Does financial development influence renewable energy consumption to achieve carbon neutrality in the USA?

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Abstract: In order to achieve the goal of carbon neutrality, as defined in the Paris climate agreement, the United States, the second-largest greenhouse gas emitter, must intensify its use of zero-carbon sources such as renewable energy. In this paper, we use the nonlinear autoregressive distributed lags (NARDL) model to investigate the influence of financial development on renewable energy consumption in the U.S. from 1975Q1 to 2019Q4. More precisely, three measures of financial development are considered: the overall financial development, bank-based financial development, and stock-based financial development indices. The model is augmented to control for the effects of real oil prices, real GDP, and trade openness. The empirical results show evidence of a long-run asymmetric effect of overall and stock-based financial development measures. Positive and negative changes in financial development measures dictate renewable energy consumption. In the short run, only negative changes of overall and stock-based financial development measures significantly impact renewable energy consumption. The latter impact is contemporaneously positive and negative at the one-lagged period. Renewable energy consumption does not react to a short-run change in bank-based financial development. Our empirical findings possess important policy implications.

Keywords: Financial Development, Renewable Energy Consumption, USA

JEL Classification: D53, P48

I. Introduction

In order to strengthen the global response to the threats of climate change, in the context of sustainable development, the Paris Agreement calls for "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C[2]. The three main GHG emitters (EU, China, U.S.) have now clearly established carbon neutrality as their horizon. The European Union has decided to become climate neutral by 2050, and China has pledged to peak its emissions 'before 2030' and achieve 'carbon neutrality before 2060'. As for the United States, the new American President- Joe Biden, has made climate change a key issue during his campaign and has set an unwavering commitment to carbon neutrality by 2050. Achieving carbon neutrality goal during global population growth and increased consumption will be possible by moving to zero-carbon sources such as nuclear power and renewable energy.

In 2019, renewable energy[3] represented 19.7 % of energy consumed in the EU-27, only 0.3% short of the 2020 target of 20%[4]. In the United States, approximately 12% of energy production relied on renewables, and the annual energy consumption from renewable sources exceeded coal consumption for the first time since before 1885, and the consumption of renewable energy in 2019 was nearly three times greater than in 2000, according to the Energy Information Administration[5]. Developed countries work together to double the share of renewable energy in the global energy mix by 2030. Similarly, the ambition of Europe is to become the world's first climate-neutral continent by 2050, and the European Green Deal is the plan to make the EU's economy sustainable.[6] The U.S. Energy Information Administration projects that U.S. renewable energy consumption will continue to increase through 2050[7]. This importance given to renewable energy is justified by its potential environmental and economic benefits that include the reduction of greenhouse gas emissions

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[2] United Nations Framework Convention on Climate Change, 2015. *Paris Agreement.* https://unfccc.int/files/meetings/paris_nov_2015/application/pdf/paris_agreement_english_.pdf (accessed 03 February 2021).

[3] Renewable energy, often referred to as clean energy, comes from natural sources or processes that are constantly replenished, such as wind power, solar power, or sustainable biomasses.

[4] Eurostat, (n.d.). Renewable energy statistics. http://ec.europa.eu/eurostat/statisticsexplained/index.php/Renewable_energy_statistics (accessed 03 February 2021).

[5] Energy Information Administration (EIA), (2020). U.S. renewable energy consumption surpasses coal for the first time in over 130 years (accessed 03 March 2021).

[6] European Commission, (n.d.). A European Green Deal, Striving to be the first climate-neutral continent. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en (accessed 03 February 2021).

[7] Energy Information Administration (EIA), (2021). Renewable energy explained. https://www.eia.gov/energyexplained/renewable-sources (accessed 03 February 2021).

from fossil fuels and some types of air pollution, the diversification of energy supply, and the creation of economic development and jobs in *green* technologies. One of the biggest challenges to deploying renewable energy is capital costs. Indeed, the initial capital cost of renewable energy is relatively high compared to conventional sources of energy. Also, renewable projects require long pay-back periods and thus demand high levels of financing. Financial development could then be an important driver of higher renewable energy consumption. Financial infrastructure can enhance economic growth and affect the demand for energy (Sadorsky, 2010). Indeed, a high level of financial development leads to developing financial markets, bank and equity markets, and subsequently, more funds available for investment (Minier 2009, Sadorsky 2010). Shahbaz and Lean (2012) explained that the impact of financial development on economic growth and, thus, energy consumption should be positive. They summarized the main mechanisms explaining how enhancements in financial markets are linked with investment activities and economic growth. The first mechanism is the level effect. It translates to developed financial markets raising funds for high-return projects. The second mechanism is the efficiency effect. It reveals that financial development increases liquidity and asset diversification and channel financial resources to appropriate ventures.

According to Sadorsky (2011), financial development improves access to financial resources, increasing demand for big-ticket items and adding to energy demand. Sadorsky (2011) explains that financial development affects energy consumption in three ways: the direct effect, the business effect, and the wealth effect. The direct effect is related to the context of improved financial development when consumers can borrow easier and cheaper in order to buy durable consumer goods and thus consume energy a lot. The business effect happens when financial development helps businesses to access financial capital easily and cost-efficiently. The wealth effect is when increased economic confidence expands the economy and promotes energy demand. Improved financial development facilitates saving, borrowing, and investment. With low borrowing costs, consumers tend to buy consumer durables, adding to energy demand. However, Islam et al. (2013) argue that financial development facilitates the purchase of energy-efficient appliances, which lowers energy use. Chiu and Lee (2020) explained that financial institutions play an important role in countries with a stable financial environment as they allowed industries to easily gain access to finance from stock market and banking sector. Thus, firms would have more financing to invest in advanced and energy-efficient equipment and technologies, and consequently, energy consumption decreases.

More recently, scant research has focused on renewable energy consumption-financial development nexus. Chang (2015) explains that financial development could impact the demand for renewable energy because developed financial institutions and the capital market make it possible to offer debt as well as equity funding to green renewable energy projects. Furthermore, a developed financial system offers the opportunity to fund environmentally friendly projects at lower costs. Anton and Nucu (2020) explain that a well-developed financial system promotes greater financing for renewable(s) industry at lower costs, increasing investment and sustaining energy demands. Most of the previous papers focused on the relationship between financial development and conventional energy consumption. It is then of great importance to better understand the connection between financial development and renewable energy.

Considering the effects of financial development on renewable energy consumption is important because it intuitively permits examining the environmental effects of financial development. Indeed, to achieve the target of carbon neutrality or a carbon-free economy, it is important to develop the right attitude of building a clean environment while enhancing economic activities. Shahbaz et al. (2020a) explained that greater use of non-renewable energy sources, such as coal, crude oil, and natural gas, rather than renewable energy in economic activities, may result in environmental degradation through the increase of carbon emissions. Additionally, Pham et al. (2020) argued that renewables help environment by reducing carbon dioxide emission levels and that the use of fossil fuels and non-renewable resources have adverse consequences for environment.

Accordingly, this study offers insights into how financial development influences renewable energy consumption. It brings five important contributions to existing literature that are methodological and empirical as well: (i) Despite the fact that our paper joins a large body of literature seeking to explain the relationship between financial development and energy consumption, we focus on renewable energy consumption, which is under-examined in the existing literature. (ii) The analysis contributes indirectly to existing literature on environmental effects of financial development where the evidence on finance-environment nexus is inconclusive (e.g., Nasir et al. 2019, Nguyen et al. 2021, Salahuddin et al. 2018, Shahbaz et al. 2018, Charfeddine and Khediri 2016, Çoban and Topcu 2013, Tamazian et al. 2009). (iii) This paper is among the first to quantitatively analyze the impact of financial development on renewable energy consumption in the United States. (iv) In order to evaluate the connection between the level of financial development and renewable energy consumption in a more accurate way, we apply the BDS test, developed by Brock et al. (1996), and the Augmented Dickey-Fuller (ADF) test, containing information about structural breaks stemming in the series, to examine the presence of nonlinearity and unit root problem in the series. (v) The NARDL bounds testing approach is applied for examining the nonlinear effect of financial development on renewable energy consumption for the U.S. economy. Our empirical evidence notes that stock-based financial development has an asymmetric effect on renewable energy consumption, i.e., positive and negative changes of financial development determine renewable energy consumption.

