMM estimator (Arellano and Bond, 1991) deals with country fixed effects simply by taking first differences of the series and then instrument the regressors in first-differenced equations using levels of the lagged two periods or more (Bond, Hoeffler and Temple, 2001). System GMM estimator (Blundell and Bond, 1998; Arellano and Bover, 1995) deals with finite sample bias, which is the one of the main problem in first differenced GMM estimator (Arellano and Bond, 1991) along with weak instrument problem. Additionally, System GMM estimator provides greater precision by using additional moment conditions that are absent in first differenced GMM estimator.

First difference GMM has following moment condition[2]:

$$E\,(y_{it-s}\,\Delta\,\varepsilon_{i,t}) = 0\,,\quad s\geq 2;\quad t=3,\ldots,\,T$$

System GMM has additional moment condition as follows:

$$E\,(\Delta y_{it-1}\;\;\varepsilon_{i,t}) = 0,\qquad t=3,\ldots,\,T$$

The main treatment variable Financial Development is used along other control variables including GDPC, urban population as a share of total population, electric consumption per capita, and trade as a share of GDP to estimate their effect on the variation in carbon emission per capita.

The basic model is in the following form:

$$C02_{i,t}=\alpha_0\,C02_{i,t-1}+\alpha_1 FINDEV_{i,t}+\alpha_2 GDPPC_{i,t}+\alpha_3 TRADE_{\,i,t}+\alpha_4 URBAN_{\,i,t}$$
$$+\alpha_5 ELECTRIC_{i,t}+\alpha_6 (FINDEV_{i,t})_2+\alpha_7 (FINDEVi_{,t}*GDPPC_{i,t})+\theta_i+\varepsilon_{i,t} \qquad (1)$$

$$i=1,\ldots..,N\;\; and\; t=1,\ldots.,T$$

The moment conditions are;

$$E\,(\theta_i)=E(\varepsilon_{i,t})=E(\theta_i\varepsilon_{i,t})=0 \qquad (2)$$

[2] Y is dependent variable, X is covariates used in the empirical model.

Where θ_i is individual fixed effects and $\varepsilon_{i,t}$ is idiosyncratic shocks. $\theta_i + \varepsilon_{i,t}$ together constitute the standard error components structure. $C02_{i,t-1}$ is the lagged value of carbon emission variable.

To avoid spurious regression, we test the series against the presence of unit root. The results are displayed at the Table 3 below. The series having unit root enters into the GMM estimation in difference form and the stationary series enter into the GMM estimation in level form. Because we augment the model in equation (1) by adding interaction and squared terms we report also their order of integration below.

Table 3. Im, Peseran and Shin Panel Unit Root Test Results

Variable	W- Statistic	p-Value	Order of Integration
CO_2	-12.02	.00	I(1)
GDPPC	-8.42	.00	I(1)
FINDEV	-16.11	.00	I(0)
TRADE	-13.5	.00	I(1)
ELECTRIC	-12.4	.00	I(1)
URBAN[3]	-45	.00	I(0)
GPPC2	-7.7	.00	I(1)
FINDEV2	-63	.00	I(0)
GDPPC*FINDEV	-10.4	.00	I(1)

Im, Peseran and Shin (1997) (IPS) unit root test results are reported in the Table 3. IPS is selected for the unit root tests because it has superior test power (Chou and Lee, 2003).

IPS, instead of pooling the data, use separate unit root tests for the *n* cross-section units (Maddala and Wu, 1999). The null hypothesis of IPS is that there is a unit root for each cross section units while the alternative hypothesis is that there is no unit root at least for one cross section units. IPS is based on Dickey-Fuller statistics averaged across cross section units. W-Statistics is the standardized version of Dickey-Fuller statistics averaged across cross section units which converges to a standard normal distribution under the null hypothesis of the presence of unit root (Hurlin and Mignon, 2007). Therefore, if the null hypothesis is rejected, the series is stationary.

IPS results show that urban population, financial development, and square of financial development are stationary at the level so that they enter equation in level form. However, carbon emission, GDP per capita, electric use, squared GDP per capita and interaction between GDP per capita and financial development has unit root. These series are tested for the unit root after taking first difference and the results are reported at the Table 3. Results indicate these series become stationary after taking first-difference thus they are integrated of order one (I(1)) while all other series are

[3] We implemented Levin-Lin-Chu (2002) unit root test for Urban serie. Because IPS did not provide optimal lag information fort he relevant series, the LLC unit root test which is very sensitive to lag augmentation is used (Barreira and Rodrigues, 2005)

integrated of order zero (I(0)). Therefore, carbon emission, GDP per capita, electric use, squared GDP and interaction between GDP and financial development enter into equation in first difference form.

