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Abstract

Using a large sample of 25 Organization for Economic Co-operation and Development (OECD) countries, we provide evidence that the growth of equity and credit markets promotes cleaner energy (biomass renewable energy, non biomass renewable energy, and total bio and non-bio renewable energy) production in those countries. We also find that the 2008 global financial crisis (*GFC*) adversely affects the production of cleaner energy. Our results are robust to alternative definitions of financial market development, cleaner energy, and controlling for the effect of government subsidy on cleaner energy. By supporting the demand-induced supply of cleaner energy, we demonstrate that the positive and significant effect of financial market development (FMD) on cleaner energy is stronger in countries with higher growth in carbon intensity and a lower availability of fossil fuels than otherwise. Our results also support the argument that financing uncertain projects such as those that produce cleaner energy should be greater in countries with a higher innovation culture than those where financial markets are already accustomed to undertaking risky investments. The overall results are also robust under the conditions of short-run and long-run homogeneity and the cross-sectional dependence in the sample. Policy implications are also provided.

JEL Classification: F21, P48, Q42.

Keywords: Biomass and cleaner energy production, common correlated effects pooled (CCEP), credit and equity markets, global financial crisis, innovation.

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1. Introduction

Proponents of cleaner energy (biomass reweable energy, non biomas renewable energy, and total renewable energy) posit that this type of energy is the nucleus of any long-run strategy aiming at offsetting enduring greenhouse gasses and addressing the paradox of economic growth and environmental sustainability. The recent convention, the 2015 United Nations Climate Change Conference (known as COP 21), reinforces the importance of cleaner energy and energy efficiency as the prime vehicle to fight the massive challenge of climate change. In line with the increasing demand and strengthened policy mandate aimed at accelerating energy security and sustainability, cleaner energy advanced at its fastest growth rate in 2016 and now represents more than 45 percent of global energy supply additions in many countries (International Energy Agency, 2016). However, a far more accelerating rate of the development and diffusion of cleaner energy is required to achieve the target of limitting global warming to two degrees celsius. A recent report on cleaner energy technology voices concern that the "*world's energy system needs to be transformed. The current path is environmentally unsustainable ... and threatens long-term economic growth and energy security. While there are encouraging signs in some areas, but the overall rate of progress towards a future sustainable energy system is too slow*" (International Energy Agency (IEA) 2012, p. 56). Ahmed and Cameron (2014) also argue that the growth of cleaner energy falls short to catch up with the growing concerns of the climate change.

Given the need for transforming the global energy system on one hand, and the enormous commercial potential of cleaner energy (Zyadin et al., 2014) on the other hand, we investigate the role of financial market development (*FMD*) and the impact of the *GFC* on the supply function of cleaner energy in a large sample of 25 OECD countries, with a strong consideration of the importance of varying degrees of grwoth in carbon intensity, dependence on fossil fuels, and the pace of innovations among those countries. Our argument for this necessary role of developed financial markets in driving cleaner energy-led economic growth in those countries is motivated by three complementary contentions. *First*, the progress in cleaner energy requires significant investment and innovations. Moreover, the entire innovation process is not only long, distinctive and fickle, but also involves an uncertainty to be successful (Holmstrom, 1989; Hsu et al., 2014). Returns on investments in technological progress are uncertain. Investors in start-ups generally stay away from capital-intensive fundamental innovations where the commercialization possibilities are uncertain (Rajan, 2012).

These concerns are likely to be true for investors in cleaner energy sources such as bio and non-biomass renewable energy. Additionally, investments in cleaner energy have significant cost disadvantages, compared with those in fossil fuels (Iskin et al., 2012). Pástor and Veronesi (2009) argue that financial markets are less likely to promote technology due to uncertainty in the technological development process. However, over the last two decades the commercial potential of cleaner energy is becoming more and more evident (Zyadin et al., 2014). During early 1990s when the debate on climate change was limited to scientific discourses and the consumer awareness about the need for cleaner energy was very limited, many investors vacillated to invest in cleaner energy due to the anticipation of high risks and low returns on in such vestments. However, as more and more scientific evidence started to attest to the disastrous consequences of global warming, today 'cleaner energy' has emerged as a political and social agenda[1]. The public awareness level of the need for cleaner energy has increased significantly (Kang et al., 2012). Currently, there is an active competition among China, USA and Germany to become the global cleaner energy superpower. Hence, yesterday's

[1] 'Clean energy' was a central focus in the race for the presidential nominees for the 2016 U.S. general election, albeit democrats are at the forefront of championing the agenda of 'cleaner energy'.

uncertainty about the commercial success of cleaner energy is becoming today's prime investment and innovation opportunities.

