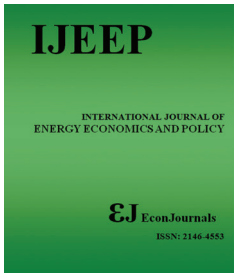

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Analysis of Coal Consumption and Growth Nexus by Environmental Kuznets Curve

Emrah Bese[1]*, Haven Swint Friday[2]

[1]Near East University, North Cyprus, Turkey. [2]The Texas A&M University System RELLIS Campus, USA.
*Email: emrahbeshe@gmail.com

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ABSTRACT

In this study, New Zealand and Finland are examined by Autoregressive distributed lag (ARDL) model for the relationship between coal consumption and economic growth. For coal consumption and economic growth relationship, coal Kuznets curve is investigated for New Zealand for the period between 1980 and 2015 and is examined for Finland for the period between 1980 and 2013. Results of this study show that coal Kuznets curve is confirmed for New Zealand and Finland. Hao et al. (2016) confirmed coal Kuznets curve as this study confirmed in New Zealand and Finland. This study contributes to the current literature by verifying coal Kuznets curve for New Zealand and Finland. Coal Kuznets curve is also not investigated for these countries before. This study recommends further investigation of coal consumption-growth nexus carries importance since the only study in the literature for coal consumption-growth nexus belongs to this study for New Zealand and Finland.

Keywords: Coal Kuznets Curve, Finland, New Zealand, ARDL Model
JEL Classifications: Q4, Q5, O5

1. INTRODUCTION

Kuznets (1955) studied the relationship between income and income inequality. Kuznets discovered inverted U shape between income and income inequality. EKC (environmental Kuznets curve) which is named after Kuznets, is the study of relationship between income and environmental degradation. EKC is studied in the literature mainly with CO_2 being dependent variable and GDP is being the independent variable. The Kyoto Protocol is an agreement also discussed in the EKC literature. Effect of the Kyoto Protocol is discussed in the EKC literature. The Kyoto Protocol is an agreement that is signed by developed and developing countries to lower signing countries' current emissions by a certain level. Effectiveness of Kyoto Protocol is discussed in the literature that whether Kyoto Protocol had a significant impact on reducing CO_2 levels of signing countries. Since sustainability is the one of the main issues in the world, studies for EKC and the agreements for reduction of greenhouse gases carry importance. In this study, coal consumption EKC hypothesis is examined for New Zealand and Finland by examining the relationships between the variables coal consumption and economic growth to cover the current gaps in the EKC literature. In this study, coal consumption environmental Kuznets curve is investigated by using ARDL model to cover the gaps in the EKC literature.

Climate change is a topic worldwide discussed by scientists, politicians, and individuals. Carbon dioxide is also discussed besides climate change since it is one of the major causes for climate change and one of main greenhouse gas emissions which are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and Sulphur hexafluoride. To cope with climate change and reduce CO_2, many initiatives take place on individual country level and global level. For global initiatives Paris Agreement and Kyoto protocol can be mentioned as two of them.

Kyoto Protocol, as being one of the global initiatives, an international agreement which was signed and ratified with

different parties on December 11, 1997 is one of the main efforts of humanity to cope with climate change and reduce CO_2 emissions. Developing and developed countries aim to reduce their GHG (Green House Gases) emissions by taking place in global initiatives. The protocol was prepared under the guidance of United Nations Framework Convention on Climate Change (UNFCC). It was first started with 37 industrialized countries and the European Union but today almost all countries involved in the protocol. Not all countries ratified Kyoto Protocol such as United States of America (USA). Kyoto Protocol went into practice by 2005 and by having a common objective for GHG emissions reduction, it also provided each participant country with a different commitment for emissions.

Kyoto Protocol's first commitment period for ratified parties was between 2008 and 2012. First commitment period required involved countries to reduce their GHG emissions by 5 percent below 1990 levels. Updates to protocol were made in 2011 in Morocco and in 2012 in Qatar. After 2012 meeting in Qatar, second commitment period was decided to be started between 2013 and end of 2020. New common objective was to reduce GHG emissions 18 percent below 1990 levels. Many discussions take place in the media and scientific community whether Kyoto Protocol is successful and its contribution to the reduction level in CO_2 and GHG worldwide.