The remainder of this paper is organized as follows: Section II briefly reviews relevant literature. Section III contains the data and methods, and empirical results are presented in Section IV. Finally, Section V entails the discussions and conclusion.

II. Literature Review

Empirically, the relationship between financial development and energy consumption has been attractive in recent years, and the results are mixed. On the one hand, some papers found that greater financial development leads to increased energy consumption. For example, Sadorsky (2010) examined the impact of financial development on energy consumption in 22 emerging economies. He used five different measures of financial development and a linear dynamic panel model, and a generalized method of moments (GMM). The empirical results show that the impact of financial development on energy demand is positive and significant. Later on, Shahbaz et al. (2010) focused on the Pakistan case and found, by using an ARDL bounds testing approach, that a significant positive effect of financial development on energy consumption exists. Similarly, Islam et al. (2013) used the Vector Error Correction Model (VECM) and found that economic growth and financial development affect energy use in Malaysia. Alongside, Tang and Tan (2014) investigated the Malaysian economy using data for the period 1972–2009 by applying Johansen–Juselius cointegration test and bounds testing approach. They found that energy consumption and financial development are correlated in the long run. Xu (2012) examined financial development and energy consumption in 29 provinces of China during the period 1999–2009 using the System GMM. His findings showed a positive and statistically significant relationship between financial development and energy consumption when financial development is measured by the ratio of loans in a financial institution to GDP and the ratio of FDI to GDP. Çoban and Topcu (2013) investigated the nexus between financial development and energy consumption in the EU over the period 1990–2011 by using the System GMM model. Their empirical results provide strong evidence of the positive impact of financial development on energy consumption in the old members, regardless of whether financial development stems from banking sector or stock market. The analysis of Chang (2015) is relied on a sample of 53 countries for the period 1999–2008 split into two regimes: high income and non-high income. Their results showed that in a non-high-income regime, energy consumption increases with financial development, i.e., private and domestic credit are used as financial development indicators. However, financial development is proxied by the value of traded stocks and stock market turnover; energy consumption slightly decreases with financial development in advanced economies and increases in higher-income countries of emerging market and developing economies. Rashid and Yousaf (2015) found evidence of a positive and significant relationship between financial development and electricity consumption. Rafindadi and Ozturk (2016) also found a positive impact of financial development on energy consumption in Japan for the period 1970–2012. Paramati et al. (2016) investigated the impact of foreign capital and stock market development on clean energy use across 20 emerging economies, using data spanning 1991–2012. They revealed that foreign capital and stock market developments have a very important role in enhancing clean energy uses on the sample of all country groups. Kahouli (2017) used the autoregressive distributed lag (ARDL) bounds approach and examines the connection between energy consumption and financial development in South Mediterranean countries. He found evidence of a positive long-run causality from financial development to energy consumption in Israel, Morocco, and Tunisia. Liu et al. (2018) also adopted the ARDL bounds approach and found that, in China, financial development positively influenced energy demand in the short run and long run from 1980 to 2014.

On the other hand, other research reveals a negative connection between financial development and energy consumption. For example, Mielnik and Goldemberg (2002), on a sample of 20 developing economies, noticed a clear decline in energy intensity as a foreign direct investment (an indicator of financial development) increases. Sadorsky (2010) showed that financial development might reduce energy consumption via the development of new technologies. This negative impact of financial development on energy consumption is called the technological effect (Tamazian et al. 2009, Jalil and Feridun 2011, Shahbaz et al. 2013, Mahalick and Mallick 2014, Shahbaz et al. 2017). Later on, Topcu and Payne (2017) investigated the impact of financial development on energy consumption for a panel of 32 high-income countries over the period 1990–2014. Their results reveal the absence of a statistical relationship between the overall financial development index and energy consumption. However, they show that an increase in stock market index leads to a slight decline in energy consumption. Destek (2018) examined the relationship between financial development, energy prices, real income, and energy consumption in 17 emerging economies from 1991 to 2015 using financial development handling with three dimensions (banking sector, stock market, and bond market). The empirical results show that banking market development and bond market development have a negative and statistically significant effect on energy consumption. Ouyang and Li (2018) studied the endogenous relationship between financial development, energy consumption, and economic growth in China by applying a GMM panel VAR approach with panel data concerning 30 Chinese provinces over the period 1996–2015 using quarter frequency data. Their results revealed that financial development in the sense of M_2, credit, and stock turnover could significantly reduce energy consumption. More recently, Canh et al. (2020) analyzed the nexus between financial development and consumption energy intensity and production energy intensity on a sample of 81 economies from 1997 to 2013. Their findings exposed that financial institutions have an increasing effect, whereas financial markets have a decreasing impact on consumption energy intensity in the long run. Also, in the face of an oil price shock, countries with higher levels of financial development experience a reduced production energy intensity, while the countries with stronger financial institutions experience a reduction in consumption energy intensity. Chiu and Lee (2020) investigated the relationship between energy consumption, financial development, and country risks from 1984 to 2015 for 79 countries and two sub-groups (34 OECD and 45 non-OECD countries). Their results showed that under the stable country risk environments, financial development leads to reduce energy consumption. However, Benkraiem et al. (2019) argued that energy consumption is positively and negatively affected by positive and negative shocks to financial development, respectively.

Besides the above literature that analyses the relationship between financial development and traditional energy consumption, only a few papers focus on renewable energy consumption. Wu and Broadstock (2015) investigated data from 22 emerging markets countries from 1990–2010 and revealed that renewable energy consumption is positively and significantly determined by financial development and institutional quality. Best (2017) used data for up to 137 countries for the period 1998–2013 to investigate the importance of financial capital for changes in the use of each energy type. He found that financial capital supports the transition to more capital-intensive energy types. For high-income countries, financial capital is a catalyst for transitions from fossil fuels to modern renewable energy sources, especially wind. Kutan et al. (2017) explored data from Brazil, China, India, and South Africa from 1990 to 2012 and showed that FDI inflows and stock market development contribute significantly to renewable energy consumption. Similarly, Burakov and Freidin (2017) investigated the causal relationship between financial development, economic growth, and renewable energy consumption in Russia from 1990 to 2014. Their results showed the absence of causality running from financial development to renewable energy consumption. Ji, and Zhang (2019), through a time series analysis based on stock market data in China from 1992 to 2013, showed that financial development is critically important and explains over 40% of the variation in the changes in the share of renewable energy. Recently, Anton and Nucu (2020) conducted an empirical analysis based on a panel fixed effects model using panel data of 28 countries in the European Union (EU) over the period 1990–2015 to examine the effect of financial development on renewable energy consumption. Their results emphasized that the different dimensions of financial development (banking sector, bond market, and capital market) increases the share of renewable energy consumption. They also mentioned that capital market development has no effect on renewable energy consumption for the new EU member States. A summary of the related literature review is reported in Table A1 in the Appendix.

Our paper various from other papers in the literature in two main aspects: first, it is the first to investigate the role of financial development in determining renewable energy consumption while accounting for the effects of real oil prices, economic growth, and trade openness as additional determinants of renewable energy consumption. Second, it considers three dimensions of financial development. In particular, financial development is proxied with an overall financial development index, and alternatively, with a bank-based financial development index and then with a stock market financial development index. Previous studies on the topic have usually considered the overall financial development index as a measure of financial development.

