Time-Varying Impact of Financial Development on Carbon Emissions in G-7 Countries: Evidence from the Long History

Shahbaz, Muhammad and Destek, Mehmet Akif and Dong, Kangyin and Jiao, Zhilun

Beijing Institute of Technology, Beijing 100081, China, Gaziantep University, Gaziantep 27410, Turkey, University of International Business and Economics, Beijing 100029, China, Nankai University, Tianjin 300071, China

4 June 2021

Time-Varying Impact of Financial Development on Carbon Emissions in G-7 Countries: Evidence from the Long History

Muhammad Shahbaz
School of Management and Economics,
Beijing Institute of Technology, Beijing 100081, China
Email: muhdshahbaz77@gmail.com

Mehmet Akif Destek
Faculty of Economics and Administrative Sciences,
Gaziantep University, Gaziantep 27410, Turkey
Email: adestek@gantep.edu.tr

Kangyin Dong*
School of International Trade and Economics,
University of International Business and Economics, Beijing 100029, China
Email: dongkangyin@uibe.edu.cn

Zhilun Jiao
College of Economic and Social Development,
Nankai University, Tianjin 300071, China
Email: zjiao@nankai.edu.cn

Abstract: Financial development has been widely proved to be a key driver of economic growth; however, its environmental impact is still inconclusive, especially for G-7 countries (i.e. Canada, France, Germany, Italy, Japan, the United Kingdom (UK), and the United State (US)). This paper, therefore, investigates the time-varying impact of financial development on carbon dioxide (CO_2) emissions for G-7 countries over a long historical period. The study analyzes historical data from 1870 to 2014 for each country using bootstrap time-varying co-integration (TVC) and bootstrap rolling window estimation approaches. In addition, the polynomial trends of the estimated parameters are obtained to observe the relationship between financial development and carbon emissions. The empirical findings reveal that the impact of financial development on CO_2 emissions over a long history is M-shaped in Canada, Japan, and the US; inverted N-shaped in France, Italy, and the UK; and inverted M-shaped (W-shaped) in Germany. This empirical evidence opens new directions for policy makers to design comprehensive economic policy for using the financial sector as an economic tool to keep environmental quality at sustainable levels.

Keywords: Financial Development; CO_2 Emissions; Non-linear Analysis; Time-varying Co-integration (TVC); G-7

JEL Classification: C32, G10, Q54, R11

I. Introduction

Climate change and global warming have been the severest and most controversial global challenges requiring urgent attention from world leaders (Boutabba, 2014, Chen et al., 2020a, Cheng et al., 2021, Zhao and Yang, 2020). The past few decades have witnessed rapidly rising carbon dioxide (CO_2) emissions across the globe, with a strong surge from 11,207.7 million tons in 1965 to 34,169.0 million tons in 2019, based on statistics from BP (formerly British Petroleum) (BP, 2020). Accordingly, the global community has started to pay attention to environmental problems associated with increasing CO_2 emissions, and in an attempt to bring these problems under control, many nations around the world have implemented a series of measures to address global climate change (Dong et al., 2020a,b, Ma et al., 2020, Ren et al., 2021, Wei et al., 2021, Zhao et al., 2021a).

On the other hand, since the global financial crisis, the role of financial development in CO_2 emissions has received much attention among policymakers and researchers (Acheampong et al., 2020), and some scholars argue that financial development can effectively reduce CO_2 emissions (Khan et al., 2021, Paramati et al., 2017, Shahbaz et al., 2013b, 2018, Zhao et al., 2021b). Supporters of this view insist that financial development can not only help local government to enhance resource allocation efficiency and understand the condition of regional pollution and economic growth (Mu, 2018), but can also help enterprises promote technology innovation and adopt new low-carbon technologies, so as to increase energy efficiency and advance low-carbon economic development; therefore, CO_2 emissions will be effectively reduced (Zhang, 2011). However, some scholars oppose the arguments above (Acheampong, 2019, Boutabba, 2014, Yin et al., 2019); they believe financial development may attract foreign direct investment (FDI) that will accelerate economic growth and, thus, promote an increase in CO_2 emissions. Also, they believe prosperous and efficient financial intermediation makes it easier for consumers to buy big-ticket items with loans and, thus, emit more CO_2 emissions (Zhang, 2011). As a result, the impact of financial development on CO_2 emissions is unclear up to now, and further investigation of the financial development–carbon emissions nexus is particularly useful not only for mitigating global warming, but also for promoting growth in the financial sector.

As an international group of governments or states from seven leading economies (i.e., Canada, France, Germany, Italy, Japan, the United Kingdom (UK), and the United States (US), the G-7 countries have a great impact on the world's economic development and the global greenhouse effect. Specifically, the G-7 countries, which accounted for approximately 45.1% of the global economy and emitted approximately 25.4% of global CO_2 emissions in 2018, are considered the world's leading economies and CO_2 emitters. Therefore, to relieve the global warming effect, it should be a matter of great urgency for the G-7 countries to coordinate the tasks of global emission reduction. Meanwhile, as the world's leading economies, the degree of financial development in the G-7 countries increases every year. Moreover, the G-7 countries, which include four of the world's top five financially developed countries (i.e. the UK, Canada, the US, and Japan), have become the most developed financial regions across the globe (IMF, 2020). Therefore, further investigation of the impact of financial development on CO_2 emissions for the G-7 countries is necessary. However, the financial development-carbon emissions nexus of the G-7 countries – comprising the world's leading economies and top CO_2 emitters – has received scant attention from scholars for a long period of time. Also, to the best of our knowledge, few studies have considered the country-level heterogeneities among G-7 countries. Furthermore, although existing studies have widely and deeply discussed the linear relationship between financial development and CO_2 emissions, potential nonlinear relations have not been systematically analyzed.

To fill the above academic gaps, this study investigates the time-varying impact of financial development on CO_2 emissions for G-7 countries using historical data between 1870 and 2014 for each country, and a bootstrap time-varying co-integration test and a bootstrap rolling window estimation approach. Also, to observe the shape of the potential nonlinear relationship between financial development and CO_2 emissions, the polynomial trends of the estimated parameters are obtained. Accordingly, this study contributes to the existing literature in three ways: (i) This is the first study to estimate the time-varying relationship between financial development and CO_2 emissions for the case of the G-7 countries; (ii) we estimate the common trend and country-specific trends for the G-7 countries. In other words, the potential country-level heterogeneities among G-7 countries are considered, which can offer new evidence for developing specific policies to tackle CO_2 emissions and promote growth in the financial sector of each G-7 country; and (iii) to investigate the potential nonlinear relationship between financial development and CO_2 emissions, the polynomial trends of the estimated parameters are further observed. The benefit of such an examination is that a clearer analysis of the impact of financial development on CO_2 emissions for each G-7 country over a long period of time can be highlighted. Our findings reveal that there is an M-shaped association between financial development and carbon emissions in Canada, Japan, and the US. Furthermore, an inverted N-shaped nexus is confirmed in France, Italy, and the UK. Interestingly, the inverted M-shaped (W-shaped) relationship between financial development and CO_2 emissions is valid only in Germany.

The remainder of this study is prepared as follows. Section-II deals with prior literature. Section-III details the empirical strategy. The empirical findings are described and discussed in Section-IV, while Section-V contains conclusions and policy implications.

II. Literature Review

Along with the rapidly increasing financial development and CO_2 emissions, further investigation of the financial development–carbon emissions nexus is particularly useful for mitigating CO_2 emissions. Therefore, a growing body of studies has investigated the impact of financial development on CO_2 emissions at the country, regional, and global levels (see Table-1). First, scholars who have explored the impact of financial development on CO_2 emissions at the country level include Abbasi and Riaz (2016) and Shahbaz et al. (2016) for Pakistan; Ali et al. (2017) and Shahbaz et al. (2013b) for Malaysia; Boutabba (2014) and Sehrawat et al. (2015) for India; Moghadam and Dehbashi (2018) for Iran; Ozturk and Acaravci (2013) for Turkey; Shahbaz et al. (2018) for France; Shahbaz et al. (2013a) for Indonesia; and Ahmad et al. (2018), Lahiani (2020), Umar et al. (2020), Xiong and Qi (2018), Yin et al. (2019), Zhao and Yang (2020), and Zhang (2011) for China. For cross-country case studies, Paramati et al. (2017) analyze the role of financial development in CO_2 emissions for the case of G20 countries; similar studies at the regional level have been conducted by Abdouli and Hammami (2020) for Middle East countries; Acheampong (2019) for 46 sub-Saharan Africa countries; Adams and Klobodu (2018) for 26 African countries; Charfeddine and Khediri (2016) and Shahbaz et al. (2020) for the United Arab Emirates (i.e., a federation of seven emirates, including Abu Dhabi, Ajman, Dubai, Fujairah, Ras-al-Khaimah, Sharjah, and Ummal-Quwain); Koengkan et al. (2019) for Latin American and Caribbean countries; Le et al. (2020) for 31 Asian countries; Saleem et al. (2020) for selected Asian countries; Seetanah et al. (2019) for 12 selected small island developing states; Wang et al. (2020a) for G-7 countries; Wang et al. (2020b) for N-11 countries; Shoaib et al. (2020) for eight developing countries (D8) and eight developed countries (G8); Tamazian et al. (2009) for BRIC countries (i.e. Brazil, Russia, India, and China); and Ziaei (2015) for

European, East Asian, and Oceania countries. In addition to country and regional levels, some scholars have explored the relationship between these two variables at the global level, including Acheampong et al. (2020) for 83 countries; Cetin and Bakirtas (2020) for 15 emerging markets; Ehigiamusoe and Lean (2019) for 122 countries; Dogan and Seker (2016) for the top renewable energy countries; Kayani et al. (2020) for the top ten CO_2 emitter countries; Nasreen and Anwar (2015) for 59 countries; Renzhi and Baek (2020) for 103 countries; and Tamazian and Rao (2010) for 24 transition economies.

Although the impact of financial development on CO_2 emissions has gained increasing attention in the recent literature, evidence concerning their nexus is mixed and can be easily categorized into three strands. The first strand of the literature indicates financial development has a negative impact on CO_2 emissions. For instance, by employing time series data over the period 1955-2016, Shahbaz et al. (2018) explore the impact of financial development on CO_2 emissions for the case of France; they conclude that financial development can lower French CO_2 emissions. Similarly, Umar et al. (2020) examine the long-run and causal effects of financial development on CO_2 emissions in China using the combined co-integration and wavelet coherence approaches over the period 1971 to 2018; they discover that in the long run, there are negative correlations between CO_2 emissions and financial development for the case of China. Furthermore, Paramati et al. (2017), Renzhi and Baek (2020), Saleem et al. (2020), Shahbaz et al. (2013b), and Zhao and Yang (2020) report the same results for the financial development-carbon emissions nexus, indicating that the effect of financial development on CO_2 emissions is negative. The second strand of literature suggests a positive effect of financial development on CO_2 emissions. For example, Boutabba (2014) examines the long-run impact of financial development on CO_2 emissions in India and concludes that financial development has had a long-run positive impact on the country's CO_2 emissions.