Kyoto Protocol was not created just being a binding agreement by participant countries and the United Nations, but it was also created to set up new initiatives to cope with GHG emissions against climate change. These initiatives are carbon trading, Clean Development Mechanism and Joint Implementation. The main common point of these initiatives is the participant countries in the Kyoto Protocol can trade their excess carbon allowance on the carbon market and gain income. Also, in clean development mechanism, a participant country can make a green investment inside its borders to gain carbon credits to count in further commitment periods toward its emissions allowances. In joint implementation, a participant country can make a green investment in another country's territory to gain carbon credits to count in further commitment periods toward its emissions allowances.

Kyoto Protocol is discussed besides Environmental Kuznets Curve (EKC), which states income increase with CO_2 to a certain level and after that level is reached CO_2 starts to decrease while income increases, as well as climate change. The impact of Kyoto Protocol on EKC is one of the determinants for countries that are involved in the protocol to determine their policy implications towards their coping strategy with climate change.

The main question of this study is that whether income has a significant effect on environmental degradation in the long run. Coal consumption environmental Kuznets curve is investigated in this study. Hao et al. (2016) analyzed coal consumption environmental Kuznets curve in China for a panel study. Coal Kuznets curve is investigated in New Zealand and Finland in this study to fill the gap in the EKC literature.

2. REVIEW OF LITERATURE

For Austria, Benavides et al. (2017) used ARDL bounds test for the relationship between methane emissions, economic growth, electricity production from renewable resources except hydro and trade openness for the period 1970 and 2012. Benavides et al. (2017) verified EKC for Austria. Benavides et al. (2017) showed that there were long-run causality running from GDP, square of GDP, electricity production from renewable resources and trade openness to methane emissions for Austria.

For Canada, He and Richard (2010) examined the relationship between CO_2 and GDP for Canada between 1948 and 2004, and did not confirm EKC for Canada and found positive correlation between CO_2 and GDP.

Day and Grafton (2003) examined the relationship between CO_2, carbon monoxide, TSP (Total Suspended Particulate Matter) and Sulphur Dioxide (SO2), and GDP, and found no long-run relationship between GDP and CO_2, carbon monoxide, TSP (Total Suspended Particulate Matter) and Sulphur Dioxide (SO2) for Canada.

For Portugal, Shahbaz et al. (2010) examined the relationship between CO_2, GDP, energy consumption, trade openness and urbanization by ARDL model for the period between 1971 and 2008. EKC is confirmed for Portugal and long-run relationship is found between variables.

For USA, Dogan and Turkekul (2016) examined the relationship between GDP, square of GDP, CO_2, energy consumption, trade openness, urbanization and financial development for USA between 1960 and 2010. ARDL model is used. Long-run relationship exists between variables. EKC is not confirmed for USA.

For India, Ahmad et al. (2016) examined the relationships between CO_2, GDP and energy consumption for India at aggregated and disaggregated levels. Long-run relationship between variables and EKC hypothesis are confirmed for India at aggregated and disaggregated levels of energy consumption (Coal, Gas, Electricity and Oil) in the long-run. In the short run EKC is valid only for gas energy consumption. Time period of the study is between 1971 and 2014 and ARDL model is used.

Kanjilal and Ghosh (2013) examined the relationships between CO_2, GDP, energy consumption and trade openness for India with ARDL model and threshold cointegration with structural breaks between 1971 and 2008. EKC hypothesis is confirmed for India.

Tiwari et al. (2013) examined the relationship between CO_2, GDP, coal consumption and trade openness for India between 1966 and 2011 by using ARDL model. EKC hypothesis is confirmed for India both in the short-run and long-run.

Boutabba (2014) examined the relationships between CO_2, GDP, energy consumption, financial development and trade openness between 1971 and 2008 for India. ARDL model is used. Long-run relationship is found between variables and EKC hypothesis is confirmed for India both in the short-run and long-run.