III. Methodology and Data

III.I Methodology

To estimate the impact of financial development on renewable energy consumption, we use the nonlinear autoregression distributed lag (NARDL) framework. The NARDL model is a multivariate econometric model largely employed to accommodate possible cointegration relationships between time series having different orders of integration. In fact, it allows time series to be a mix of I(0) and I(1). The conventional cointegration models such as Johansen (1998), Engle and Granger (1987) require time series to have the same order of integration, i.e., I(1). Thus, they become inappropriate and could lead to misleading results when cointegration exists between the positive or negative components of considered variables. The NARDL model is relevant in this particular framework where time series are not cointegrated, but their respective positive or negative components are linked in the long run. The latter pattern, called hidden cointegration, is important to detect the effectiveness of economic and energy policies (Granger and Yoon, 2002). Furthermore, the NARDL model allows for nonlinearity between underlying variables in the long run and/or short run and hence is flexible enough to avoid under-fitted or over-fitted modeling of long-run and short-run adjustments of system variables. Efficient and credible energy policies can only result from properly specified models (Lahiani et al. 2017).

Overall, the NARDL model jointly analyzes nonlinearity and non-stationarity, which is capable of capturing the short-run and long-run asymmetric effects simultaneously. Additionally, it is now largely accepted that economic and financial time series are characterized by different types of nonlinearities in their dynamics. For instance, Naeem et al. (2020) highlight the presence of nonlinearity in stock market data through the application of the BDS test (Brock et al. 1996). Nonlinearity in time series commodity data (Gold, Oil, Palladium, Platinum, Silver, Titanium) dynamics is also shown in Shahzad et al. (2017), who used the BDS nonlinearity test and the adjusted ICSS structural break test of Sanso et al. (2004). The previous findings are important as they highlighted the existence of linearity at two different levels: (i) in the dynamics of time series returns and (ii) in the dependence structure between time series returns. The linear ARDL model has the following form:

$$\Delta lnREC_t = \alpha_0 + \alpha_{REC} lnREC_{t-1} + \alpha_{FD} lnFD_{t-1} + \alpha_Y lnY_{t-1} + \alpha_{ROP} lnROP_{t-1} + \alpha_{TO} lnTO_{t-1} + \sum_{i=1}^{p-1} \delta_i \Delta lnREC_{t-i} + \sum_{i=0}^{q-1} \gamma_i \Delta lnFD_{t-i} + \sum_{i=0}^{q-1} \omega_i \Delta lnY_{t-i} + \sum_{i=0}^{q-1} \varphi_i \Delta lnROP_{t-i} + \sum_{i=0}^{q-1} \pi_i \Delta lnTO_{t-i} + \varepsilon_t \quad (1)$$

where $REC_t, FD_t, Y_t, ROP_t,$ and TO_t denote renewable energy consumption, financial development, real gross domestic product, real oil prices, and real trade openness, respectively. Δ denotes the first difference transformation, p and q refer to the lag orders of dependent and explanatory variables, respectively. The ε_t error term was assumed to have the required properties for OLS estimation (Greene, 2008). The nexus between financial development and renewable energy consumption is analyzed considering three indices to measure financial development, namely overall financial development index (overall), bank-based financial development index (BI), and stock-market-based financial development index (SI).

Although the model in equation-1 has several advantages over competing standard cointegrating techniques, it presents the risk of becoming simplistic and reductive in a context where reality forces the relationship between economic and financial variables to become nonlinear. Extension of the linear ARDL model in equation 1 to a nonlinear framework leads to the following NARDL model:

$$\Delta lnREC_t = \alpha_0 + \alpha_{REC} lnREC_{t-1} + \alpha_{FD}^{+} lnFD_{t-1}^{+} + \alpha_{FD}^{-} lnFD_{t-1}^{-} + \alpha_{Y}^{+} lnY_{t-1}^{+} + \alpha_{y}^{-} lnY_{t-1}^{+} + \alpha_{ROP}^{+} lnROP_{t-1}^{+} + \alpha_{ROP}^{-} lnROP_{t-1}^{-} + \alpha_{TO}^{+} lnTO_{t-1}^{+} + \alpha_{TO}^{-} lnTO_{t-1}^{-} + \sum_{i=1}^{p-1} \delta_i \Delta lnREC_{t-i} + \sum_{i=0}^{q-1} (\gamma_i^{+} \Delta lnFD_{t-i}^{+} + \gamma_i^{-} \Delta lnFD_{t-i}^{-}) + \sum_{i=0}^{q-1} (\omega_Y^{+} \Delta lnY_{t-i}^{+} + \omega_Y^{-} \Delta lnY_{t-i}^{-}) + \sum_{i=0}^{q-1} (\varphi_{ROP}^{+} \Delta lnROP_{t-i}^{+} + \varphi_{ROP}^{-} \Delta lnROP_{t-i}^{-}) + \sum_{i=0}^{q-1} (\pi_{TO}^{+} \Delta lnTO_{t-i}^{+} + \pi_{TO}^{-} \Delta lnTO_{t-i}^{-}) + \varepsilon_t \quad (2)$$

In equation-2, $lnFD_t^{+}$ and $lnFD_t^{-}$ represent positive and negative partial sums computed as:

$$lnFD_t^{+} = \sum_{j=1}^{t} \Delta lnFD_j^{+} = \sum_{j=1}^{t} \max(0, \Delta lnFD_j)$$

and

$$lnFD_t^{-} = \sum_{j=1}^{t} \Delta lnFD_j^{-} = \sum_{j=1}^{t} \min(0, \Delta lnFD_j).$$ [8]

In order to ensure an appropriate specification for the NARDL model, it is required to test for short-run and long-run asymmetric effects of each explanatory variable on renewable energy consumption. In particular, the short-run asymmetric impact of financial development on

[8] lnY_t^{+}, lnY_t^{-}, $lnROP_t^{+}$, $lnROP_t^{-}$, $lnTO_t^{+}$ and $lnTO_t^{-}$ were calculated similarly.

renewable energy consumption is tested using a Wald test of the null $\gamma_i^+ = \gamma_i^-, i = 1, 2, \ldots, q-1$[9]; in contrast, the long-run asymmetric influence of financial development on renewable energy consumption is tested using a Wald test of the null $\beta_{FD}^+ = \beta_{FD}^-$, where the previous long-run coefficients are calculated such as $\beta_{FD}^+ = -\frac{\alpha_{FD}^+}{\alpha_{REC}}$ and $\beta_{FD}^- = -\frac{\alpha_{FD}^-}{\alpha_{REC}}$[10]. The NARDL model as represented by equation-2 would be over-parametrized if Wald test fails to reject the null of long-run or short-run asymmetry for at-least one explanatory variable. The respective effects of a one-unit change of explanatory variables on renewable energy consumption could be measured using dynamic multipliers. For example, the impact of a one-unit increase and a one-unit decrease of financial development on renewable energy consumption are evaluated as follows:

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial REC_{t+1}}{\partial FD_t^+} \quad \text{and} \quad m_h^+ = \sum_{j=0}^{h} \frac{\partial REC_{t+1}}{\partial FD_t^+}$$

The calculated dynamic multipliers show the adjustment path from an initial equilibrium towards a new equilibrium following a perturbation hitting the considered explanatory variable(s). It is crucial to notice that the adjustment path pattern depends on NARDL model specification, thus showing the importance of a prior correct specification of the NARDL model to the investigated set of variables.