Wang et al. (2020b) analyze the dynamic effect of financial development on CO_2 emissions for N-11 countries from 1990 to 2017 and reveal a positive relationship between CO_2 emissions and financial development as well as economic growth. Similar findings are also confirmed by Acheampong (2019), Cetin and Bakirtas (2020), Kayani et al. (2020), Le et al. (2020), Shoaib et al. (2020), Tamazian and Rao (2010), Wang et al. (2020a), and Yin et al. (2019). The third strand of literature implies that no significant linkage exists between financial development and CO_2 emissions. For instance, Ozturk and Acaravci (2013) find that financial development has no significant effect on CO_2 emissions in the case of Turkey. Using the case of 12 emerging economies, Koshta et al. (2020) explore the causal relationship between CO_2 emissions, GDP, financial development, agriculture value-added, foreign trade, and renewable and nonrenewable energy consumption for the period 1990 to 2014; they find that financial development does not have a statistically significant impact on CO_2 emission. Similarly, according to Acheampong et al. (2020), Bekhet et al. (2017), Charfeddine and Khediri (2016), Omri et al. (2014), and Tamazian and Rao (2010), there is no significant relationship between financial development and CO_2 emissions.

Table-1: Summary of Studies on the Emission-Financial Development Nexus.

Author [ref.]	**Study area**	**Study period**	**Results**
Part I: Country level			
Abbasi and Riaz, 2016	Pakistan	1990-1990	Positive
Ahmad et al., 2018	China	1980-2014	Positive
Ali et al., 2017	Malaysia	1971-2012	Positive
Boutabba, 2014	India	1971-2008	Positive
Lahiani, 2020	China	1977-2013	Negative
Moghadam and Dehbashi, 2018	Iran	1970-2011	Positive
Ozturk and Acaravci, 2013	Turkey	1960-2007	No
Sehrawat et al., 2015	India	1971-2011	Positive
Shahbaz et al., 2013a	Indonesia	1975-2011	Negative
Shahbaz et al., 2013b	Malaysia	1971-2011	Negative
Shahbaz et al., 2016	Pakistan	1985-2014	Positive

Shahbaz et al., 2018	France	1955-2016	Negative
Xiong and Qi, 2018	China	1997-2011	Negative
Yin et al., 2019	China	2007-2014	Negative
Zhao and Yang, 2020	China	1995-2010	Negative
Zhang, 2011	China	1980-2009	No
Part II: Regional level			
Abdouli and Hammami, 2020	Middle East countries	1980-2014	Negative
Acheampong, 2019	46 sub-Saharan Africa countries	2000-2015	Positive
Adams and Klobodu, 2018	26 African countries	1985-2011	Positive
Charfeddine and Khediri, 2016	UAE	1975-2011	No
Koengkan et al., 2019	Latin American and Caribbean countries	1980-2014	Positive
Paramati et al., 2017	G20 countries	1991-2012	Negative
Seetanah et al., 2019	12 selected small island developing states	2000-2016	Negative
Shahbaz et al., 2020	UAE	1975-2014	Positive
Tamazian et al., 2009	BRIC countries	1992-2004	Negative
Ziaei, 2015	European, East Asian and Oceania countries	1989-2011	No
Part III: Global level			
Acheampong et al., 2020	83 countries	1980-2015	No
Dogan and Seker, 2016	Top renewable energy countries	1985-2011	Negative
Ehigiamusoe and Lean, 2019	122 countries	1990-2014	No
Nasreen and Anwar, 2015	59 countries	1980-2010	No
Tamazian and Rao, 2010	24 transition economies	1993-2004	No

Notes: 'Positive' in the last column in Table-1 indicates that financial development has a positive impact on CO_2 emissions, 'Negative' suggests a negative impact of financial development on CO_2 emissions, and 'No' implies that no significant linkage exists between financial development and CO_2 emissions.

Although scholars have explored the impact of financial development on CO_2 emissions, certain research gaps still exist. First, as the G-7 countries comprise the world's leading economies and CO_2 emitters, and represent the most developed financial regions, it is important to explore the dynamic relationships among economic growth, financial development, and CO_2 emissions among these countries; however, to date very few studies have focused on the impact of financial development on CO_2 emissions in the G-7 countries over a long period. Second, significant differences exist in the nexus between financial development and CO_2 emissions across various G-7 countries and, thus, the impact of financial development on CO_2 emissions in different G-7 countries may be heterogeneous; however, to the best of our knowledge, the previous literature has often ignored significant country-level heterogeneities among the G-7 countries. Third, most existing studies assume that the linkage between financial development and CO_2 emissions is linear; however, very few studies have systematically discussed the potential nonlinear relations between the two variables, especially for the case of G-7 countries.

III. Empirical Strategy

III.I. Data

In this study's empirical analysis, we have used the annual data of financial development and CO_2 emissions of G-7 countries for the period 1870 to 2014. As Calderón and Liu (2003) indicate, a higher M2 implies a larger financial sector and therefore greater financial intermediary development. Therefore, in this study, the financial development is measured by M2, which is the ratio of broad money to GDP. The data of M2 were extracted from the Global Financial Data (GFD) database (see https://library.udel.edu/databases/global-financial-data/). In addition, the data on CO_2 emissions are used as metric ton per capita and downloaded from the Carbon Dioxide Information Analysis Center (see https://cdiac.ess-dive.lbl.gov/). The dataset was created in 2014, which enabled us to access these long historical data.

III.II. Time-Varying Co-integration

Especially in equilibrium relations with long-term historical trends, structural breaks are more likely to be seen, and these breaks cause breaks in the co-integration relationship between variables, which is the main reason for the need for co-integration tests that change over time (Martins, 2015). In this direction, we benefited from the time-varying co-integration (TVC) test developed by Bierens and Martins (2010) due to the existence of our dataset containing the historical trend between 1870 and 2014. In the procedure of this test, we first constructed a time-varying VECM (p) model in which the co-integration vectors change smoothly over time, as follows:

$$\Delta Y_t = \mu + \sum_{j=1}^{p-1} \Phi_j \Delta Y_{t-j} + \alpha\beta_t' Y_{t-1} + \varepsilon_t, \quad t = 1, \dots, T \tag{1}$$

where β_t' refers to the time-varying $k*r$ matrix, and the other coefficients are fixed. In this case, the null hypothesis of the time-invariant co-integration $H_0: \beta_t = \beta$ for all t is checked to the alternative hypothesis of the TVC. In addition, the assumption that the TVC vector changes smoothly over time is constructed with the following function:

$$\beta_t = \beta_m(t/T) = \sum_{i=0}^{m} \xi_{i,T} P_{i,T}(t)\,, \quad t = 1, \dots, T \tag{2}$$

where m is the order of Chebyshev; $P_{i,T}(t)$ denotes the orthonormal Chebyshev period polynomial, which can be formulized as $P_{0,T}(t) = 1, P_{i,T}(t) = \sqrt{2}\cos\left(\frac{i\pi(t-0.5)}{T}\right)$; $\xi_{i,T} = \frac{1}{T}\sum_{t=1}^{T} \beta_T P_{i,T}(t)$ indicate the Fourier coefficient; and $1 \le m < T-1$.

In the next procedure, Equation-1 can be written as $\Delta Y_t = \alpha\xi' Y_{t-1}^{(m)} + \Upsilon X_t + \varepsilon_t$, with

$$Y_{t-1}^{(m)} = (Y'_{t-1}, P_{1,T}(t)Y'_{t-1}, P_{2,T}(t)Y'_{t-1}, \dots, P_{m,T}(t)Y'_{t-1})'. \quad (3)$$

Finally, the LR test statistics are defined as $LR_{m,T}^{tvc} = T\sum_{j=1}^{r} ln\left(\frac{1-\widehat{\lambda_{0J}}}{1-\widehat{\lambda_{mJ}}}\right)$, where $1 > \lambda_{m1} \geq \lambda_{m2} \geq \cdots \geq \lambda_{mr} \geq \cdots \geq \lambda_{m,(m+1)k}$ are the ordered solutions of the following generalized eigenvalue problem: $\det\left[\lambda S_{11,T}^{(m)} - \lambda S_{10,T}^{(m)}\lambda S_{00,T}^{-1}\lambda S_{01,T}^{(m)}\right] = 0$, with

$$S_{00,T} = \frac{1}{T}\sum_{t=1}^{T}\Delta Y_t \Delta Y'_t - \left(\frac{1}{T}\sum_{t=1}^{T}\Delta Y_t X'_t\right)\left(\frac{1}{T}\sum_{t=1}^{T} X_t X'_t\right)^{-1}\left(\frac{1}{T}\sum_{t=1}^{T} X_t \Delta Y'_t\right) \quad (4)$$

$$S_{11,T}^{(m)} = \frac{1}{T}\sum_{t=1}^{T} Y_{t-1}^{(m)} Y_{t-1}^{(m)\prime} - \left(\frac{1}{T}\sum_{t=1}^{T} Y_{t-1}^{(m)} X'_t\right)\left(\frac{1}{T}\sum_{t=1}^{T} X_t X'_t\right)^{-1}\left(\frac{1}{T}\sum_{t=1}^{T} X_t Y_{t-1}^{(m)\prime}\right) \quad (5)$$

$$S_{01,T}^{(m)} = \frac{1}{T}\sum_{t=1}^{T}\Delta Y_t Y_{t-1}^{(m)\prime} - \left(\frac{1}{T}\sum_{t=1}^{T}\Delta Y_t X'_t\right)\left(\frac{1}{T}\sum_{t=1}^{T} X_t X'_t\right)^{-1}\left(\frac{1}{T}\sum_{t=1}^{T} X_t Y_{t-1}^{(m)\prime}\right) \quad (6)$$

$$S_{10,T}^{(m)} = \left(S_{01,T}^{(m)}\right)' \quad (7)$$

In the case of both $m \geq 1$ and $r \geq 1$, Bierens and Martins (2010) argue that $LR_{m,T}^{tvc}$ follows χ_{mkr}^2 distribution. However, Bierens and Martins (2010) show that the test statistics suffer from size distortions and tend to over-reject the null hypothesis in the case of small T and large m. Based on this reason, Martins (2018) developed the bootstrap version of $LR_{m,T}^{tvc}$ statistics. Therefore, we used both the TVC test of Bierens and Martins (2010) and the bootstrap TVC test of Martins (2018) for robustness.