Table 4 below displays the System GMM estimation results suggesting the presence of EKC. In other words, carbon emission increases with decreasing rate by GDP per capita implying the presence of threshold where the carbon emission begin to decrease by GDP per capita. Electric consumption per capita increases carbon emission which suggests that energy use increases carbon emission. Moreover, urban population has positive significant effect on the carbon emission indicating that in more crowded urban places, production and consumption activities result in more carbon emission.

Table 4. Estimation Results[4]

Dependent Variable : ΔCO_2	**Coefficients**
$L.CO_2$	-.49**
Δ(GDPC)	.00095**
Δ(GDPC2)	-1.16e-08*
FINDEV	-.0075**
FINDEV2	8.03e-06**
FINDEV*Δ(GDPC)	9.27e-08**
Δ(TRADE)	-.046
Δ(ELECTRIC)	.00018**
URBAN	.021**
Prob > F	.000
Number of Countries	52
Number of Instruments	13
Sargan	.092
AR(2)	.102

On the other hand, financial development leads to reduction in carbon emission confirming the optimistic view about the carbon reduction effect of financial development. This approach emphasizes that financial development would lead to improvements in clean energy using technologies, and lead to R&D activities on renewable energy technologies resulting in reduced carbon emission. Moreover, this result also confirms finding of the studies reporting that environmental awareness is endogenous to financial markets development particular to development in stock market. As market prices move according to expected profitability of the firm, environmental degradation firms caused might reduce the demand for the products of the firm which might decrease its profitability and its price for market shares.

However, the result alone does not explain the nature of relation between carbon emission and financial development. Therefore, the squared financial development variable is added into the equation. The result conflicts with the results in the literature. The results show that even the effect is very small,

[4] *** shows that the estimated coefficient is statistically significant at the level of 1 %, ** shows that the estimated coefficient is statistically significant at the level of 5 %, * shows that the estimated coefficient is statistically significant at the level of 10 %

positive significant coefficient for squared variable indicating the U-shaped, convex, relation between carbon emission and financial development.

Because there are very few studies on this issue and all studies conducted, as of my knowledge, confirms the presence of inverted-U shaped relation, this findings conflict with the findings in the literature. The current study in the light of the empirical findings argues that financial development would lead to increase in the number of more risky and illiquid projects undertaken which are mostly likely to be technology intensive, environment friendly and on renewable energy technologies. However, due to portfolio diversification, the firm would also undertake less risky and solid investment projects mostly in non-service and less technology intensive sectors along with risky projects in such as high technology sector. Therefore, the number of investment projects would increase both in technology intensive sectors as well as other sectors demanding high energy which is mostly fossil fuel leading to increase in carbon emission.

The interaction variable between GDP and financial development indicates that, even the effect is small, the negative impact of financial development on carbon emission decreases, in absolute sense, at higher GDP per capita levels. We should emphasize that financial development is at higher income levels implies the availability of greater level of funds to be used in larger scale of investments particularly in renewable energy sectors, clean energy technologies and in other sectors such as non-service, less technology intensive sectors which might result in higher carbon emissions.

6. CONCLUSION

The nexus between the environmental degradation and economic development has become popular in recent years. Particularly since seminal work of Grossman and Krueger (1993) several scholars use empirical methods to validate the EKC. On the other hand, financial development as one of the significant engine of economic growth would have significant effect on the environmental degradation that needs to be examined from all relevant respects. Particularly, financial development enables opportunities to raise and channel funds resulting in increase in number of investment projects undertaken which might increase the environmental degradation or decrease it depending on the pollution intensity of (new) produced goods in the country.

Therefore, we argue that financial development would induce environmental degradation depending on commodities to be produced and clean energy intensiveness of investment projects to be undertaken. However, we should emphasize that there would be different set of investment projects demanded to be financed at various levels of financial development stages. The empirical results show that the relation between financial development and carbon emission is U-shaped. U-shaped relation shows that at the initial stages of financial development carbon emission would decrease and then increases at latter stages of financial development. There are evidences provided in the literature

showing the inverted-U shaped relation. This study provides evidence about the presence of the former, U shaped relation.

The mechanism we offer in the study explaining the result is about investors' portfolio diversification behavior. Investors, as financial market develops, purchase shares of large-size, illiquid and risky projects including renewable energy technologies and advanced technologies which are more likely to reduce carbon emission. However, investors also increase their purchase of shares of short term more liquid and less risky investments particularly in non-service sectors (such as construction, manufacturing) to spread risk over investment projects which increase carbon emission.

The study uses data for 52 developed/developing countries for the period of 2001-2014. In order to deal with endogeneity and unobservable country specific effects, the System GMM estimator is used. The estimation results indicate the validity of EKC. Moreover, results indicate that electric consumption per capita, share of urban population has positive significant effect on the carbon emission whereas trade does not have significant effect on the carbon emission.

One another significant findings of the paper is that the interaction variable between GDP and the financial development is positive significant suggesting that the negative impact of financial development on carbon emission at higher GDP levels decreases, in absolute sense.

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