III.II Data

We use quarterly[11] data for renewable energy consumption, overall financial development index, bank-based financial development index, stock-market financial development index, GDP per capita, real oil prices, and trade openness over the period 1975Q1–2019Q4. The data have been collected from World Development Indicators (CD-ROM, 2020) published by World Bank (2020). Table-1 reports descriptive statistics and stochastic properties of variables. The empirical results show that GDP per capita has the highest standard deviation while the lowest standard deviation is recorded for real oil prices. The empirical analysis also shows that all series are positively skewed, indicating a longer right tail of variables distribution except for renewable energy consumption and economic growth, for which the

[9] The Wald test was also conducted to test the short-run asymmetric effect of Y, ROP, and TO on REC.

[10] Similar computations and tests were performed to test for the asymmetric long-run impact of Y, ROP, and TO on REC.

[11] While all other variables are available at a quarterly frequency, the financial development index is only available at an annual frequency. Thus, the financial development index was converted into a quarterly frequency by applying the method by Sbia et al. (2014).

skewness is negative, indicating a longer left tail for their respective distribution. In addition, Kurtosis shows that the distributions of all series have thinner tails than those of normal distribution. The Jarque-Bera test rejects the null of normality for all considered variables.

Table-1: Descriptive Statistics

	REC	Overall	BI	SI	ROP	Y	TO
Mean	1898.965	646.164	57.305	216.854	14.099	10094.320	2365.186
Maximum	2112.313	2153.186	108.371	583.346	28.652	13583.260	3855.814
Minimum	1698.850	22.028	24.698	22.411	4.338	6196.849	944.194
Std. Dev	102.430	624.411	24.159	163.626	6.681	2186.610	945.202
Skewness	-0.216	0.654	0.272	0.383	0.579	-0.138	0.204
Kurtosis	2.289	2.083	1.668	1.735	2.158	1.634	1.602
J-B Stat	5.073*	18.724***	15.176***	16.036***	15.044***	14.229***	15.556***

IV. Empirical Results and Their Discussion

The ARDL-type models are appropriate when time series data are I(1) at most. Thus, before carrying out the estimation of the NARDL model(s) in our setting, it is important to check the order of integration of the variables. To this end, we perform an ADF unit root test with structural breaks. This test is preferred to the conventional ADF test, as the latter may lead to biased in the presence of structural breaks (Perron, 1989). Additionally, ADF unit root test with structural breaks is more powerful than traditional ADF unit root test when time series are characterized by structural breaks. As explained by Nasir et al. (2018), many reasons explain the presence of structural breaks in macroeconomic variables dynamics. For instance, macroeconomic policy decisions or financial events lead macroeconomic variables to exhibit structural breaks in their trends. The empirical results of the breakpoint Augmented Dickey-Fuller unit root test are reported in Table-2. These results show that renewable energy consumption is stationary at a level I(0). In contrast, the overall financial development index, bank-based financial development index, stock market financial development index, real oil prices, real GDP, and trade openness are stationary at the first difference, meaning that all the variables are I(1). This mix of I(0) and I(1) variables justifies the application of the NARDL-type model. The breaks occurred in 2007, 1994, 1998, 1982, and 1993 for renewable energy consumption, financial development indices, real oil prices, GDP per capita, and trade openness, respectively. These correspond to major events, such as the global financial crisis 2007–2008, which led to a significant drop in renewable energy consumption due to a sharp decrease in economic growth. Similarly, the year 1994 corresponded to the Mexican Peso crisis. The crash of oil prices in 1998 reflected the significant impact of the Asian financial crisis. The decline in GDP was due to the Latin American debt crisis in 1992; the decline in trade openness resulted from the 1993 Russian constitutional crisis.

Table-2: Unit Root Analysis with Structural Breaks

	EC	Overall	BI	SI	ROP	Y	TO
Level	-5.268*** [0.000]	-2.936 [0.719]	-2.576 [0.878]	-2.866 [0.755]	-2.599 [0.869]	-3.621 [0.320]	-2.250 [0.955]
Break Year	2007Q1	1994Q1	1994Q1	1994Q1	1998Q1	1982Q1	1993Q1
1st Difference		-6.279*** [0.000]	-5.845*** [0.000]	-6.814*** [0.000]	-6.861*** [0.000]	-6.156*** [0.000]	-7.027*** [0.000]
Break Year		1977Q1	1978Q1	1977Q1	1978Q1	1978Q1	1978Q4

Table-3: Brock et al. BDS Analysis

	m = 2	m = 3	m = 4	m = 5	m = 6
EC	0.185***	0.307***	0.389***	0.443***	0.477***
Overall	0.201***	0.339***	0.433***	0.498***	0.543***
BI	0.203***	0.343***	0.441***	0.508***	0.555***
SI	0.198***	0.334***	0.428***	0.492***	0.537***
ROP	0.182***	0.303***	0.382***	0.430***	0.458***
Y	0.206***	0.350***	0.451***	0.521***	0.571***
TO	0.202***	0.341***	0.438***	0.504***	0.550***

The possible nonlinear structure in the data series is also checked out using the BDS test (Brock et al. 1996). The BDS test is a nonparametric test robust to the form of nonlinearity in the data. The results reported in Table-3 show that the null of linearity is highly rejected for different embedding dimensions. The NARDL model is then well suited to accommodate for the nonlinearity present in our data. Table-4 reports the estimation results of the NARDL models in equations 2–4. The empirical results show that the speed of adjustment parameter is significantly negative for the three considered dimensions of financial development, namely, the overall financial development index (equation-2), bank-based financial development index (equation-3), and stock market financial development index (equation-4). The latter finding highlights the stability of the estimated NARDL models. Furthermore, the bounds test rejects the null of the absence of a long-run relationship between the variables. Before going through the estimation results of NARDL models, we first evaluate their respective goodness of fit statistics. The ARCH (Ljung-Box) test results fail to reject the null of homoskedasticity (serial independence of residual). The CUSUM and CUSUM of squares (Figure-1) indicate that the structure of the models is stable. Consequently, our estimated models pass the goodness of fit tests and present good quality of fit, with an R^2 exceeding 75%.