III.III. Time-Varying Estimation

In order to observe the time-varying impacts of financial development on the environment, this study employs the bootstrap rolling window technique proposed by Balcilar et al. (2010). The estimation procedure of this technique which is based on the bivariate VAR(p) process can be explained as follows:

$$\begin{bmatrix} y_{CO,t} \\ y_{FD,t} \end{bmatrix} = \begin{bmatrix} \varphi_{CO} \\ \varphi_{FD} \end{bmatrix} + \begin{bmatrix} \varphi_{CO,CO}(L) & \varphi_{CO,FD}(L) \\ \varphi_{FD,CO}(L) & \varphi_{FD,FD}(L) \end{bmatrix} \begin{bmatrix} y_{CO,t} \\ y_{FD,t} \end{bmatrix} + \begin{bmatrix} \varepsilon_{CO,t} \\ \varepsilon_{FD,t} \end{bmatrix} \tag{8}$$

where $y_{X,t}{}'s$ indicate the natural logarithms of both variables, respectively. Further, $\varepsilon_{X,t}$'s are stochastic noise progressions with the mean at zero, and with the non-singular covariance matrix Σ and $\varphi_{ij}(L) = \sum_{k-1}^{p} \varphi_{ij,k} L^k$, $i,j = CO, FD$ where the lag operator (L) is computed as $L^k x_t = x_{t-k}$ (Balcilar et al. 2010). In such a situation, the impact of financial development on carbon emissions is estimated as follows:

$$B^{-1} \sum_{k-1}^{P} \hat{\varphi}^{*}_{CO,FD,k} \tag{9}$$

where B^{-1} represents the number of bootstrap repetitions, and $\hat{\varphi}^{*}_{CO,FD,k}$ is obtained from the bootstrap estimation of the VAR model in Equation-1. Moreover, the 95 percent level confidence interval is computed as determining the upper and lower bounds with the 97.5 and 2.5 quantiles of $\hat{\varphi}^{*}_{CO,FD,k}$, respectively (Nyakabawo et al. 2015).

IV. Empirical Findings and Discussion

We focused on examining the long-run relationship between financial development and carbon emissions. Although the relationship between the variables has generally been examined under the assumption of a linear relationship, the possibility of financial development creating a quadratic or cubic environmental impact has also been included in the empirical system in recent years. However, it is possible to see that the probability of a quadratic or cubic relationship here is due to the researcher's premise assumptions before starting the analysis. Therefore, while studying the long-run relationship between financial development and carbon emissions, we experience two basic differences instead of acting with a premise assumption. First, while observing the co-integration relationship, we tested a time-invariant relationship against a time-variant relationship to see if the effect has changed over time, which gives us a chance to observe and purify the effects of sudden shocks that disrupt a linear or non-linear course. Second, if there is a parabolic relationship, it gives us information on how many polynomial trends we should add, rather than a subjective assumption regarding the number of turning points.

Further, we applied the TVC test developed by Bierens and Martins (2010) and the bootstrap TVC test proposed by Martins (2018) to obtain consistent findings while examining the validity of the TVC relationship. As presented in Table-2, time-invariant co-integration between the variables is strongly rejected at most 4 (m = 4) Chebyshev polynomials according to both TVC tests. This shows that the relationship between financial development and carbon emissions is too complex to be reduced to a linear relationship, so the environmental impacts of financial development should be examined through time-varying parameters. We also deduce that a maximum of four polynomial trends should be taken into account when determining the turning points of time-varying parameters.

Table-2: Results of TVC Tests.

Countries	**Test Statistic**	**Bierens and Martins (2010) TVC**		**Martins (2018) Bootstrap TVC**	
		5% CV	**p-value**	**5% CV**	**p-value**
Canada					
m=1	1.347	5.991	0.509	13.055	0.837

m=2	18.480	9.487	0.001	12.185	0.007
m=4	41.426	15.507	0.000	20.301	0.000
France					
m=1	2.861	5.991	0.239	6.064	0.255
m=2	11.913	9.487	0.018	11.601	0.042
m=4	36.320	15.507	0.000	25.138	0.007
Germany					
m=1	10.610	5.991	0.005	8.389	0.027
m=2	31.048	9.487	0.000	13.417	0.000
m=4	40.729	15.507	0.000	26.620	0.000
Italy					
m=1	10.320	5.991	0.005	13.569	0.098
m=2	15.755	9.487	0.003	23.939	0.145
m=4	63.994	15.507	0.000	28.287	0.000
Japan					
m=1	26.711	5.991	0.000	8.777	0.052
m=2	30.266	9.487	0.000	29.015	0.037
m=4	51.262	15.507	0.000	40.239	0.005
UK					
m=1	11.485	5.991	0.003	6.545	0.012
m=2	12.430	9.487	0.014	9.231	0.012
m=4	25.726	15.507	0.001	15.881	0.005
US					
m=1	1.005	5.991	0.606	12.574	0.844
m=2	16.277	9.487	0.002	17.002	0.060
m=4	33.871	15.507	0.000	27.605	0.002

Note: We follow Lucey et al. (2017) in reporting results for m up to four and conclude that time-variation is observed unless at least one m fails to reject the null hypothesis.

Now we observe the time-varying impact of financial development on carbon emissions with a rolling window estimation technique, and the findings are plotted in Figure-1. A closer inspection of Canada shows that positive and negative effects of financial development are observed from period to period, and fluctuate constantly throughout the observed process. First of all, it is possible to interpret that the negative effect in the sub-period 1885-1893 was due to the panic of 1873. The main reason for this negative impact is the failure of the financial system to fund a production process that causes an increase in carbon emissions. The stock market crash in North America was typical of such a crisis. After this period, in the sub-period of 1894-1920, emissions-increasing financial development is generally noticeable. Interestingly, Brown and Cook (2016) stated that Canada recorded the fastest growing economic performance in the world for the period 1896-1914, under the influence of settlement of the west. During this period, financial development and economic performance led to an increase in industrial production in that they fed each other, thus leading to an increase in emissions between 1921 and 1963 (negative). The positive effect of financial development is noticeable in the sub-period 1964-1981. This effect was possibly attributed to the National Oil Policy of Canada. The aim of this policy, prepared in 1964 after the discovery of new fossil resources, was to promote the Alberta oil industry by securing a protected share of the domestic market. As a natural result of these incentives, financial investments also focused on the oil industry, which led to an increase in emissions. After two major oil crises in the 1970s, Canada, like many countries, sought an alternative energy source in the early 1980s. Thus, since 1982, the provinces in Canada have been empowered to explore and develop renewable and non-renewable energy sources, and to manage facilities (and sites) responsible for generating electricity. Similar to our findings, He and Richard (2010) claimed that the oil shock of the 1970s was an important trigger for the transition to less polluting technology and production in Canada. In line with our findings, financial development contributed to the environment in the 1982-1999 sub-period because of funds provided by the financial system to R&D projects. Although the negative effect in question decreased periodically, it started to become more evident, especially after 2009. This situation can be evaluated as a result of the Green Energy and Green Economy Act (GEGEA) project that was put into practice in 2009. The objectives of this project are to bring more renewable energy sources to the provinces and to establish an energy efficiency measure. In the bill, even homeowners were provided with facilities such as low or interest-free loans to finance the capital cost of renewable energy-generating facilities such as solar panels.

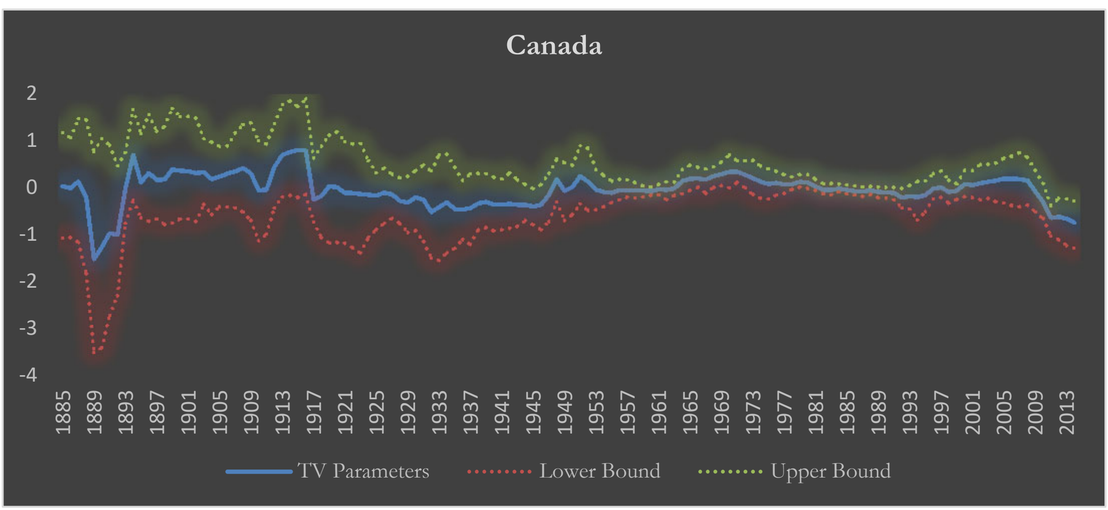
In France, as in Canada, the financial sector funded the emissions-increasing industrial sector during the last quarter of the 19th century and the early 20th century, an era known as the Second Industrial Revolution. As a matter of fact, the emissions-increasing effect of financial development stands out in the sub-period 1885-1945, excluding the short sub-periods of 1923-1928 and 1934-1939, especially during World War II. The short-term negative effects in question are largely due to the lagged effects of the Great Depression on France. As a matter of fact, private investments in France decreased by approximately 61.6% between 1930-1939 (Beaudry and Portier, 2002). In addition, the emissions-increasing effect reversed in the 10-year period after World War II, and the effect was negative between 1946 and 1956. Conversely, the emissions-increasing effect was seen again in the 1957-1980 sub-period. Interestingly, 1957 is considered to be the year France began developing its natural gas after discovering a gas field in Lacq, in the southwestern part of the country. Investors in the energy sector directed their resources to the newly developing natural gas sector during this period. During the oil crisis of the 1970s France's financial activities continued to increase pollution. Although the National Center for Scientific Research (CNRS) launched renewable energy research in the late 1970s, France, an important nuclear power, had difficulty adapting to and adopting renewable energy technologies. The empirical findings also suggest that the financial sector continued to invest in existing high-profit areas rather than high-cost, short-term renewable energy research. The negative impact observed in the 1981-1993 sub-period is closely related to the recession the country experienced in the 1980s. The fact that existing investment areas are regarded as risky reveals that companies conducting research in the field of renewable energy are funded to a small extent. As a matter of fact, after the economic recovery, the financial development of carbon emissions continued in the sub-period of 1994-2007. Finally, the emissions-reducing financial impact during the 2008-2014 sub-period has emerged largely as a result of adherence to the EU renewable energy directive of 2009. The financial sector has also evaluated the opportunities the country has to use in order to fulfill these obligations, and has started to contribute to the reduction of emissions.