For Iran, Saboori and Soleymani (2011) examined the relationships between CO_2, GDP and energy consumption between 1971 and 2007. ARDL model is used. Long-run relationship between variables is found but EKC hypothesis is not confirmed for Iran.

Taghvaee and Parsa (2015) examined the relationships between CO_2, and capital value added from manufacturing and mining, and services sectors and rural population in Iran. EKC hypothesis is not confirmed between value added in manufacturing and mining sectors and CO_2, and between services sector and CO_2.

Asghari (2012) examined the relationship between GDP and CO_2 in Iran by two-stage least squares method between 1980 and 2008. Asghari (2012) did not confirm EKC for Iran.

For Malaysia, Begum et al. (2015) examined the relationships between CO_2, GDP, population and energy consumption for Malaysia between 1980 and 2009. EKC hypothesis is not confirmed for Malaysia. ARDL model and dynamic ordinary least squared (DOLS) are used.

Azlina et al. (2014) examined the relationships between industrialization, GDP, CO_2, renewable energy use and energy consumption in the transport sector for Malaysia between 1975 and 2011. EKC hypothesis is not confirmed for Malaysia.

Saboori et al. (2012) examined the relationships between GDP and CO_2 for Malaysia between 1980 and 2009. ARDL model is used. EKC hypothesis is confirmed for Malaysia.

Saboori and Sulaiman (2013) examined the relationships between CO_2, GDP and energy consumption at aggregated and disaggregated (oil, gas, electricity and gas) levels for Malaysia between 1980 and 2009. EKC hypothesis is not confirmed at aggregated level but confirmed at disaggregated levels.

Gill et al. (2017) examined the relationship between CO_2, GDP and renewable energy between 1970 and 2011 for Malaysia. EKC hypothesis is not confirmed for Malaysia. ARDL model is used.

Lau et al. (2014) examined the relationships between CO_2, GDP, FDI and trade openness for Malaysia between 1970 and 2008. EKC hypothesis is confirmed for Malaysia both in the long-run and short-run.

Sulaiman et al. (2013) examined the relationships between CO_2, GDP, trade openness and electricity generation from renewable energy supply between 1980 and 2009 for Malaysia. ARDL model is used. Long-run relationship between variables is confirmed and EKC hypothesis is confirmed for Malaysia.

For Morocco, Haq et al. (2016) examined the relationships between CO_2, GDP, energy consumption and trade openness for Morocco between 1971 and 2011. Johansen cointegration model is used. EKC hypothesis is not confirmed for Morocco.

Kharbach and Chfadi (2017) examined the EKC hypothesis in the road transport sector in Morocco. Kharbach and Chfadi (2017) confirmed the EKC hypothesis in Morocco's road transport sector. Long run relationship between CO_2, GDP and energy consumption in the road transport sector (Diesel Consumption) is confirmed for the period between 1971 – 2011 by VECM model.

For Nigeria, Chuku (2011) examined the relationship between GDP and CO_2 by standard EKC equation and modified EKC equation. Johansen cointegration test is used. Chuku (2011) confirmed EKC hypothesis with standard EKC equation, and rejected EKC hypothesis with modified EKC equation (added several variables to the equation).

Oyinlola (2010) examined the relationship between CO_2, GDP, FDI, manufacturing, energy consumption and traded stock in Nigeria between 1980 and 2008. EKC is not confirmed for Nigeria.

Akpan and Chuku (2011) examined the relationship between CO_2 and GDP between 1960 and 2008. ARDL model is used. EKC hypothesis is not confirmed for Nigeria.

Olusegun (2009) examined the relationship between CO_2 and GDP for Nigeria between 1970 and 2005. EKC hypothesis is not confirmed for Nigeria. Johansen cointegration model is used.

For selected studies for the EKC hypothesis covering the period 2018 to 2021, Sarkodie and Strezov (2018) confirmed the EKC relationship between emissions and economic growth for China and Australia. Sarkodie and Strezov did not find evidence for the EKC relationship for the USA and Ghana. Sarkodie and Strezov also analyzed the environmental sustainability curve relationship between biocapacity and growth. Sarkodie and Strezov confirmed the environmental sustainability curve relationship for Australia and the USA.