Second, despite the increased commercial opportunities, it is still true that investment and innovation remain the most significant challenge for cleaner energy production. However, we believe that financial market development is the answer to help overcome the challenge. We recall the view of Schumpeter (1911) which states that improvement in financial markets is vital for furthering technological progress. Research contends that enhancing technological progress necessitates a well-functioning financial market that reduces financing costs, improves allocation efficiency, assesses innovative projects and manages risk (Hsu et al., 2014). Hence, the thrust for cleaner energy requires the critical support of well-developed financial markets for greater investment, innovation and efficiency. In fact, IEA (2016) asserts that financial intermediation and better resources are the catalyst for the cost-effective deployment of the most dynamic technologies like cleaner energy into newer markets. Emphasizing a similar line of contention, the COP 21 Energy Day highlights the need for motivating financial markets to channel massive private sector's investments in cleaner energy and energy-efficient technology to reduce CO_2 emissions.

Finally, OECD countries provide an important setting for investigating the link between financial markets and cleaner energy production. Since a governmental political mandate is important for a complete transformation of a country's energy system, governments of major OECD economies and the IEA have agreed to intensely upsurge and co-ordinate the public-sector's investments in low-carbon research and development (R&D), aiming to double such investments (IEA, 2015). Note that the financial sectors in OECD countries (constituting approximately 80% of the global financial sector) are far more matured than similar sectors in any other regions in the world. Consequently, cleaner energy technology is thriving in many OECD countries including the United States, Denmark, Spain, UK and Germany.

Considering the sound rationale for the positive role of *FMD* in promoting cleaner energy, one would expect that financial crises may hurt or weaken growth of cleaner energy. The recent evidence shows that the global financial crisis (GFC) of 2008 has hurt long-term investment in innovations as some companies abridged the size of their investments (Filippetti and Archibugi, 2011; Paunov, 2012). The *GFC* has offered a prospect for some firms, industries and economies to restructure their productive facilities and to discover new opportunities (Archibugi et al., 2013). Hence, in contrast to the positive role of *FMD* on cleaner energy, *GFC* may have an inconclusive impact on cleaner energy.

The study on Intergovernmental Panel on Climate Change (2013) finds that the atmospheric concentration of CO2 emissions contributes 182% of the total 229% increase in total radioactive forcing (RF) in the world since year1750. OECD (2008) argues that without further policies such as geoengineering to combat climate change, the growth of greenhouse gas emissions is going to be 52% by 2050. Therefore, countries with higher growth in carbon intensity are expected to make more robust mitigation adjustments such as building capacity, communication, and outreach financing models to alleviate carbon intensity through prioritizing cleaner energy generation.

The development of cleaner energy is a subset of the entire innovation development matrix. A country with proven abilities in R&D stands for a greater chance to lead the cleaner energy revolution. On top of that, the enormous private sector's commercial potential of cleaner energy supplemented by higher *FMD* should attract more energy companies to invest in cleaner energy. Thus, we expect a far more profound role of *FMD* in advancing cleaner energy in countries with a higher level of an ex-post innovation success, such as the United States, Germany, Denmark and so on.

Fossil fuels are much cheaper in contrast with cleaner energy (Iskin et al., 2012), implying a higher commercial desirability of fossil fuels than cleaner energy. OECD countries like the United States have enough coal reserves that can generate energy for hundreds of years. Hence, the substitution effect suggests that the role of *FMD* in promoting cleaner energy production is likely to be stronger only in countries with a lower dependency on fossil fuels.