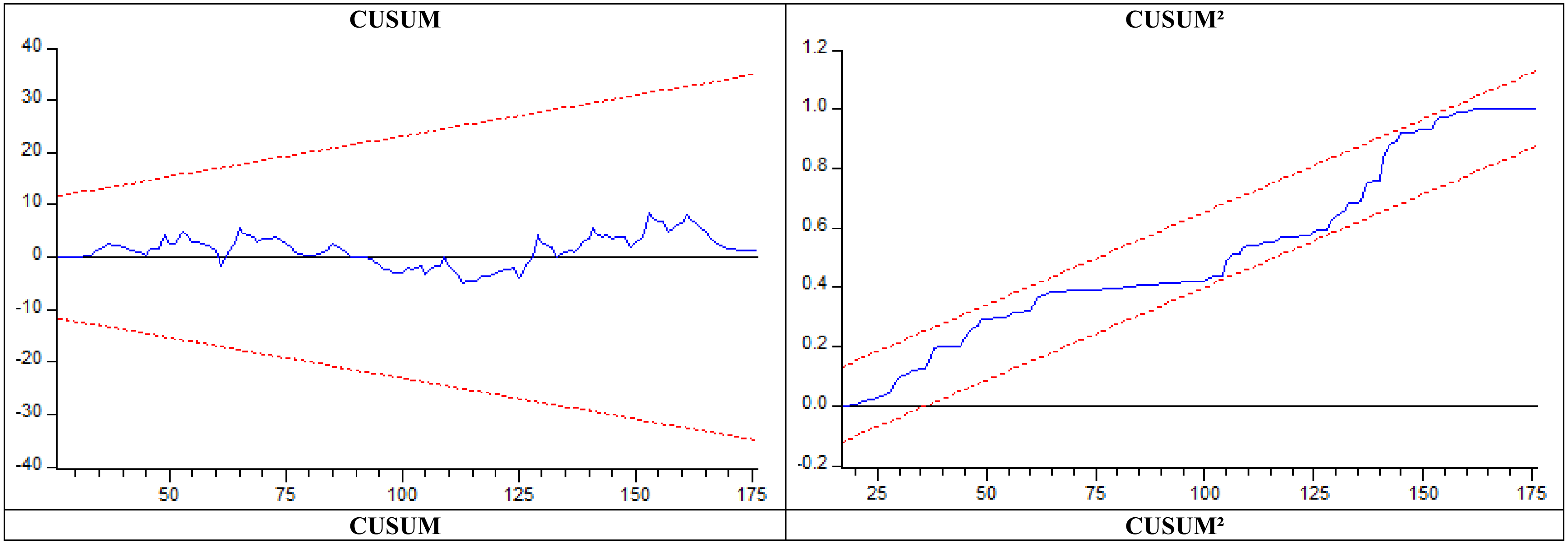
Table-4: The NARDL Regression Analysis

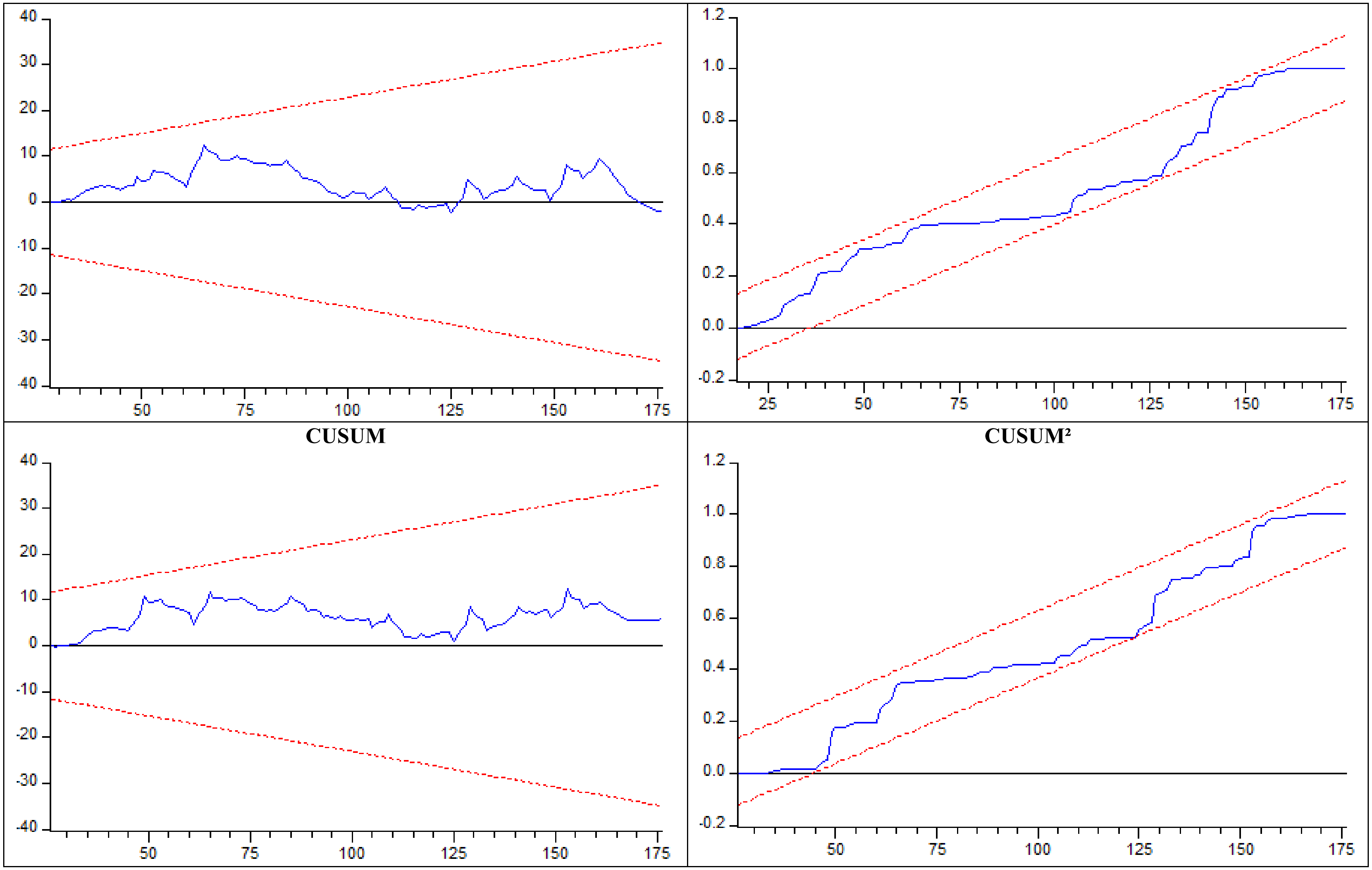
Model 1		Model 2		Model 3	
$Intercept$	0.790*** (0.149)	$Intercept$	0.764*** (0.153)	$Intercept$	0.791*** (0.149)
EC_{t-1}	-0.104*** (0.020)	EC_{t-1}	-0.101*** (0.020)	EC_{t-1}	-0.104*** (0.020)
$overall_{t-1}^{+}$	0.007** (0.003)	BI_{t-1}^{+}	0.014 (0.009)	SI_{t-1}^{+}	0.008** (0.003)
$overall_{t-1}^{-}$	-0.012*** (0.004)	BI_{t-1}^{-}	-0.054* (0.032)	SI_{t-1}^{-}	-0.010*** (0.003)
ROP_{t-1}^{+}	-0.008*** (0.003)	ROP_{t-1}^{+}	-0.007** (0.003)	ROP_{t-1}^{+}	-0.006** (0.002)
ROP_{t-1}^{-}	-0.003** (0.001)	ROP_{t-1}^{-}	-0.005*** (0.001)	ROP_{t-1}^{-}	-0.004*** (0.001)
Y_{t-1}^{+}	-0.011 (0.017)	Y_{t-1}^{+}	0.002 (0.023)	Y_{t-1}^{+}	-0.008 (0.016)
Y_{t-1}^{-}	0.158** (0.062)	Y_{t-1}^{-}	0.105 (0.077)	Y_{t-1}^{-}	0.149** (0.059)
TO_{t-1}^{+}	-0.006 (0.008)	TO_{t-1}^{+}	-0.0003 (0.009)	TO_{t-1}^{+}	-0.008 (0.008)
TO_{t-1}^{-}	0.020* (0.011)	TO_{t-1}^{-}	0.027* (0.014)	TO_{t-1}^{-}	0.025** (0.011)
dEC_{t-1}	0.455*** (0.069)	dEC_{t-1}	0.469*** (0.069)	dEC_{t-1}	0.453*** (0.070)
dEC_{t-2}	0.094* (0.051)	dEC_{t-2}	0.098* (0.054)	dEC_{t-2}	0.124** (0.056)
$doverall_{t}^{-}$	0.028** (0.011)	$dROP_{t}^{-}$	0.010 (0.006)	dSI_{t}^{-}	0.039*** (0.010)
$doverall_{t-1}^{-}$	-0.029*** (0.010)	dY_{t}^{+}	0.566*** (0.118)	dSI_{t-1}^{-}	-0.030*** (0.010)
$dROP_{t}^{-}$	0.007 (0.005)	dY_{t-1}^{+}	-0.388*** (0.118)	dY_{t}^{+}	0.649*** (0.111)
dY_{t}^{+}	0.651*** (0.114)	dY_{t}^{-}	0.542*** (0.159)	dY_{t-1}^{+}	-0.396*** (0.113)
dY_{t-1}^{+}	-0.405*** (0.115)	dTO_{t}^{+}	0.081*** (0.025)	dY_{t}^{-}	0.623*** (0.106)
dY_{t}^{-}	0.625*** (0.110)	dTO_{t}^{-}	0.060* (0.035)	dY_{t-1}^{-}	-0.281** (0112)
dY_{t-1}^{-}	-0.294** (0.115)	dTO_{t-1}^{-}	-0.088*** (0.025)	dTO_{t}^{+}	0.082*** (0.022)
dTO_{t}^{+}	0.078*** (0.023)				
D_t	-0.003*** (0.001)		-0.002 (0.002)		-0.002 (0.002)
Long-run estimates					