Dong et al. (2018) confirmed the EKC hypothesis for China. Du, Liu, Lei and Huang (2018) confirmed N-shaped relationship between emissions and growth for China. Hao et al. (2018) confirmed N-shaped relationship between environmental degradation and growth for a panel study for China.

Gui et al. (2019) analyzed and did not confirm waste Kuznets curve for China. Song et al. (2019) confirmed the EKC hypothesis for China and the USA. Zhou et al. (2019) confirmed the EKC hypothesis for China. He and Lin (2019) analyzed the nonlinear relationships between income and emissions for China and confirmed the EKC hypothesis for a panel study for China.

Cohen et al. (2019) confirmed the EKC hypothesis for a panel study for China. Chai et al. (2019) analyzed and confirmed N-shaped relationship between coal consumption and income for China. Chai et al. (2019) analyzed coal Kuznets curve in China and did not confirm. Liu and Lin (2019) confirmed N-shaped relationship between environmental degradation and economic growth.

Sarkodie et al. (2020) confirmed the EKC relationship between environmental degradation and economic growth for China. M. Ahmad et al. (2020) confirmed the EKC relationship between emissions and economic growth for China. Kacprzyk and

Kuchta (2020) confirmed the EKC hypothesis for a panel of 161 countries.

Purcel (2020) stated that most of the reviewed studies in the literature confirmed the cointegration between income and environmental degradation in the literature review for environmental Kuznets curve. Purcel suggested that developing and transitional economies should contribute more efforts for climate change to support developed countries. Özden and Beşe (2021) analyzed the EKC hypothesis in Australia by linear and nonlinear cointegration models. Özden and Beşe did not confirm the EKC hypothesis in Australia.

3. MATERIALS AND METHODS

GDP is gross domestic product per capita. ENC is energy consumption (kg of oil equivalent per capita). SQ is the square of gross domestic product. CS is coal consumption (million tons of oil equivalent). Data for GDP, SQ and ENC is retrieved from World Bank website. Data for CS is retrieved from U.S. energy information administration website.

$$\ln(CS)_t = r_0 + r_1 \ln(GDP)_t + r_2 \ln(GDP)_t^2 + e_t \quad (1)$$

$$\ln(CS)_t = r_0 + r_1 \ln(GDP)_t + r_2 \ln(GDP)_t^2 + r_3 \ln(ENC)_t + e_t \quad (2)$$

For all models e is the error term and r_0, r_1, r_2, and r_3 are coefficients. For time series analysis in this study, ADF unit root test is used to determine the levels of unit roots of the variables.

For time series analysis of New Zealand, first model is used. For time series analysis of Finland, second model is used. For CS-GDP-SQ nexus, ARDL model is used. For CS-GDP-SQ-ENC nexus, ARDL model is used as well. Coal consumption environmental Kuznets curve is investigated for New Zealand and Finland for the period between 1980 and 2015, and the period between 1980 and 2013 respectively. The stability of the model is examined by CSSM (Cusum Test), CSQM (Cusum Square Test), HE (Heteroscedasticity Test Breusch-Pagan-Godfrey), CO (Breusch-Godfrey Serial Correlation LM Test), RE (Ramsey Reset Test) and NO (Normality Test) tests.

Table 1: UR results for New Zealand

	Level	First Difference
CS	−1.169973	−6.304463 (1%)
GDP	−0.662049	−3.789428 (1%)
SQ	−0.577469	−3.828574 (1%)

4. RESULTS AND DISCUSSION

Coal consumption-GDP-SQ nexus is examined for New Zealand for the period between 1980 and 2015. Coal consumption-GDP-SQ-ENC nexus is examined for Finland for the period between 1980 and 2013. ARDL model is used in this chapter.

4.1. New Zealand

4.1.1. ARDL model

CS, GDP and SQ are at I(1) level according to unit root (UR) test results (Table 1). Lag length is determined according to results in VAR model (Table 2). According to ARDL bounds test results, F-statistics value is 7.541927 which is more than 6.36 which is I1 bound value of 1%. ARDL model is stable according to the stability test results (Table 3, Figures 1 and 2). ARDL Error Correction Model (ARDL-ECM) is run and according to the results, coal Kuznets curve is confirmed for New Zealand (Table 4). The long run coefficient of GDP is positive and significant at 5%, and the long run coefficient of SQ is negative and significant at 5%.