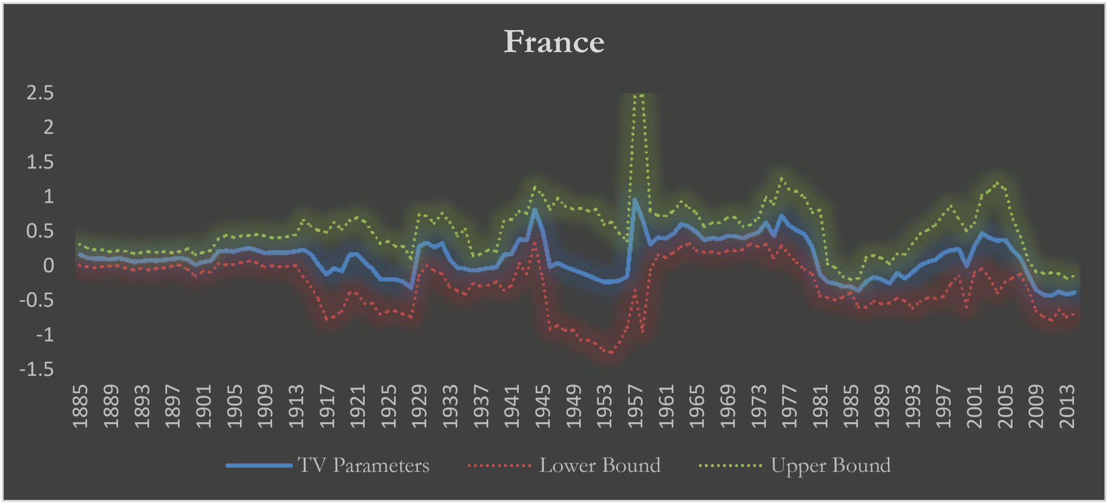
In Germany, in the sub-period of 1885-1931, the emissions-increasing effect of financial development took place due to rapid industrialization and the transfer of financial resources to emissions-increasing activities. However, the effect was negative in the 1932-1944 sub-period, which interestingly included the Nazi era, and provided incentives for military force especially for the government. In the post-war period, during which the German economy made its biggest contribution to industrialization, the pollution-enhancing effect of financial development remained intact until 1983. As seen in other countries, after the second oil crisis in 1978, Germany turned to alternative energy sources, and established the first big wind farm in 1983. This trend has increased steadily and as of 2019, Germany ranked third in the world after China and the US in terms of wind energy capacity (Song et al., 2020). Our findings also reveal the presence of an emissions-reducing effect of financial development in the 1983-2010 period. The financial sector also financed researches on renewable energy technologies in this period. However, unlike other observed countries, the emissions-increasing effect of financial development was determined during period 2010-2014.

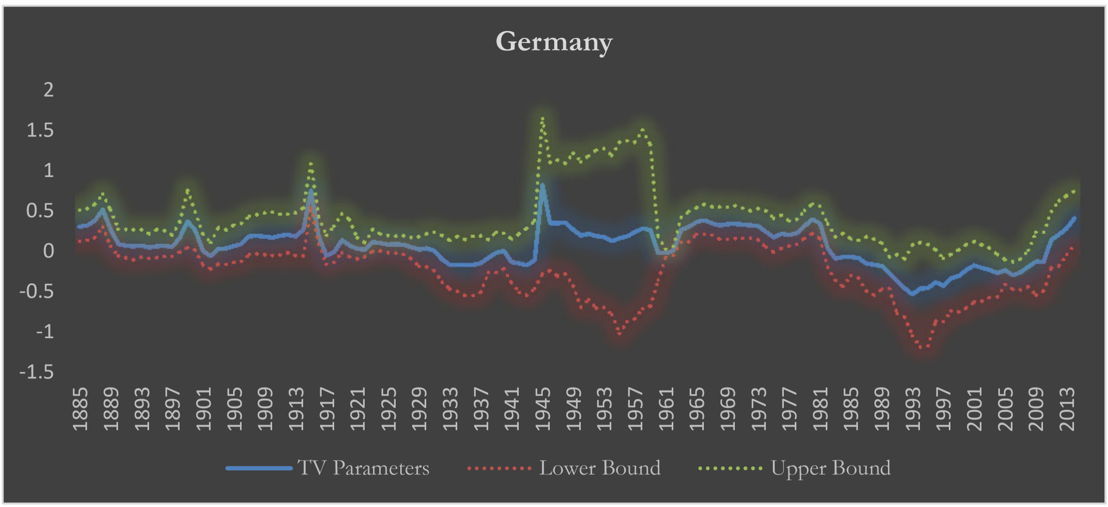
In Italy, as a natural outcome of industrialization strategy, financial instruments were used in emissions-enhancing areas in the 1885-1939 sub-period (except for the 1901-1905 period). The negative impact of financial development on emissions in the 1940-1957 sub-period was a result of hydroelectric energy investments, which started to increase in the 1940s. As a matter of fact, the use of hydroelectricity occupied an important place in the country's energy consumption portfolio until the 1960s. Low fossil-fuel prices in the 1960s put hydropower in second place. The fact that our findings point to an emissions-increasing effect of financial development in the 1958-1993 sub-period shows that investors also turned to emissions-increasing areas in the 1960s due to this cost advantage. The only exception during this period was a negative impact between 1976-1981, as a consequence of oil crises. Even if there was a periodic positive effect in Italy during the 1994-2014 period, the financial sector generally provided funding for the renewable energy sector.

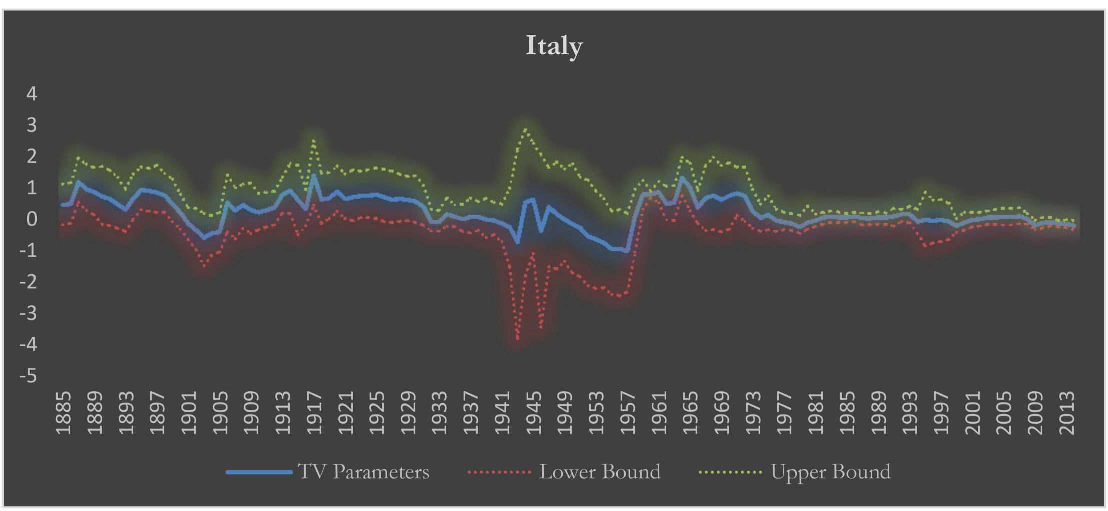
In the case of Japan, during the 1885-1936 sub-period, rapid industrialization resulted in financial resources being transferred to areas based on fossil fuel consumption; therefore, financial development increased carbon emissions. During the 1937-1960 period, the pollution-enhancing effect of financial development reversed because financial resources were transferred to the restructuring process during World War II and after it. The emissions-increasing effect observed in the 1961-1973 sub-period is not surprising and applied in all countries. This period, known as “the golden age of capitalism,” during which financial instruments also served the industrial sector, saw industrial production peak. The negative impact of financial development on carbon emissions in the 1974-1988 sub-period was due to the search for alternative energy resulting from oil crises, similar to other countries. Indeed, since the early 1970s, the Japanese government has encouraged the settlement of nuclear power plants through various policy instruments, including soft social control and financial incentives. Starting in the mid-1990s, investors have considered the nuclear power sector controversial and risky due to events such as the Tokaimura nuclear accident, the Mihama vapor explosion, and an accident in the Monju reactor. This situation increased the use of fossil-fuel resources in production especially during the 2000s. However, in recent years, the share of renewable energy consumption of total energy consumption has started to increase slightly (WDI, 2020). The emissions-increasing effect observed in the 1989-2014 sub-period is an inevitable result of the excessive increase in fossil-fuel use especially in the 2000s. On the other hand, the fact that the emissions-increasing effect approached 0 after 2002 indicates that financial resources predominantly finance renewable energy technologies.

In the case of the UK, the emissions-increasing effect of financial development was valid for almost the entire period of 1885-1973, and this situation reversed in the sub-periods of 1908-1917 and 1928-1946. There was no significant break in the country's energy policies or economic strategies for the two periods in question, and the financial crises experienced did not coincide with these sub-periods. When we investigate the common features of these two periods, we find that the UK played an active role only during World War I and II. Therefore, we find that the financial sector financed the war economy instead of the industrial sector for these two periods. A negative effect started after 1973 and continued until 2014 as a result of the renewable and nuclear energy orientation of the UK's financial system after the oil crises. For the US economy, the findings reveal that the association between financial development and carbon emissions can be explained largely by financial crises and sudden changes in the country's energy portfolio. Namely, until 1890, the energy needs of the country were largely covered by wood energy, and in 1890 coal consumption exceeded wood consumption (EIA, 2011). Accordingly, our findings determine that the impact of financial development on carbon emissions was negative for the sub-period 1885-1890 and positive for the sub-period 1891-1899. The impact for the period of 1900-1911 was negative. This period is associated with the 1901 panic and the 1907 panic, which led to crashes in the country's banking system. Financial development after the recovery process had an emissions-increasing role until 1924. However, a negative impact started after 1925 and lasted about 40 years. During this period natural gas exceeded the share of coal in the country's energy portfolio. Contrary to expectations, the decline in oil consumption was replaced by a greater increase in coal consumption during the 1970s when oil crises were experienced (EIA, 2011). Therefore, the financial impact was positive during the 1962-1978 sub-period. The US kept up with the trend towards alternative energy sources that started in the 1980s, and the use of nuclear and hydroelectric energy started to increase during this period. Our findings also point to a negative effect during the 1979-1992 period. From the 1990s to 2005, the share of oil and coal consumption increased together, and a positive effect was determined as expected. Clean energy investments of the financial sector started to become more evident only after 2006 and, as a result of these investments, the shares of nuclear, biomass, and hydroelectricity increased for the first time in the country.