Using this large sample of OECD countries and applying the most appropriate panel method to overcome the problems of cross-sectional dependence, spatial spillover and omitted common factor bias, we provide robust evidence that *FMD* significantly promotes cleaner energy in our sample countries in the long run. Our finding also holds for the sub-sample of biomass and non-biomass renewable energy sources and for the aggregate and disaggregate measures of financial market development (e.g., in terms of credit and equity markets). We also find that the impact of the equity market development on cleaner energy is far more significant than that of the credit market. We also document that the *GFC* has a negative effect on cleaner energy in the long run, which provides an indirect support for our main findings. Consistent with our prediction of consumer-driven growth of cleaner energy, we find that the impact of the financial markets on cleaner energy production is consistently positive and significant in countries with a higher growth in carbon intensity, but not in countries with a lower growth in carbon intensity.

In support of our argument about the beneficial effect of existing innovation culture within countries, we find that the role of financial market development in enhancing cleaner energy is far more significant in countries with a higher ex-ante innovation status than in countries with a lower innovation culture. We document that the impact of financial markets on cleaner energy is consistently positive and significant in countries with a lower dependence on fossil fuels. Finally, our results are also robust to alternative measures of cleaner energy, while controlling for the roles of available technology and government grants and subsidies to promote cleaner energy.

We contribute to the energy finance literature in a number of ways. *First*, to the best of our knowledge, our work is the first to empirically investigate the overall role of *FMD* in promoting cleaner energy production under the conditions of short-run heterogeneity and long-run homogeneity. We extend the prior works of Lee (2013) and Paramati et al. (2017) but with significant differences**.** Both Lee (2013) and Paramati et al. (2017) estimate the role of finance in the cleaner energy consumption function[2]. We, however, estimate the role of financial markets in the cleaner energy production function. Hence, our results are new to the literature.

Second, our result of a far more significant impact of equity markets than credit markets in the cleaner energy production function contributes to the debate on the relative merits of the bank-based vs. market-based financial systems (Levine, 2002). *Third*, supporting the demand-induced supply of cleaner energy, we are the first to document that the effect of *FMD* on cleaner energy output is stronger in countries with higher growth of carbon intensities than others. We also present new evidence on the mediating roles of innovation growth and dependence on fossil fuels in the linkage between *FMD* and cleaner energy output. The role of innovation growth in the link between financial markets and cleaner energy also supports the entrepreneurial growth theory and extends the work of Schumpeter (1911) and Hsu et al. (2014). We also extend the results of the work of Iskin, et al. (2012) by presenting evidence of a weaker effect of finanial markets on cleaner energy output in countries with a higher use of fossil fuels vis-à-vis higher economic incentives for using those fuels since the former do not undertake massive investments to move toward cleaner energy. *Finally,* we contribute to the debate between the command approach versus the market approach to promoting cleaner energy by showing that governments' subsidies do not have any significant impact on the cleaner energy supply function.

[2] Paramati et al. (2017) include foreign direct investment (*FDI*), output and stock market as independent variables in a similar model. However, the concern in that study is that a significant portion of *FDI* flows in the form of equity capital. Moreover, both the FDI and equity market are endogenously related to output.

The remainder of the paper is organized as follows. Section 2 presents the literature review and hypothesis development. Section 3 discusses the data and methodology. Section 4 provides the sample descriptive statistics, the panel unit root test, and the main results. Section 5 presents various robustness tests. Section 6 presents economic rationale for the link between financial market development and cleaner energy. Section 7 presents test to rule out alternative explanation of our result. Section 8 concludes.

2. Literature review and hypothesis development

2.1 Financial market development and the thrust to cleaner energy

Cleaner energy is a crucially sociall optimum public policy's objective that guarantees inter-generational energy security and energy efficiency (Inglesi-Lotz, 2015), mitigation of greenhouse gasses to preserve environmental sustainability (Edenhofer et al., 2013), and social desirability (Inglesi-Lotz, 2015). Nevertheless, global growth of cleaner energy up to date is substantially inadequate. In addition to the inertia of some governments, the low level of public awareness and the availability of cheap fossil fuels partly explain such inadequacy. However, the financial constraint is the prime obstacle in advancing technological innovations and moving towards low-carbon economies (EIA, 2015).