$L_{overall^+}$	0.069** (0.028)	L_{BI^+}	0.144 (0.100)	L_{SI^+}	0.079** (0.035)
$L_{overall^-}$	-0.124*** (0.037)	L_{BI^-}	-0.541* (0.310)	L_{SI^-}	-0.097** (0.033)
L_{ROP^+}	-0.079*** (0.025)	L_{ROP^+}	-0.078** (0.030)	L_{ROP^+}	-0.062** (0.024)
L_{ROP^-}	-0.027* (0.014)	L_{ROP^-}	-0.046*** (0.016)	L_{ROP^-}	-0.035*** (0.014)
L_{Y^+}	-0.103 (0.172)	L_{Y^+}	0.017 (0.225)	L_{Y^+}	-0.081 (0.154)
L_{Y^-}	1.516*** (0.475)	L_{Y^-}	1.042 (0.666)	L_{Y^-}	1.435*** (0.462)
L_{TO^+}	-0.054 (0.080)	L_{TO^+}	-0.004 (0.088)	L_{TO^+}	-0.077 (0.081)
L_{TO^-}	0.192 (0.105)	L_{TO^-}	0.267** (0.133)	L_{TO^-}	0.237** (0.102)
Model diagnostics					
$Adj. R^2$	0.786	$Adj. R^2$	0.753	$Adj. R^2$	0.788
AIC	-8.498	AIC	-8.362	AIC	-8.538
SIC	-8.115	SIC	-7.998	SIC	-8.153
$ARCH(2)$	1.150 [0.319]	$ARCH(2)$	1.873 [0.392]	$ARCH(2)$	1.891 [0.388]
Q(2)	1.355 [0.508]	Q(2)	1.291 [0.524]	Q(2)	0.882 [0.643]
$CUSUM$	Stable	$CUSUM$	Stable	$CUSUM$	Stable
$CUSUM^2$	Stable	$CUSUM^2$	Stable	$CUSUM^2$	Stable
$F - bounds\ test$	5.118***	$F - bounds\ test$	4.383***	$F - bounds\ test$	4.785***

In the long-run positive and negative changes of overall financial development and stock market financial development lead to an increase in renewable energy consumption. This signifies the effectiveness of the financialization channel to boost renewable energy consumption in the U.S. The report by Mendelsohn and Feldman (2013) states the possible effectiveness of public capital vehicles to boost renewable energy sector in the U.S., and this was reinstated in the recent report by Bloomsberg (Rathi and Hodges, 2020). Therefore, the public financing mechanism and the channelization of green financing through financial market might have a catalytic impact on renewable energy consumption. Hence, any slump in this financing mechanism might have a dampening impact on renewable energy consumption. This segment of the results extends the findings of Mazzucato and Semieniuk (2018) and Zafar et al. (2019).

Figure-1: CUSUM and CUSUM²




CUSUM
CUSUM²

In contrast, only negative change of bank-based financial development rises renewable energy consumption. The latter does not react to an increase in bank-based financial development. The empirical results also show that increases in real oil prices reduce renewable energy consumption; in contrast, decreased oil prices increase renewable energy consumption. It is worth noting that the Wald test for long-run asymmetry highly rejects the null of symmetry for overall and stock market-based financial development indices. It also rejects the null of symmetry for the bank-based financial development index at the 5% level. Contrariwise, the Wald test for long-run asymmetry fails to reject the null of the symmetric effect of real oil prices on renewable energy consumption regardless of the measure of financial development included in the model (Table-5). The financing mechanism of renewable energy consumption in the U.S. is largely driven by financial market and public finance mechanism and is less dependent on banking channel. In this regard, the case of *Green Banking* mechanism in the U.S. needs to be mentioned, which was introduced in the U.S. during 2008. In the subsequent year, a similar concept referred to as the *American Clean Energy and Security Act* was proposed, but eventually, it was declined by the Senate (Parrish, 2021). Consequently, the diffusion of Green Banking mechanism was restricted to state-level only, and the prominence of this channel was not visible until 2015 (Connecticut Green Bank, 2016). Therefore, it can be assumed that the banking sector will have no or insignificant impact on renewable energy consumption. However, the impact of real oil prices demonstrates high oil prices' elasticity of demand of the manufacturing sector. As a result, during the high oil prices regime, the dependence on renewable energy goes up, while during the low oil prices regime, the dependence on crude oil goes up. Given this evidence, the environmental unsustainability of the manufacturing sector is surfaced. The recent report by EIA (2020) substantiates this claim, which was already stated in the Sustainable Development Goals Report 2018 concerning the U.S. (SDSN, 2018). In both these reports, the manufacturing sector of the U.S. has been criticized for having substantial crude oil dependence. This segment of the findings extends the results obtained by Troster et al. (2018).

It is also lit that increases in real GDP and trade openness do not cause any change in renewable energy consumption. However, negative variations of real GDP cause renewable energy consumption to fall in a model including overall and stock market financial development indices; they do not impact renewable energy consumption when bank-based financial index is accounted for. This impact is found to be asymmetric for models including overall and stock-based financial development indices while symmetric for a model including bank-based financial development index (Table-5). Negative changes of trade openness have a similar impact on renewable energy consumption for models including bank-based and stock market financial development index, respectively. The trade openness asymmetric effect on renewable energy consumption is recorded in a model including only the stock-based financial development measure (Table-5). These two segments of the results complement the findings of the previous two sections. While the manufacturing sector demonstrates its environmentally unsustainable nature, trajectories of economic growth and trade openness also show similar patterns. This traces back to the classic debate on *Limits to Growth* initiated by the Club of Rome economists (Meadows et al. 1972). The economic growth pattern in the U.S. is largely dependent on fossil fuel-based solutions, and a recent critique by the United Nations Foundation stresses this issue (Brown and Rasmussen, 2020). And while economic growth is discussed, the impact of trade openness should be discussed in conjunction with the impact of economic growth. A recent study by Menton et al. (2020) shows the unsustainable trade pattern of the U.S., and this issue has been highlighted in the latest industry-oriented SDG progress report, as well (UNDP, 2020). In the wake of these events, it becomes evident that a financial market-oriented greening mechanism might be a pathway to realign economic growth and trade patterns of the U.S. for ascertaining sustainable development.

Turning to the analysis of the short-run influence of financial development, real oil prices, real GDP, and trade openness on renewable energy consumption, findings in Table-4 indicate that past levels of renewable energy consumption exert a positive effect on its current level. Moreover, this effect is positive at one-lagged and two-lagged periods, with a lower impact at the two-lagged period. Regarding the impact of financial development on renewable energy consumption, results are dependent on the considered dimension of financial development. In particular, positive and negative changes of bank-based financial index do not impact current levels of renewable energy consumption. Similarly, renewable energy consumption is insensitive to positive changes in the overall financial development index and stock-based financial development index. However, past overall financial development index and stock market financial development index have a positive (negative) contemporaneous (one-period lagged) effect on renewable energy consumption.