4.2. Finland

4.2.1. ARDL model

CS, GDP and SQ are at I(1) level according to unit root test results (Table 5). ENC is at I(0) level according to unit root test results (Table 5). Lag length is determined according to results in VAR model (Table 6). According to ARDL bounds test results, F-statistics value is 6.625140 which is more than 5.61 which is I1 bound value of 1%. ARDL model is stable according to the stability

Figure 1: CSSM test results for ARDL model of New Zealand

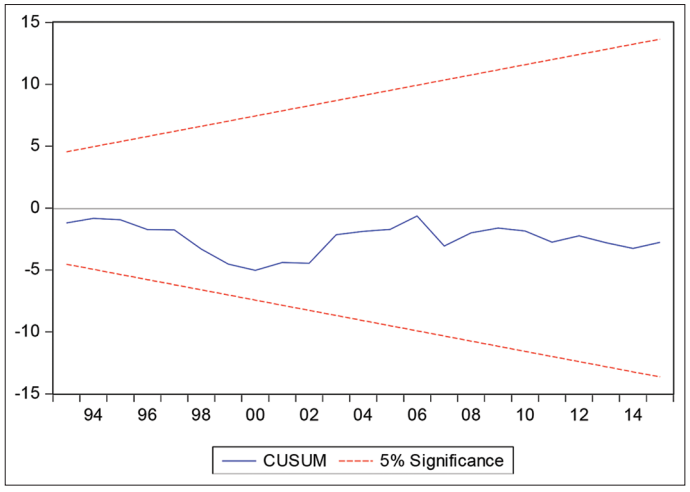

Table 2: Lag Length Results for New Zealand

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−18.06897	NA	0.000749	1.316810	1.454223	1.362359
1	73.21686	159.7502	4.39e-06	−3.826053	−3.276402	−3.643860
2	89.18937	24.95706*	2.89e-06	−4.261836	−3.299947*	−3.942997*
3	98.79603	13.20915	2.91e-06	−4.299752	−2.925624	−3.844267
4	109.3961	12.58764	2.86e-06*	−4.399759*	−2.613393	−3.807629

*LR: Sequential modified LR test statistic, FPE: Final Prediction Error, AIC: Akaike Information Criteria, SC: Schwarz information criterion, HQ: Hannan-Quinn Information Criterion

test results (Table 7, Figures 3 and 4). ARDL-ECM (ARDL Error Correction Model) is run and according to the results, coal Kuznets curve is confirmed for Finland (Table 8). The long run coefficient of GDP is positive and significant at 5%, and the long run coefficient of SQ is negative and significant at 5%.

5. CONCLUSION

Main findings of this study are as below.

i. Coal Kuznets curve is confirmed for New Zealand and Finland.
ii. This study contributes to the current literature by verifying coal Kuznets curve for New Zealand and Finland. Coal Kuznets curve is also not investigated for these countries before.

In this study, the EKC hypothesis is examined by using ARDL model. For coal consumption, long run relationship is found between growth and coal consumption for New Zealand and Finland. Finland have certain policies against coal consumption. Finland's current policy is to ban coal consumption before 2030. Finding is important since countries like Finland is an experiment

Table 3: Stability test results for ARDL model of New Zealand

	F-statistic	Jarque-Bera
RE Test	1.476031 (0.2373)	-
HE Test	1.047418 (0.4348)	-
CO Test	0.758028 (0.5653)	-
NO Test	-	2.041149 (0.360388)