Financing is not only a challenge to the production of cleaner energy but is also vital for the R&D process to increase economic viability, investment in consumer awareness building, lobbying for policy making, and investing in the wholesale and retail cleaner energy markets. Although the financing concern to cleaner energy is still significant, things are however changing. The recent global movement towards environmental sustainability by various stakeholders (initiatives of academia, activism of NOGs, civil societies and action groups, among others) culminates the efforts towards green economic policies and politics vis-a-vis increased consumer awareness and greater demand for cleaner energy. Today, there exists an enormous awareness-led and demand-driven commercial potential of cleaner energy that provides a signal to prospective investors to grab unprecedented future market opportunities (Hirth, 2013; Zyadin et al., 2014).

The role of financial development in driving innovations is evident (Holmstrom, 1989; Cornaggia et al., 2015; Hsu et al., 2014; Fang et al., 2014; Amore et al., 2013; Chava et al., 2013; Nanda and Rhodes-Kropf, 2013; Aghion and Howitt, 2005; Fang et al., 2014; Amore et al., 2013; Chava et al., 2013; Aghion and Howitt, 2005). In particular, Hsu et al. (2014) show that financial challenges involved in the production process of the innovation can be reduced by financial deepening, thus reducing financing costs, improving cost and allocative efficiency, and tracking the innovative projects. Rajan (2012) shows that innovation is an outcome of the ability of firms to secure capital and that equity markets can provide external capital by reducing asymmetric information, and the risk and cost of capital. Although traditionally credit markets would generally avoid investments in highly risky innovative projects (Hall and Lerner, 2010; King and Levine, 1993), the recent evidence however suggests that deregulation of the banking sector (Chava et al., 2013), credit supply by banks (Mario et al., 2013), and banking competition (Cornaggia et al., 2015) increase innovations. Therefore, we believe that financial market development is the answer to promoting innovations towards a far more robust and commercially viable cleaner energy future.

Financial markets also facilitate the risk diversification of investors, leading the way for technological innovations (Hsu et al., 2014; King and Levine, 1993). Hence, financial markets can facilitate the risk diversification for investors in cleaner energy and can encourage companies to tap into the enormous commercial potential of cleaner energy (Zyadin et al., 2014). Paramatta et al. (2017) document that foreign direct investment (FDI) and stock markets can increase consumption of cleaner energy. While financial markets facilitate channeling FDI into investments, more importantly the increased consumer demand will provide additional motivation for investors to finance cleaner energy solutions. Recent finance literature also shows that the market performance underpinned by investors' preference of socially responsible funds is significantly higher than that of the S&P 500 index (Statman, 2000; 2006). This should further encourage investors to invest in cleaner energy. The recent anecdotal evidence also supports this view.

In more recent time, numerous cleaner energy companies envision the growth potential of this energy type and the relevance of floated initial public offerings (IPOs) to expand their business sizes. Particularly, in the United States and in other OECD countries, where both the equity and credit markets are highly developed, a significant number of cleaner energy companies expand their production and operation[3]. Notably, the average growth of the photovoltaics industry is 60 percent, the biodiesel industry is 42 percent, and the wind industry is 25 percent over the years from 2002 to 2008[4]. More strikingly, as of 2015, the size of the cleaner energy industry is $285.9 billion which was only $72.2 billion in 2005[5].

Synthesizing the above evidences, we hypothesize that the development of financial markets will allow investors to tap into the socially desirable and commercially potentials of the cleaner energy market as well as to diversify investment risk. Hence, we formulate the following hypothesis:

H1: The development of financial markets promotes cleaner energy.

2.2 The financial crisis and the thrust for cleaner energy

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[3] Companies such as Enphase Energy, Americas Wind Energy Corporation, Ascent Solar Technologies, Ballard Power Systems, Brookfield Renewable Energy Partners LP, DayStar Technologies, INC etc. flourished in the United States with financing access from equity markets. Similarly, other OECD countries experienced tremendous growth in cleaner energy companies such as Alterra Power, Anwell Technologies, INC, Ballard Power Systems, Clenergen Corporation, Carnegie Wave Energy, LTD, Ceramic Fuel Cells, LTD, Comtec Solar Systems Group Limited and so on.

[4] REN21 (2008) *Renewables 2007 Global Status Report* (Paris: REN21 Secretariat and Washington, DC: Worldwatch Institute).