France
TV Parameters
Lower Bound
Upper Bound


Germany
TV Parameters
Lower Bound
Upper Bound


Italy
TV Parameters
Lower Bound
Upper Bound

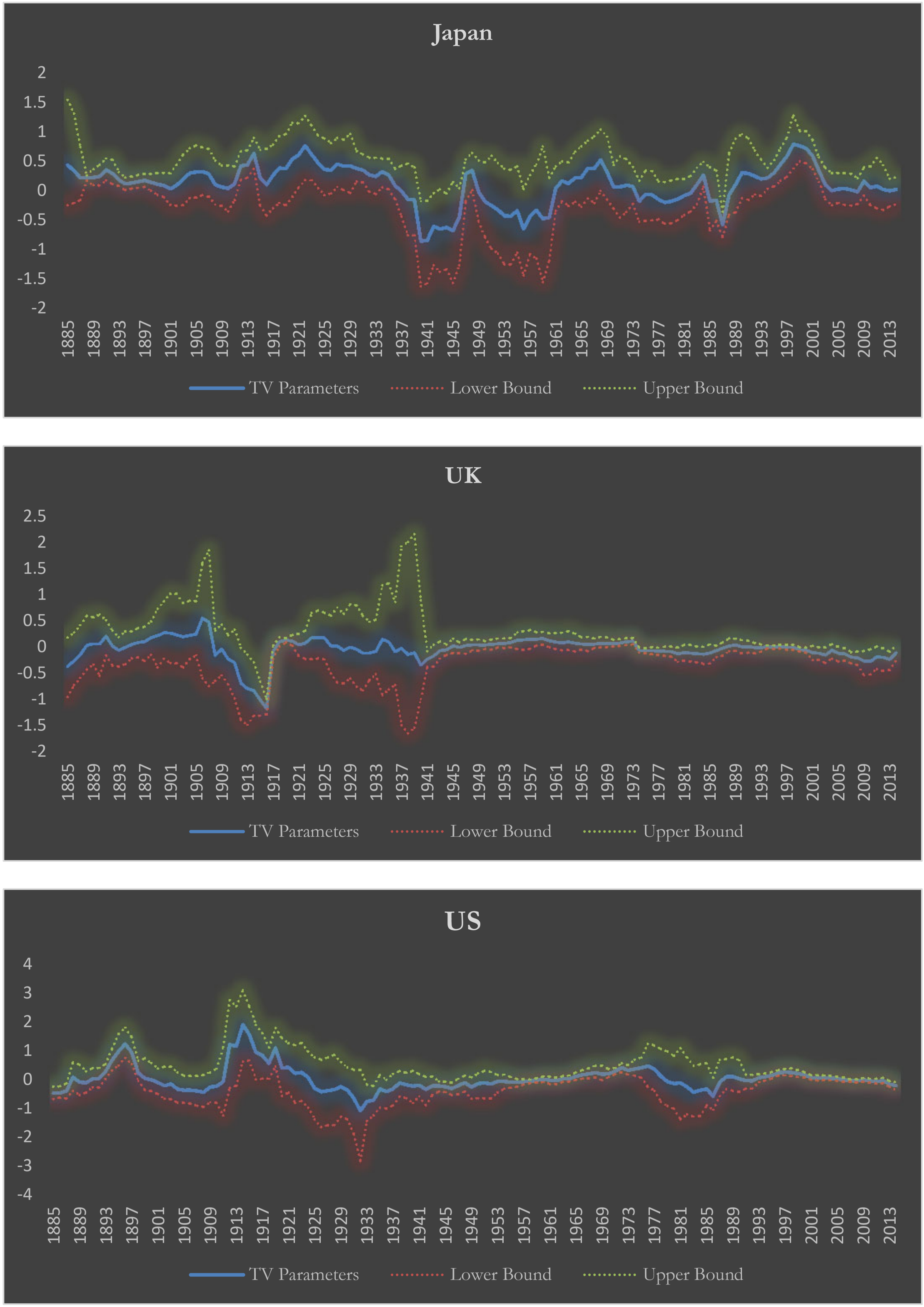
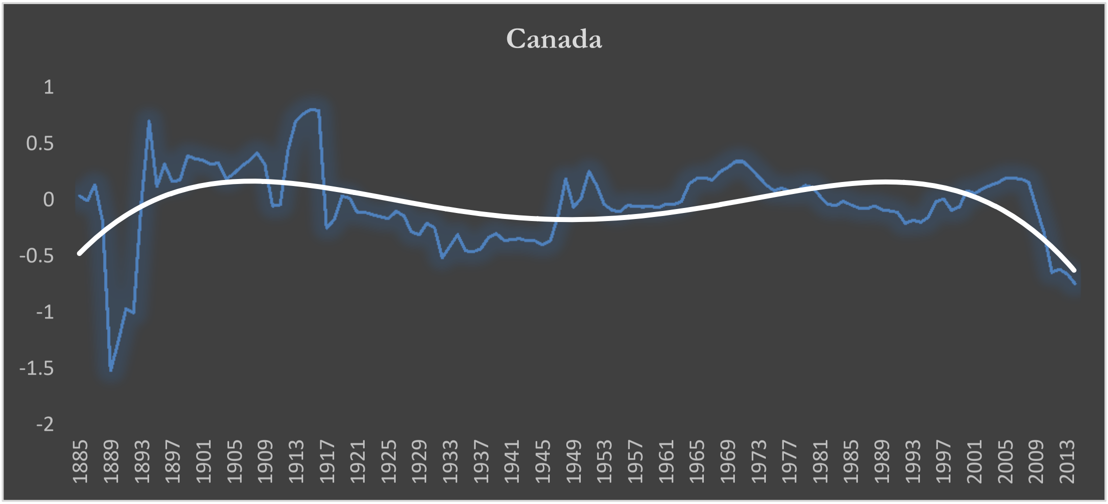


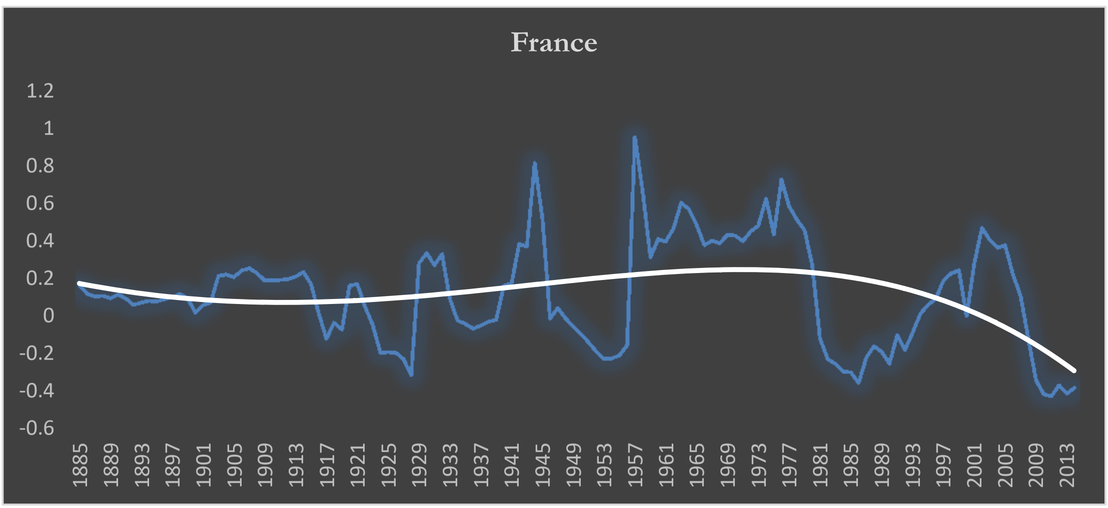
Figure-1: Time-Varying Parameters of Financial Development on Carbon Emissions.

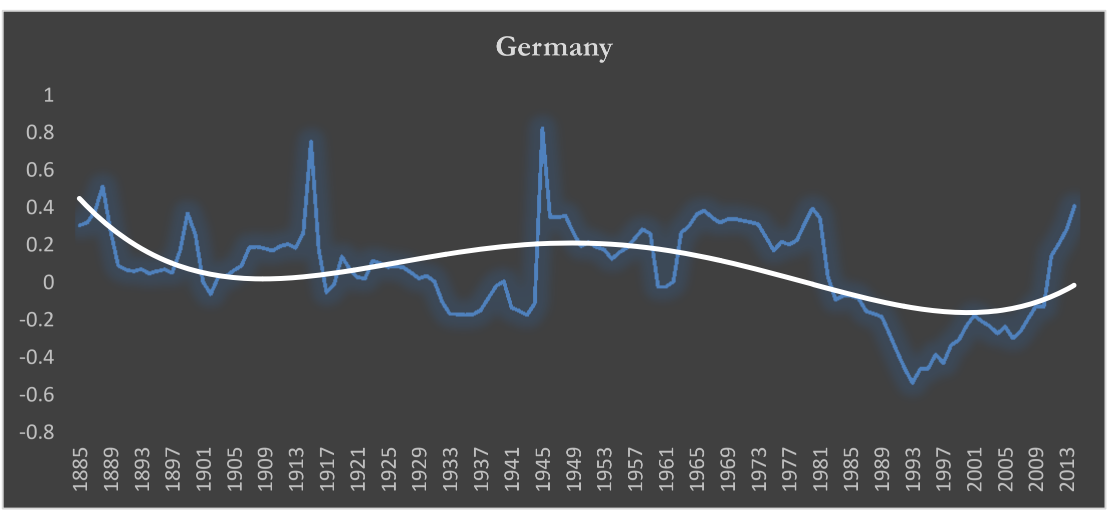
In polynomial trends of time-varying parameters analysis, we also observe the turning points for the effect of financial development on carbon emissions considering the maximum of four polynomial trends for the time-varying parameters of each county. In Figure-2, the blue lines indicate the time-varying parameters, and the white lines imply the polynomial trends of the parameters. At first glance, it seems there is an M-shaped association between financial development and carbon emissions in Canada, Japan, and the US. Moreover, an inverted N-shaped nexus is confirmed in France, Italy, and the UK. Interestingly, the inverted M-shaped (W-shaped) relationship between financial development and CO_2 emissions is valid only in Germany. Even when we compare our findings with the findings of the study examining the EKC hypothesis with the assumption that financial development moves in parallel with the development of the country's economy, the limited number of studies working with historical data in the literature makes it difficult to examine the compatibility of our findings with the findings in the literature. Nevertheless, the creation of EKC literature based mainly on datasets starting from the 1960s allows the aforementioned study findings to be compared with the trend after 1960 in our study. Thus, it can be said that the validations of an inverted U-shaped relation from Ang (2007) for France during the period 1960-2000, Aldy (2005) for the US during the period 1960-1999, Yaguchi et al. (2007) for Japan during the period 1975-1999, Iwata et al. (2010) for France during the period 1960-2003 and Bento and Moutinho (2016) for Italy during the period 1960-2011 are consistent with our findings for the same sub-sample period. Similarly, the N-shaped evidence of Lipford and Yandle (2010) for Germany during the period 1950-2004 is compatible with our results. When studies working with historical data are observed, the M-shaped evidence of Destek et al. (2020) for Canada during the period 1870-2010 is consistent with our study. On the other hand, Sephton and Mann (2016) determined an inverted U-shape for 1830-2003, unlike our finding for Germany. This difference is due to the empirical model of the study created with the quadratic assumption, which is the main criticism of our study of the literature.