To sum up, the overall financial development index has a negative cumulative short-run effect, whereas stock market-based financial development index has a positive cumulative short-run effect on renewable energy consumption. The impact of renewable energy consumption in the U.S. is gradually getting prominence, and the positive impact of lagged values of renewable energy consumption substantiates this argument. This shows the growing potential of renewable energy consumption in the U.S., which might leverage policymakers in improving environmental quality and sustaining economic growth patterns. However, in order for financialization channels to gain full potential, a certain time is required, as its impact on renewable energy consumption is indirect. Moreover, during the initial implementation phases, the inertia to transform energy sources might be reflected by the negative impact of financialization on renewable energy consumption. Green financing through the stock market might be used as a short-term tax-saving instrument and create a positive environmental externality. Shahbaz et al. (2021) demonstrated this in the Indian context.

Table-5: Wald Test for Long-Run and Short-Run Asymmetry

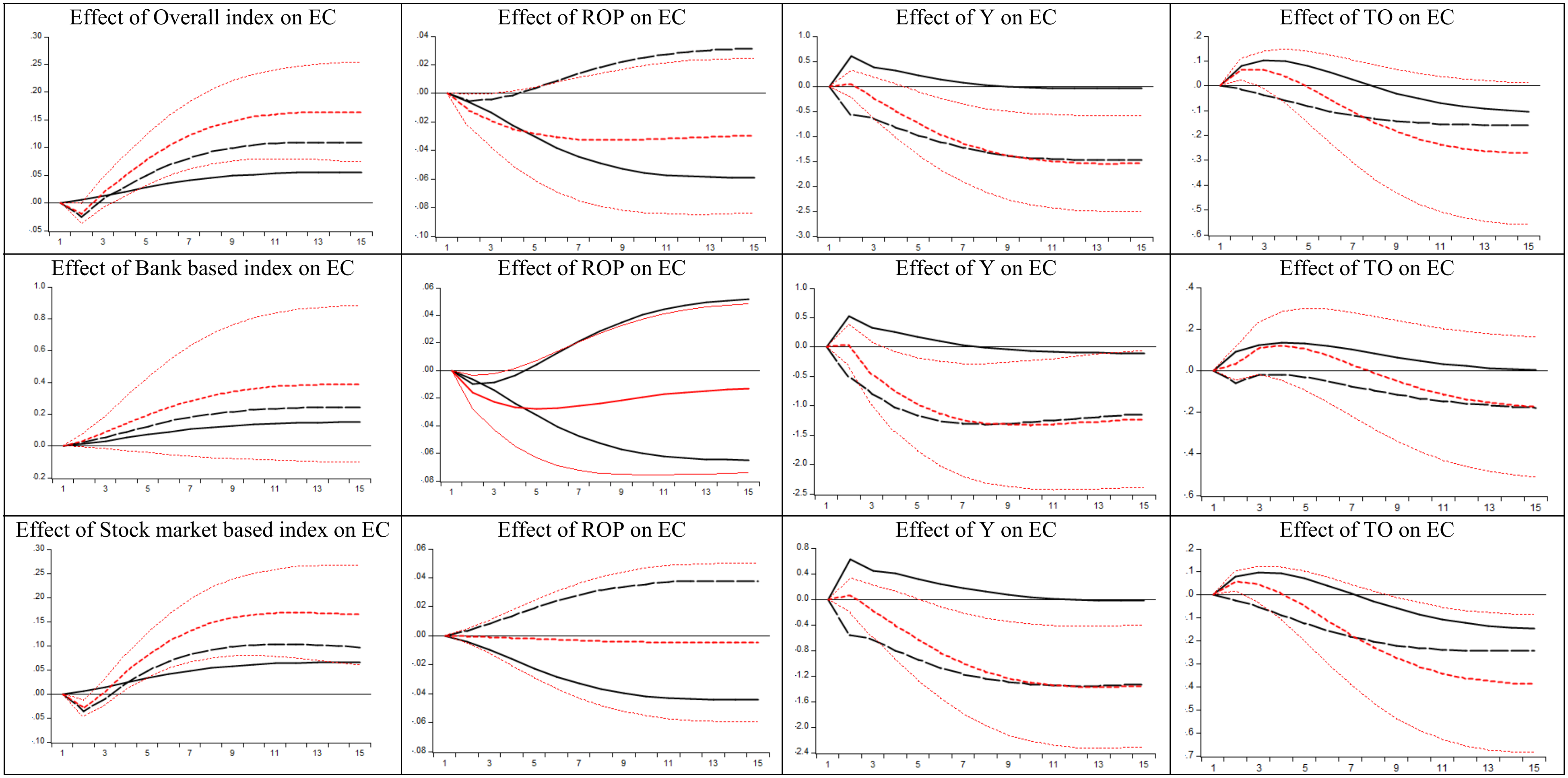
Variables	Model 1 (overall)		Model 2 (BI)		Model 3 (SI)	
	LR	SR	LR	SR	LR	SR
FD	12.481*** [0.000]	0.007 [0.932]	6.481** [0.037]	5.415** [0.022]	9.347*** [0.002]	0.017 [0.897]
ROP	2.738 [0.100]	1.247 [0.264]	0.799 [0.371]	9.413*** [0.003]	0.796 [0.372]	1.346 [0.248]
Y	7.679*** [0.006]	0.040 [0.841]	2.134 [0.144]	0.401 [0.528]	6.958*** [0.008]	3.966** [0.049]
TO	2.649 [0.104]	2.016 [0.156]	2.354 [0.125]	3.826* [0.053]	4.318** [0.038]	5.587** [0.020]

The short-run impact of real oil prices on renewable energy consumption is related to the nature of financial development introduced in the model. Indeed, renewable energy consumption does not react to an increase in real oil prices. Nevertheless, renewable energy consumption reacts positively and significantly to a decline of real oil prices in conjunction with the overall financial development index. In addition, renewable energy consumption is responsive to positive and negative changes in economic growth at different lagged periods. On the one hand, the cumulative short-run effect of positive economic growth changes is positive in models including overall, bank-based, and stock market-based financial development. On the other hand, negative economic growth has a cumulative positive effect on renewable energy consumption regardless of the considered measure of financial development. As for the short-run impact of trade openness on renewable energy consumption, results reported in Table-4 suggest that a rise of trade openness dictates renewable energy consumption to indiscriminately increase regardless of the measure of financial development employed. Conversely, a fall of trade openness has a negative

cumulative short-run cumulative effect on renewable energy consumption in a model including bank-based financial development. The empirical findings in Table-5 show that, in the short run, only in models including bank-based financial development index and stock market financial development index that explanatory variables exert an asymmetric effect on renewable energy consumption. More precisely, the Wald test rejects the null of symmetry for bank-based financial development index and real oil prices at the 5% and 1% level, respectively, and for trade openness at the 10% level. Similarly, in a model including the stock market financial development index, the Wald test rejects the null of symmetry for economic growth and trade openness at the 5% significance level.
The adjustment paths towards a new long-run equilibrium following a one unit positive and negative change of explanatory variables are depicted in Figure-2. The red bold dashed line asymmetry curve represents the asymmetry curve, a linear combination of the positive and negative shock effects. The continuous (dashed) black line depicts the effect of a one-unit positive shock; the dashed black line represents the effect of a one-unit negative shock. The dotted red lines represent the lower and upper limits of 95% confidence interval for asymmetry.