Table 4: ARDL-ECM Test Results for New Zealand

	Variable	Coef.	Standard Error	t-Stat.	Probability
Short-run Coefficients	D (CS(−1))	0.102793	0.157636	0.652091	0.5208
	D (CS(−2))	0.271383	0.144308	1.880587	0.0728
	D (GDP)	4.770916	3.168924	1.505532	0.1458
	D (GDP(−1))	−14.263593	3.857773	−3.697365	0.0012
	D (SQ)	−0.231627	0.161423	−1.434910	0.1648
	D (SQ(−1))	0.742427	0.197288	3.763160	0.0010
	CointEq(−1)	−0.442717	0.114486	−3.866995	0.0008
Long-run coefficients	GDP	12.129168	3.458242	3.507322	0.0019
	SQ	−0.599427	0.177671	−3.373797	0.0026
	C	−60.796118	16.791139	−3.620726	0.0014

Table 5: UR results for Finland

	Level	First Difference
CS	−3.313695 (5%)	-
GDP	−0.935354	−4.091487 (1%)
SQ	−0.866728	−4.155341 (1%)
ENC	−1.568279	−6.613416 (1%)

Figure 2: CSQM Test Results for ARDL Model of New Zealand

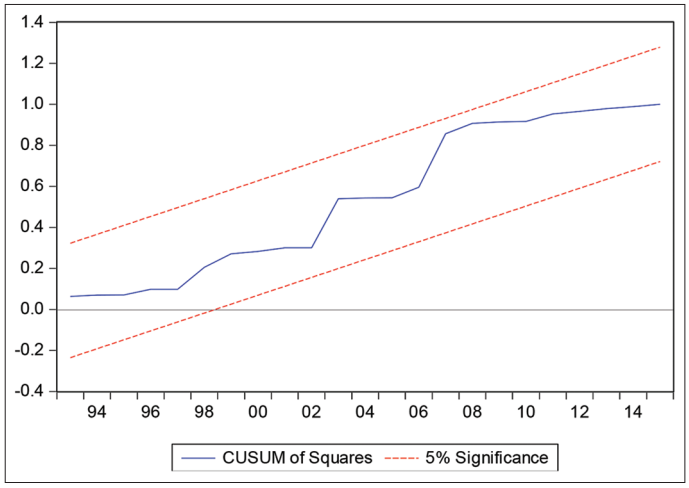

Figure 3: CSSM Test Results for ARDL Model of Finland

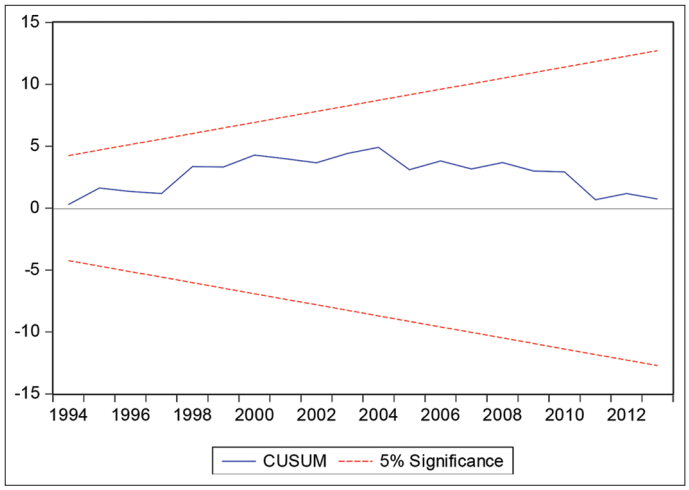

Figure 4: CSQM Test Results for ARDL Model of Finland

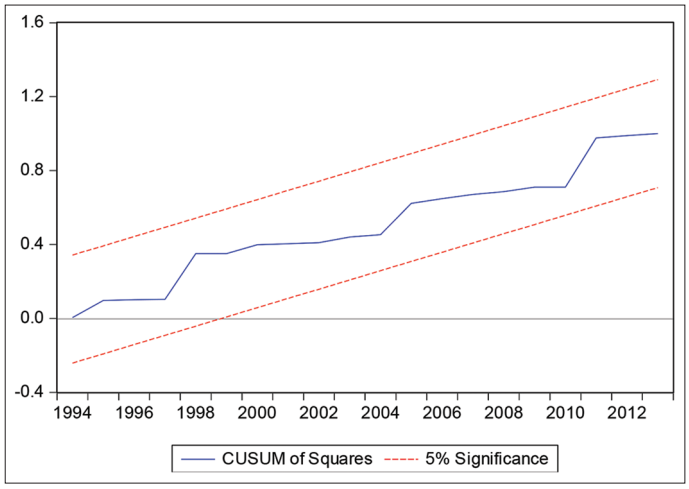

Table 6: Lag length results for Finland

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−8.459043	NA	2.70e-05	0.830603	1.017429	0.890370
1	97.11426	175.9555	6.96e-08	−5.140950	−4.206819*	−4.842114
2	122.2977	35.25677*	4.02e-08*	−5.753178	−4.071741	−5.215272*
3	138.6355	18.51619	4.66e-08	−5.775698	−3.346956	−4.998723
4	156.0706	15.11048	6.08e-08	−5.871376*	−2.695329	−4.855332

Table 7: Stability test results for ARDL Model of Finland

	F-statistic	Jarque-Bera
RE Test	0.411273 (0.5290)	-
HE Test	0.350381 (0.9613)	-
CO Test	1.247566 (0.3109)	-
NO Test	-	1.445746 (0.485356)

Table 8: ARDL-ECM Test Results for Finland

	Variable	Coef.	Standard Error	t-Stat.	Probability
Short-run Coefficients	D (CS(-1))	−0.173342	0.171012	−1.013626	0.3229
	D (GDP)	−15.432370	21.546929	−0.716221	0.4821
	D (GDP(-1))	−29.542696	25.161799	−1.174109	0.2541
	D (SQ)	0.779350	1.059203	0.735789	0.4704
	D (SQ(-1))	1.349766	1.238331	1.089988	0.2887
	D (ENC)	15.904177	2.359748	6.739777	0.0000
	D (ENC(-1))	1.400658	4.252801	0.329349	0.7453
	CointEq(-1)	−0.638493	0.141473	−4.513189	0.0002
Long-run Coefficients	GDP	53.568471	14.608278	3.666994	0.0015
	SQ	−2.598180	0.713300	−3.642481	0.0016
	ENC	22.500556	3.880123	5.798928	0.0000
	C	−442.005056	66.285110	−6.668241	0.0000

for bigger countries such as USA. Countries like USA can apply similar policies that are carried out by Finland. Current market mechanisms are in favor of renewable energy generation systems over fossil fuel systems such as coal.