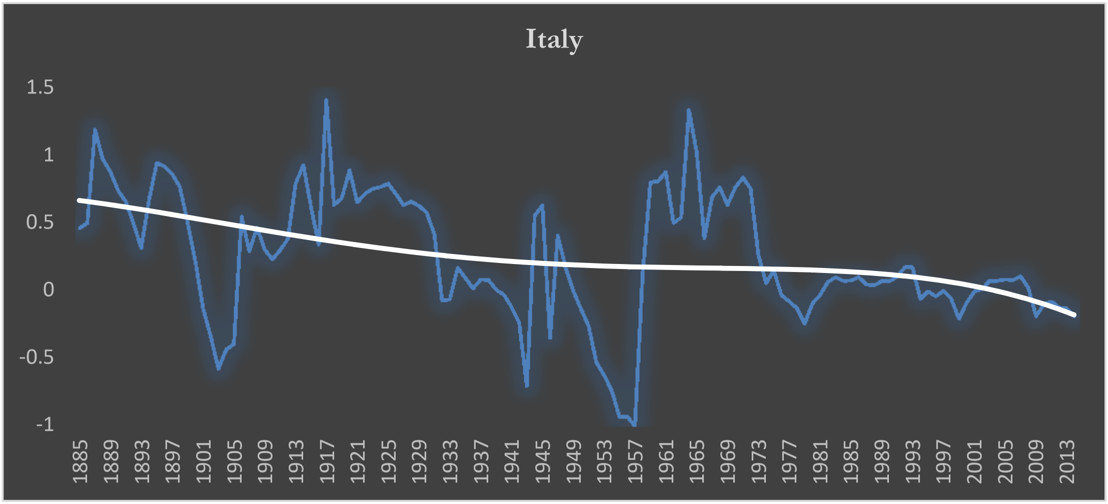
The empirical findings obtained, especially for countries with an M-shaped and inverted-N shaped relationship, are also closely related to the financial-induced EKC hypothesis. Also, after the 1970s, an inverted-U shaped relationship is valid for G-7 countries. The trend towards renewable energy technologies occurred predominantly a little after the oil crisis of the 1970s. The positive or negative effects of the financial sector on the environment preceding the 1970s generally changed depending on three different factors. The first factor was the war economy, which determined the indicators and effects for all of the countries observed due to World War I and World War II before the 1970s. During this period the financial sectors of the countries involved turned to finance their war effort, thereby increasing their military power. The second factor is the financial crises experienced by the countries. As a matter of fact, during banking crises, financing the industrial sector decreased, and thus the emissions-reducing effect of financial development emerged. The third and most important factor was the resource reserves discovered or technological developments made. Each fossil resource discovery, which reduced countries' dependence on energy and offered cost advantages, led to a shift of financial resources in that area and increased emissions. In the event that a country turned to nuclear energy or renewable energy, investments were transferred to these areas and emissions reduced in order to benefit from the incentives provided by governments. After the 1970s, the impact of financial development on the environment was an inverted U-shape in all of these countries. The financial sector provided some funding to the renewable energy sector at the beginning of this period, but mainly financed the industrial sector for higher profits and contributed to fossil-based industrial production, increasing emissions (scale effect). Later, the financial sector provided financing opportunities for a transition from the industrial sector to the service sector (composition effect). Finally, with the advancement of clean energy technologies in terms of cost, the financial sector transferred its resources to the financing of renewable energy technologies and served to reduce emissions (technique effect).

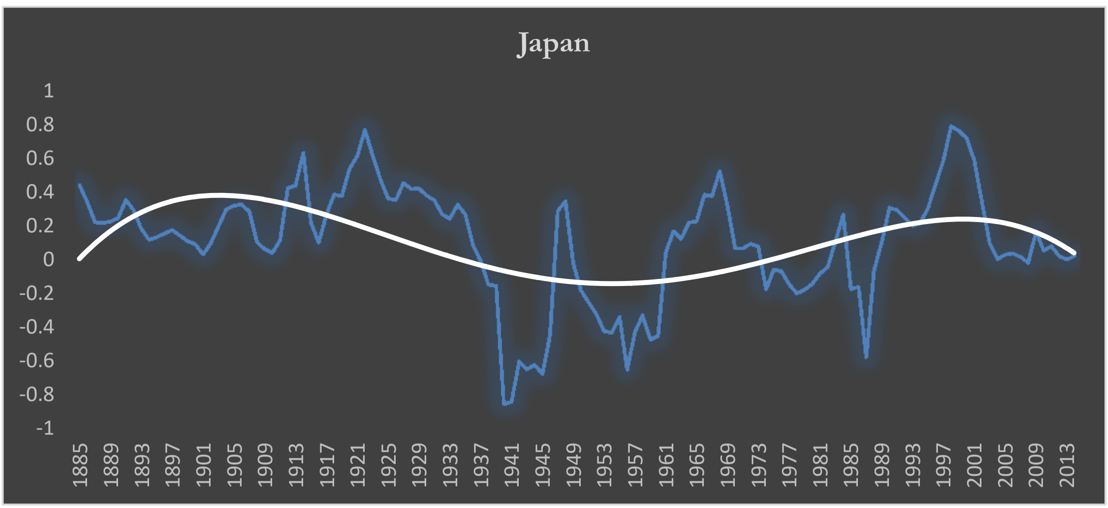
Unlike other countries, an inverse-M (W) relationship is observed in Germany. In fact, the impact of financial development on the environment has not been taken into consideration in recent years; it looks like a reverse-N curve. Therefore, the part that needs to be differentiated and focused here is why the emissions-reducing effect has reversed in recent years. Although Germany is one of the most active EU countries in terms of public policies on climate change, large electricity companies responsible for high emissions have difficulty keeping up with this green transformation (Kiyar and Wittneben, 2015). In fact, the Carbon Disclosure Project (CDP) (2015) report shows the low-carbon potentials of 16 electrical companies in Europe. The report focuses on aspects such as carbon risk, renewable energy sources, coal exposure, and water risk. The report states that lower-ranking firms were exposed to higher risk, and concluded that E.ON, EnBW and RWE, which are major electricity firms in Germany, are ranked 9th, 12th, and 13th, respectively. The low performance of these companies was explained by their high dependence on coal reserves, and thus their high carbon cost. Therefore, the public authorities have announced various incentives and measures for transitioning to green energy. The large electricity companies in question are vital for the country's economy and make significant use of financial instruments. In summary, in order to reverse the emissions-increasing effect of financial development, measures should be taken to reduce the carbon costs of companies highly dependent on coal reserves, and facilities should be provided for these companies to keep up with green transformation.

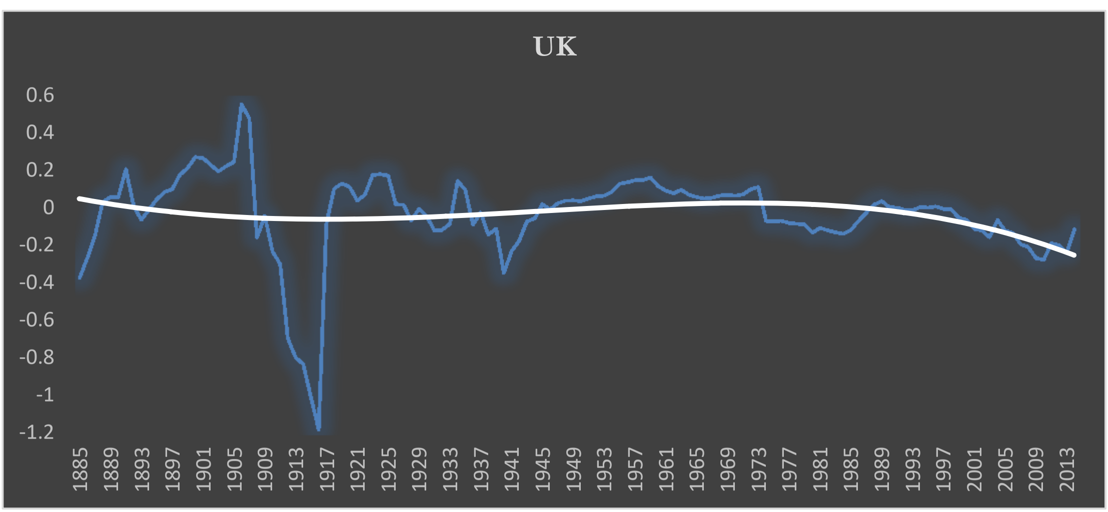

Canada
1
0.5
0
-0.5
-1
-1.5
-2
1885
1889
1893
1897
1901
1905
1909
1913
1917
1921
1925
1929
1933
1937
1941
1945
1949
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
2005
2009
2013


France
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
1885
1889
1893
1897
1901
1905
1909
1913
1917
1921
1925
1929
1933
1937
1941
1945
1949
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
2005
2009
2013


Germany
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
1885
1889
1893
1897
1901
1905
1909
1913
1917
1921
1925
1929
1933
1937
1941
1945
1949
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
2005
2009
2013


Italy
1.5
1
0.5
0
-0.5
-1
1885 1889 1893 1897 1901 1905 1909 1913 1917 1921 1925 1929 1933 1937 1941 1945 1949 1953 1957 1961 1965 1969 1973 1977 1981 1985 1989 1993 1997 2001 2005 2009 2013