Overall, Figure-2 shows that positive and negative changes in financial development measures cause renewable energy consumption to move up. Furthermore, there is a greater reaction of renewable energy consumption to the negative changes of financial development measures than the positive changes. A cumulative significant positive adjustment is observed for overall and stock-based financial development measures. However, the cumulative adjustment following a one-unit shock of bank-based financial development is insignificant. The new equilibrium state is reached after 10 quarters. The adjustment towards a new equilibrium state following a one-unit shock of real oil prices is significantly negative during three quarters in models including overall and bank-based financial development measures, whereas it is insignificant in models including stock-based financial development measure. In contrast, the cumulative adjustment after a one-unit shock of real GDP becomes significantly negative starting from quarter 5 onwards regardless of financial development measure considered in the model. Lastly, the cumulative adjustment resulting from a one-unit shock of trade openness is significantly positive after one quarter and vanishes afterward in a model including overall financial development. In contrast, it becomes significantly negative starting from quarter 9 onwards in models including stock-based financial development measure.

Figure-2: Dynamic Multipliers



V. Conclusion and Policy Implications

The manufacturing sector in the U.S. seems to be inelastic towards oil prices. As such, policymakers need to ponder the possibilities of import substitution for crude oil while gradually removing the subsidies on domestic production of crude oil. This policy move will gradually reduce oil's dependence on the economy. However, this policy move should not be carried out overnight, as the renewable energy sector might be incapable of catering to surplus energy demand. Therefore, this policy move needs to be implemented in a phased manner so that the energy-driven economic growth pattern remains unharmed. During the initial phase, the government must provide renewable energy solutions to industrial sector at a pro-rata rate; financial institutions can be directed to provide loans and advances to access those solutions. However, the rate of interest on borrowing needs to be discriminatory, and this discrimination might be based on carbon footprint of firms. It will put pressure on polluting firms to adopt renewable energy solutions while comparatively incentivizing cleaner firms. While carrying out this exercise, reliance on public finance and green bonds should be emphasized, as these two modes of financialization have been preferred by industrial sector. This phase aims to initiate the fossil fuel replacement process in the economy, based on financialization channels.

Once this phase is implemented, policymakers need to enhance the scope of financial development so as to catalyze the diffusion of renewable energy solutions across the nation. In order to achieve this, policymakers need to strengthen the bank-based financialization channel. One of the major reasons behind this policy move is to protect the sectors from market volatility arising out of the demand-supply considerations in stock-market-led financialization. Moreover, the small and medium-scale enterprises will be benefitted from the ease of access to bank-based finances, and it might have a multiplier effect on the economy. Once access to finances is enhanced, the firms will be able to achieve economies of scale, and it will further help them achieve cost-effectiveness in international market. Once these policy initiatives are implemented, the U.S. economy will be benefitted from several aspects. First, the gradual reduction in the dependence on fossil fuel-based solutions will help them achieve a sustainable energy future, where energy will be green and cost-effective. Thus, it will help the U.S. progress towards achieving the objectives of SDG 7, i.e., affordable and clean energy. Second, by reducing the dependence on fossil fuel-based solutions, the U.S. can improve environmental quality by reducing ambient air pollution levels and protecting biodiversity. These will help the U.S. progress towards achieving the objectives of SDG 13, i.e., climate action. Third, reducing dependence on crude oil will help policymakers improve trade balance, thereby protecting the economy from possible fluctuations in the global crude oil market. Fourth, easing access to finance will help the industrial sector create more jobs, which will help the economy grow while bringing further improvements to the livelihood pattern of its citizens. This will help the U.S. progress towards achieving the objectives of SDG 8, i.e., decent work and economic growth.

While the core policy framework can be derived directly from the results obtained in the study, certain extrapolation of the results can be carried out to derive the tangential policy framework, which might be used to cushion the core policy framework. This policy framework will be based on the two phases of the core policy framework, with the objective of sustaining them. While policymakers need to focus on strengthening the financialization channels, without proper research and development facilities within the nation, the diffusion of renewable energy solutions might not be effective. Along with this, a sense of environmental awareness and the benefits of renewable energy should be manifested among the citizens. In order to achieve this, policymakers need to bring certain transformations in educational curricula so that the future labor force can be well-aware of green technologies and environmental protection from an early age. This move might help policymakers to foster the ecology of innovation at a grassroots level. Furthermore, policymakers need to encourage people-public-private partnerships in creating new green jobs based on the creation and diffusion of renewable energy solutions, as renewable energy generation infrastructure must be enhanced to commensurate future energy demands. Once this policy framework is in place, the core policy framework might achieve its intended objectives.

As the policy frameworks are recommended, it is needed to mention the policy caveats and assumptions, without which the policy frameworks might not produce the intended outcome. First, the import duties and subsidies on crude oil should not be relaxed, as it might revert the energy generation scenario developed by far. Second, while the renewable energy-generation sector is boosted, it will create excess pressure on traditional fossil fuel-based energy generation sector. This pressure might bring about unemployment in that sector. Hence, policymakers might intervene to tackle this situation by providing adequate vocational rehabilitation facilities to surplus labor so that they can be employed in the growing renewable energy generation sector. This initiative will help the economy in maintaining social order. Third, legislation concerning environmental protection and property rights should be made stringent to stop the unwarranted depletion of natural resources. Fourth, policies towards increasing the availability of finances to renewable energy sector and consequently to green finance through financial development represent an important step for promoting technological development in this sector, possibly playing a crucial role in achieving environmental sustainability. This could be achieved through the development of biomass and non-biomass renewable technologies. Fifth, the development of technologies using renewable energy sources allows assorting the energy balance and expands energy security, reducing dependence on conventional fuels and greenhouse gases. Energy technologies can help decrease dependence on imported fossil fuels, improve air quality, and secure healthy households. Overall, energy technologies have a threefold advantage as it helps rising access to energy security, increasing economic growth, and reducing unemployment.

In concluding the study, it is necessary to mention that no policy framework is absolute or all-encompassing, and the policy framework suggested in the study is not an exception. Given the boundary of the research question, this study has only looked into the impacts of various financialization channels. The policy framework could have been enriched by considering the sectoral aspects and the facades of energy innovation; therein lies the study's limitations. While saying this, it is also needed to remember that this policy framework can cater to the other developed nations as a baseline approach, which is struggling to attain energy security through renewable energy solutions. This policy framework can flexibly be redesigned in accordance with the contextual setting, and bringing about this policy-level generalizability aspect is the contribution of the present study. Future research in this area should consider aspects of international trade, energy innovation, and sector-specific dynamics.

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Appendix

Table-A1: Literature Review on the Relationship between Financial Development and Renewable Energy Consumption

Author	Methodology	Sample	Findings
Wu and Broadstock (2015)	Dynamic panel model estimation techniques (GMM)	22 emerging markets countries from 1990 to 2010	renewable energy consumption is positively and significantly determined by financial development and institutional quality
Best (2017)	Cross-section analysis (OLS), static panel model estimation techniques (FE)	137 countries for the period of 1998-2013	financial capital supports transition to more capital-intensive energy types and for high-income countries, financial capital is a catalyst for transitions from fossil fuels to modern renewable energy sources, especially wind
Kutan et al. (2018)	Group-Mean FMOLS panel data model estimation and Panel causality test	Brazil, China, India, and South Africa from 1990 to 2012	FDI inflows and stock market development contribute importantly in renewable energy consumption
Burakov and Freidin (2017)	Vector error correction model and Granger causality test	Russia from 1990 to 2014	Absence of causality running from financial development to renewable energy consumption
Anton and Nucu (2020)	Panel fixed effects model estimation	28 countries in the European	Different dimensions of financial development (banking sector, bond

		Union (EU) over the period of 1990-2015	market, and capital market) increases the share of renewable energy consumption