Renewable energy prices are falling and since consumers are becoming more aware of climate change, investing in coal-based energy plants are getting riskier. Since risk increases, investors are becoming less likely to invest in new coal-based energy plants. Current trend shows that closure of coal-based energy plants will exceed the opening of new coal-based energy plants.

Energy generation from coal will not finish in the short run but energy generation from coal will likely decrease significantly and current growth levels of developed and developing countries are in favor of reduction of coal consumption. Finding inverted U curve between coal consumption and growth is important since coal consumption alone is responsible for 30% of energy related carbon dioxide emissions.

For further similar studies in the literature of coal Kuznets curve, Magazzino et al. (2020) examined the relationship between coal consumption, emissions and economic growth for South Africa for the period 1965 to 2017. Magazzino et al. confirmed coal Kuznets curve for South Africa. Wang et al. (2018) examined the relationship between coal consumption, economic growth, investment, energy structure and industrial structure for the period 1981 and 2015, and analyzed the peak of coal consumption in China. Wang et al. confirmed that industrial structure and investment had a significant effect on coal consumption and confirmed coal consumption peaked under business as usual scenario. Qiao et al. (2019) examined the relationship between coal consumption and economic growth for a panel of Chinese provinces for the period 2000 to 2016. Qiao et al. confirmed coal Kuznets curve for national level in China. Qiao et al. also stated that provincal level differences should be taken into account for determining energy policies.

This study confirmed coal Kuznets curve for New Zealand and Finland as Magazzino et al. (2020) and Qiao et al. (2019), and Beşe et al. (2020) confirmed coal Kuznets curve for South Africa, China and China respectively.

This study recommends further investigation of coal consumption-growth nexus carries importance since the only study in the literature for coal consumption-growth nexus belongs to this study for New Zealand and Finland.

The time periods analyzed and the countries of the study which are New Zealand and Finland are the limits of this study.

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