Japan
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1885 1889 1893 1897 1901 1905 1909 1913 1917 1921 1925 1929 1933 1937 1941 1945 1949 1953 1957 1961 1965 1969 1973 1977 1981 1985 1989 1993 1997 2001 2005 2009 2013


UK
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
1885 1889 1893 1897 1901 1905 1909 1913 1917 1921 1925 1929 1933 1937 1941 1945 1949 1953 1957 1961 1965 1969 1973 1977 1981 1985 1989 1993 1997 2001 2005 2009 2013

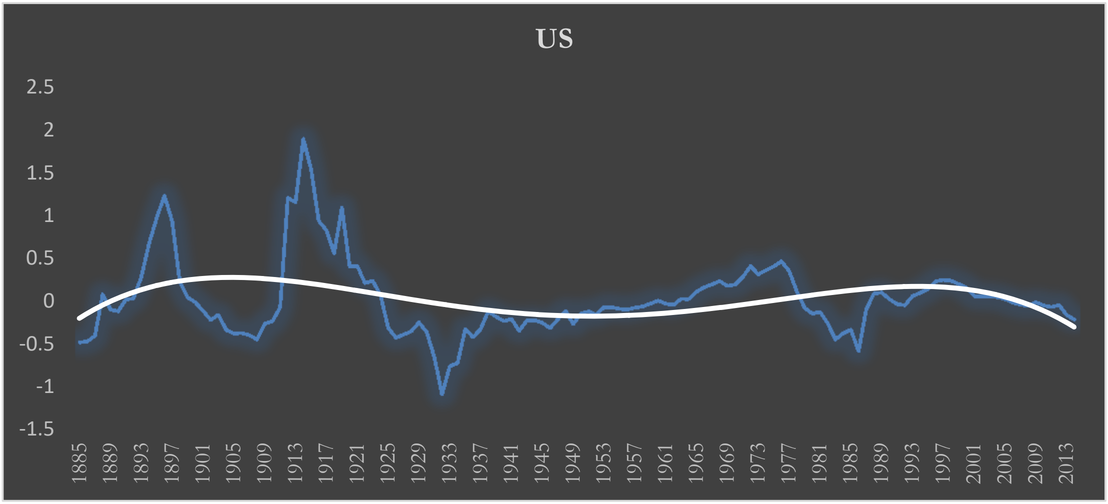


Figure-2: The Polynomial Trends of Time-varying Parameters.

V. Conclusion and Policy Implications

To deeply understand the relationship between financial development and environmental pollution in developed countries, this study has observed the effects of financial developments of G-7 countries on their carbon emissions year by year using historical data. Accordingly, we investigated the data of countries covering the period 1870-2014 through time-varying tests (i.e., the TVC and bootstrap rolling window estimation). We identified vital breaks in the finance-emissions connection and tried to determine possible triggers for these breaks. In addition, unlike linear or non-linear (e.g., quadratic and cubic) assumptions in the extant literature, polynomial trends of the relationship between variables were formed without any pre-assumptions, and turning points, if any, were determined. From our empirical analysis we can infer that the effects of developments in the financial system on the environment differ from time to time due to the specific economic and political shocks for each country. However, in some sub-periods, such as the 1970s, when oil crises were experienced, we found that finance had similar effects on emissions. These similarities become more evident when the polynomial trends of the parameters are mapped. Namely, our evidence shows that an M-shaped association exists between financial development and carbon emissions in Canada, Japan, and the US. Moreover, an inverted

N-shaped nexus is confirmed in France, Italy, and the UK. In particular, countries with an M-shaped and inverted N-shaped relationship are also closely related to the financial-induced EKC hypothesis because the inverted U-shaped relationship is valid in these countries. On the other hand, we observed that the policy differences in the periods before the 1970s, when the effects also differed, were due to three main factors. The first factor was the war economy that prevailed during the years of the two world wars. Due to this factor, the financial sectors of the countries turned to financing the war effort to increase their military power during wartime. The second factor is the financial crises experienced by countries. During the banking crisis periods, financing of the industrial sector decreased; thus, the emissions-reducing effect of financial development emerged. The third and most important factor was resource reserves discovered or technological advances made. Every fossil resource discovery, which reduces countries' dependence on energy and offers cost advantages, has caused financial resources to shift and emissions to increase in that region. If a country has turned to nuclear energy or renewable energy, investments have been transferred to these areas and emissions have been reduced to take advantage of incentives provided by governments. Unlike the other countries, our findings surprisingly show that an inverted M-shaped (W-shaped) relationship exists between twin variables only for Germany.

In the context of policy recommendations, some precautions should be taken against economic and political shocks that are likely to reverse the emission-reducing effect trend, especially in countries where the relationship between financial development and carbon emissions is M-shaped or inverted N-shaped. In the historical perspective, we can see that these shocks are usually caused by the discovery of a new fossil resource or financial crisis (except in extraordinary situations such as war periods).

i) In the event of a new fossil resource discovery, measures should be taken to prevent sectors based on those resources from being more attractive to clean energy sectors; in other words, tax facilities and subsidies that encourage clean energy sector investments should be increased.

ii) In times of financial crisis, action should be taken by considering the possibility of decreasing funds flowing from the financial sector to sectors showing pollution-reducing characteristics. That is, in times of economic prosperity, a reserve should be created to finance eco-friendly technologies, and these reserves should be used to continue projects on these technologies in times of crisis.

On the other hand, the current situation is negative for a country in which the financial development-carbon emission relationship is M-shaped (inverted W-shaped). Therefore, to reverse the emissions-increasing effect of financial development, measures should be taken to reduce the carbon costs of companies highly dependent on coal reserves, and facilities should be provided for these companies to keep pace with green transformation.

Finally, we need to mention the limitations of this study in order to create a roadmap for future studies. This study shows that analyses of historical data using time-varying tests can provide us with very detailed findings regarding the financial-environment relationship. However, the findings also show that in recent years, almost all developed countries have been able to encourage their financial sectors to invest in eco-friendly technologies. However, it is unclear whether developing countries achieve this incentive, and examining those countries (especially China) through time-varying tests on historical data is vital for the global goal of mitigating carbon emissions (Chen et al., 2020b, Wu et al., 2020). Unfortunately, the most important limitation of this study is that there is not enough data for developing countries and those countries are not analyzed and compared with developed countries. In the coming years, this comparison opportunity will arise if a comprehensive dataset is created for these countries.

Acknowledgements

The article is supported by the Beijing Xi Jinping Thought on Socialism with Chinese Characteristics for a New Era Center & Beijing Social Science Foundation (Grant No. 21LLLJC028). The authors gratefully acknowledge the helpful reviews and comments from the editors and anonymous reviewers, which improved this manuscript considerably. Certainly, all remaining errors are our own.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Abbasi, F., Riaz, K., 2016. CO_2 emissions and financial development in an emerging economy: an augmented VAR approach. Energ. Policy 90, 102-114.

Abdouli, M., Hammami, S., 2020. Economic growth, environment, FDI inflows, and financial development in Middle East countries: Fresh evidence from simultaneous equation models. J. Knowl. Econ. 11(2), 479-511.

Acheampong, A. O., 2019. Modelling for insight: does financial development improve environmental quality? Energ. Econ. 83, 156-179.

Acheampong, A. O., Amponsah, M., Boateng, E., 2020. Does financial development mitigate carbon emissions? Evidence from heterogeneous financial economies. Energ. Econ. 88, 104768.

Adams, S., Klobodu, E. K. M., 2018. Financial development and environmental degradation: Does political regime matter? J. Clean. Prod. 197, 1472-1479.

Ahmad, M., Khan, Z., Ur Rahman, Z., Khan, S., 2018. Does financial development asymmetrically affect CO_2 emissions in China? An application of the nonlinear autoregressive distributed lag (NARDL) model. Carbon Manag. 9(6), 631-644.

Aldy, J. E., 2005. An environmental Kuznets curve analysis of US state-level carbon dioxide emissions. J. Environ. Dev. 14(1), 48-72.

Ali, W., Abdullah, A., Azam, M., 2017. Re-visiting the environmental Kuznets curve hypothesis for Malaysia: fresh evidence from ARDL bounds testing approach. Renew. Sust. Energy. Rev. 77, 990-1000.

Ang, J. B., 2007. CO_2 emissions, energy consumption, and output in France. Energ. Policy 35(10), 4772-4778.

Beaudry, P. and Portier, F., 2002. The French depression in the 1930s. Rev. Econ. Dyn. 5(1), 73-99.

Bekhet, H. A., Matar, A., Yasmin, T., 2017. CO_2 emissions, energy consumption, economic growth, and financial development in GCC countries: Dynamic simultaneous equation models. Renew. Sust. Energy. Rev. 70, 117-132.

Bento, J. P. C., Moutinho, V., 2016. CO_2 emissions, non-renewable and renewable electricity production, economic growth, and international trade in Italy. Renew. Sust. Energy. Rev. 55, 142-155.

Boutabba, M. A., 2014. The impact of financial development, income, energy and trade on carbon emissions: Evidence from the Indian economy. Econ. Model. 40, 33-41.

BP, 2020. BP Statistical Review of World Energy 2020. https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/downloads.html.

Brown, R. C., Cook, R., 2016. Canada 1896-1921: A nation transformed (Vol. 14). McClelland & Stewart.

Calderón, C., Liu, L., 2003. The direction of causality between financial development and economic growth. J. Dev. Econ. 72(1), 321-334.

CDP, 2015. Carbon Disclosure Project, Flicking the switch: Are electric utilities prepared for a low carbon future. https://6fefcbb86e61af1b2fc4-c70d8ead6ced550b4d987d7c03fcdd1d.ssl.cf3.rackcdn.com/cms/reports/documents/000/000/617/original/electric-utilties-report-exec-summary-2015.pdf?1470222702.

Cetin, M. A., Bakirtas, I., 2020. The long-run environmental impacts of economic growth, financial development, and energy consumption: Evidence from emerging markets. Energ. Environ. 31(4), 634-655.

Charfeddine, L., Khediri, K. B., 2016. Financial development and environmental quality in UAE: Cointegration with structural breaks. Renew. Sust. Energy. Rev. 55, 1322-1335.

Chen, J., Wang, B., Huang, S., Song, M., 2020a. The influence of increased population density in China on air pollution. Sci. Total Environ. 735, 139456.

Chen, J., Gao, M., Mangla, S. K., Song, M., Wen, J., 2020b. Effects of technological changes on China's carbon emissions. Technol. Forecast. Soc. Change 153, 119938.

Cheng, C., Ren, X., Dong, K., Dong, X., Wang, Z., 2021. How does technological innovation mitigate CO_2 emissions in OECD countries? Heterogeneous analysis using panel quantile regression. J. Environ. Manage. 280, 111818.

Destek, M. A., Shahbaz, M., Okumus, I., Hammoudeh, S., Sinha, A., 2020. The relationship between economic growth and carbon emissions in G-7 countries: evidence from time-varying parameters with a long history. Environ. Sci. Pollut. R. 27, 29100–29117.

Dogan, E., Seker, F., 2016. The influence of real output, renewable and non-renewable energy, trade and financial development on carbon emissions in the top renewable energy countries. Renew. Sust. Energy. Rev. 60, 1074-1085.

Dong, K., Dong, X., Jiang, Q., 2020a. How renewable energy consumption lower global CO_2 emissions? Evidence from countries with different income levels. World Econ. 43(6), 1665-1698.

Dong, K., Dong, X., Ren, X., 2020b. Can expanding natural gas infrastructure mitigate CO_2 emissions? Analysis of heterogeneous and mediation effects for China. Energ. Econ. 90, 104830.

Ehigiamusoe, K. U., Lean, H. H., 2019. Effects of energy consumption, economic growth, and financial development on carbon emissions: Evidence from heterogeneous income groups. Environ. Sci. Pollut. R. 26(22), 22611-22624.

EIA, 2011. Energy Information Administration. History of energy consumption in the United States, 1775-2009. https://www.eia.gov/todayinenergy/detail.php?id=10.

He, J., Richard, P., 2010. Environmental Kuznets curve for CO_2 in Canada. Ecol. Econ. 69(5), 1083-1093.

IMF, 2020. International Monetary Fund, Financial Development Index Database. https://data.imf.org/?sk=F8032E80-B36C-43B1-AC26-493C5B1CD33B&sId=1481207801912.

Iwata, H., Okada, K., Samreth, S., 2010. Empirical study on the environmental Kuznets curve for CO_2 in France: the role of nuclear energy. Energ. Policy 38(8), 4057-4063.

Kayani, G. M., Ashfaq, S., Siddique, A., 2020. Assessment of financial development on environmental effect: Implications for sustainable development. J. Clean. Prod. 261, 120984.

Khan, Z., Ali, S., Dong, K., Li, R. Y. M., 2021. How does fiscal decentralization affect CO_2 emissions? The roles of institutions and human capital. Energ. Econ. 94, 105060.

Kiyar, D., Wittneben, B. B., 2015. Carbon as investment risk—The influence of fossil fuel divestment on decision making at Germany's main power providers. Energies 8(9), 9620-9639.

Koengkan, M., Santiago, R., Fuinhas, J. A., Marques, A. C., 2019. Does financial openness cause the intensification of environmental degradation? New evidence from Latin American and Caribbean countries. Environ. Econ. Policy Stud. 21(4), 507-532.

Koshta, N., Bashir, H.A., Samad, T.A., 2020. Foreign trade, financial development, agriculture, energy consumption and CO_2 emission: Testing EKC among emerging economies", Indian Growth Dev. Rev. https://doi.org/10.1108/IGDR-10-2019-0117.

Lahiani, A., 2020. Is financial development good for the environment? An asymmetric analysis with CO_2 emissions in China. Environ. Sci. Pollut. R. 27(8), 7901-7909.

Le, T. H., Le, H. C., Taghizadeh-Hesary, F., 2020. Does financial inclusion impact CO_2 emissions? Evidence from Asia. Financ. R. Lett. 34, 101451.

Lipford, J. W., Yandle, B., 2010. Environmental Kuznets curves, carbon emissions, and public choice. Environ. Dev. Econ. 15(4), 417-438.

Ma, M., Ma, X., Cai, W., Cai, W., 2020. Low carbon roadmap of residential building sector in China: Historical mitigation and prospective peak. Appl. Energ. 273, 115247.

Moghadam, H. E., Dehbashi, V., 2018. The impact of financial development and trade on environmental quality in Iran. Empir. Econ. 54(4), 1777-1799.

Mu, R., 2018. Bounded rationality in the developmental trajectory of environmental target policy in China, 1972-2016. Sustainability 10(1), 199.

Nasreen, S., Anwar, S., 2015. The impact of economic and financial development on environmental degradation. Stud. Econ. Financ. 32(4), 485-502.

Omri, A., Nguyen, D. K., Rault, C., 2014. Causal interactions between CO_2 emissions, FDI, and economic growth: Evidence from dynamic simultaneous-equation models. Econ. Model. 42, 382-389.

Ozturk, I., Acaravci, A., 2013. The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. Energ. Econ. 36, 262-267.

Paramati, S. R., Mo, D., Gupta, R., 2017. The effects of stock market growth and renewable energy use on CO_2 emissions: evidence from G20 countries. Energ. Econ. 66, 360-371.

Ren, X., Cheng, C., Wang, Z., Yan, C., 2021. Spillover and dynamic effects of energy transition and economic growth on carbon dioxide emissions for the European Union: A dynamic spatial panel model. Sustain. Dev. 29(1), 228-242.

Renzhi, N., Baek, Y. J., 2020. Can financial inclusion be an effective mitigation measure? Evidence from panel data analysis of the environmental Kuznets curve. Financ. R. Lett. 37, 101725.

Saleem, H., Khan, M. B., Shabbir, M. S., 2020. The role of financial development, energy demand, and technological change in environmental sustainability agenda: evidence from selected Asian countries. Environ. Sci. Pollut. R. 27(5), 5266-5280.

Seetanah, B., Sannassee, R. V., Fauzel, S., Soobaruth, Y., Giudici, G., Nguyen, A. P. H., 2019. Impact of economic and financial development on environmental degradation: evidence from small island developing states (SIDS). Emerg. Mark. Financ. Tr. 55(2), 308-322.

Sehrawat, M., Giri, A. K., Mohapatra, G., 2015. The impact of financial development, economic growth and energy consumption on environmental degradation. Manage. Environ. Qual. 26(5), 666-682.

Sephton, P., Mann, J., 2016. Compelling evidence of an environmental Kuznets curve in the United Kingdom. Environ. Resour. Econ. 64(2), 301-315.

Shahbaz, M., Haouas, I., Sohag, K., Ozturk, I., 2020. The financial development-environmental degradation nexus in the United Arab Emirates: the importance of growth, globalization and structural breaks. Environ. Sci. Pollut. R. 27, 10685-10699.

Shahbaz, M., Hye, Q. M. A., Tiwari, A. K., Leitão, N. C., 2013a. Economic growth, energy consumption, financial development, international trade and CO_2 emissions in Indonesia. Renew. Sust. Energy. Rev. 25, 109-121.

Shahbaz, M., Nasir, M. A., Roubaud, D., 2018. Environmental degradation in France: the effects of FDI, financial development, and energy innovations. Energ. Econ. 74, 843-857.

Shahbaz, M., Shahzad, S. J. H., Ahmad, N., Alam, S., 2016. Financial development and environmental quality: The way forward. Energ. Policy 98, 353-364.

Shahbaz, M., Solarin, S. A., Mahmood, H., Arouri, M., 2013b. Does financial development reduce CO_2 emissions in Malaysian economy? A time series analysis. Econ. Model. 35, 145-152.

Shoaib, H. M., Rafique, M. Z., Nadeem, A. M., Huang, S., 2020. Impact of financial development on CO_2 emissions: A comparative analysis of developing countries (D8) and developed countries (G8). Environ. Sci. Pollut. R. 27, 12461-12475.

Song, M., Xie, Q., Tan, K. H., Wang, J., 2020. A fair distribution and transfer mechanism of forest tourism benefits in China. China Econ. Rev. 63, 101542.

Tamazian, A., Chousa, J. P., Vadlamannati, K. C., 2009. Does higher economic and financial development lead to environmental degradation: Evidence from BRIC countries. Energ. Policy 37(1), 246-253.

Tamazian, A., Rao, B. B., 2010. Do economic, financial and institutional developments matter for environmental degradation? Evidence from transitional economies. Energ. Econ. 32(1), 137-145.

Umar, M., Ji, X., Kirikkaleli, D., Xu, Q., 2020. COP21 Roadmap: Do innovation, financial development, and transportation infrastructure matter for environmental sustainability in China? J. Environ. Manage. 271, 111026.

Wang, L., Vo, X. V., Shahbaz, M., Ak, A., 2020a. Globalization and carbon emissions: Is there any role of agriculture value-added, financial development, and natural resource rent in the aftermath of COP21? J. Environ. Manage. 268, 110712.

Wang, R., Mirza, N., Vasbieva, D. G., Abbas, Q., Xiong, D., 2020b. The nexus of carbon emissions, financial development, renewable energy consumption, and technological innovation: What should be the priorities in light of COP21 Agreements? J. Environ. Manage. 271, 111027.

Wei, W., Li, J., Chen, B., Wang, M., Zhang, P., Guan, D., ... & Xue, J., 2021. Embodied greenhouse gas emissions from building China's large-scale power transmission infrastructure. Nat. Sustain. 1-9.

Wu, Y., Wang, P., Liu, X. Chen, J., Song, M., 2020. Analysis of regional carbon allocation and carbon trading based on net primary productivity in China. China Econ. Rev. 60, 101401.

Xiong, L., Qi, S., 2018. Financial development and carbon emissions in Chinese provinces: a spatial panel data analysis. Singap. Econ. Rev. 63(02), 447-464.

Yaguchi, Y., Sonobe, T., Otsuka, K., 2007. Beyond the environmental Kuznets curve: a comparative study of SO_2 and CO_2 emissions between Japan and China. Environ. Dev. Econ. 12(3), 445-470.

Yin, W., Kirkulak-Uludag, B., Zhang, S., 2019. Is financial development in China green? Evidence from city level data. J. Clean. Prod. 211, 247-256.

Zhang, Y. J., 2011. The impact of financial development on carbon emissions: An empirical analysis in China. Energ. Policy 39(4), 2197-2203.

Zhao, J., Jiang, Q., Dong, X., Dong, K., 2021a. Assessing energy poverty and its effect on CO_2 emissions: The case of China. Energ. Econ. 97, 105191.

Zhao, J., Shahbaz, M., Dong, X., Dong, K., 2021b. How does financial risk affect global CO_2 emissions? The role of technological innovation. Technol. Forecast. Soc. Change 168, 120751.

Zhao, B., Yang, W., 2020. Does financial development influence CO_2 emissions? A Chinese province-level study. Energy 200, 117523.

Ziaei, S. M., 2015. Effects of financial development indicators on energy consumption and CO_2 emission of European, East Asian and Oceania countries. Renew. Sust. Energy. Rev. 42, 752-759.