[5] See Global Trends in Renewable Energy Investment 2016 reports. Accessed from http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2016lowres_0.pdf

In the event of a major global economic crisis, the economy faces huge uncertainties about the future direction of consumer demand, the availability of new future market opportunities and the future direction of technological change. The recent evidence, however, suggests that global economic shocks, notably the GFC in 2008 onward, have hurt long-term investments, which in turn caused a sluggish growth of innovations (Filippetti and Archibugi, 2011; OECD, 2009; Paunov, 2012; Archibugi et al., 2013). Since innovation is central to the success of the cleaner energy goal, the possibility that a major crisis like GFC may affect the growth of cleaner energy is real. The 2009 study on the Sustainable Energy Finance Initiative documents that the global cleaner energy sector was continuously flourishing from 2004 to early 2008. But during the early stages of the *GFC*, cleaner energy grew up modestly, rising from $148bn in $2007 to $155bn in 2008. However, in the first quarter of 2009, new investment spending dropped 42% than in previous quarter due to the adverse shock of the GFC, thereby reducing the flow of bank financing to renewable energy developers[6].

Schumpeter (1911) however foretold that although economic crises adversely influence and may also wipe out many of the economic agents in the long-run, yet there is the possibility of having both winners and losers. The losers, most in numbers, react not only by just reducing employment and productive capacity in general, but also by scaling down the size of investments in innovations during the crisis. The winners are: (a) firms that allow dynamic adjustments to their products and services by acquiring new knowledge and innovation to increase their chances of tapping comparative advantages, and (b) firms that enter the markets during the financial crises to compete against existing vulnerable firms and seize fresh market opportunities. In fact, Archibugi et al. (2013) document that companies with in-house R&D facilities, strategic focuses on new market opportunities and are already committed to long run

[6] The G8 Energy Ministers' Meeting. The impact of the financial and economic crisis on energy investment, May 2009. Accessed from https://www.iea.org/publications/freepublications/publication/impact.pdf

R&D investment continue to maintain their innovation activities in financial crises. Hence, financial crises sometimes may offer a prospect for some firms and industries that restructure their productive facilities and to discover new opportunities. A recent report titled "Global Trends in Renewable Energy Investment 2016" suggests that global investment in cleaner energy is $285.9 billion in 2015, more than double the amount invested in new coal and gas generation and exceeds the previous record of $278.5 billion in 2011[7]. Hence, we test the following hypothesis:

H2: *Global financial crisis impedes (fosters) the growth of cleaner energy.*

2.3 Financial markets and cleaner energy: Role of the growth of carbon intensity

Industrial emissions of CO_2 and other carbon-containing gasses contribute almost 80% of the total increase in anthropogenic radioactive forces in 2011 (Intergovernmental Panel on Climate Change, 2013). Hopefully, some industrial countries with a higher level of CO_2 emissions are taking steps to mitigate the CO_2 emissions. For example, the UK adopted the Climate Change Act in 2008, thereby targeting a reduction in its greenhouse gas emissions by at least 80% (from the 1990 baseline level) by 2050. Other OECD countries with higher growth in carbon-intensity such as Germany, France and Denmark are also exerting significant efforts to this end, while the United States aims to be a superpower in cleaner energy.

The European Union (EU) member countries are mandated to meet by 2020 a target of achieving a 20% of renewable resources in the energy supply and a 10% of those resources in the energy of the transport sector to reduce carbon intensity in the EU regional market (Union, 2009). EU has adopted climate change acts and several action plans to achieve this goal of reducing carbon intensity, including increasing the use of low-carbon technologies, reducing the emissions from the power sector and encouraging investments in low-carbon

[7] http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2016lowres_0.pdf

technologies by reforming the electricity markets, providing funds for innovations in the low-carbon technologies and cleaner energy and fostering financial market development.

H3: The finance and cleaner energy nexus is sensitive to the degree of carbon intensity.

2.4 Financial markets and cleaner energy: Role of innovation growth

Innovations play a crucial role in long-run economic growth in the neo-classical models (Solow, 1956). Also, the neo-Schumpeterian theory proposes that techno-organizational development is central to the evolution of economic systems (Dosi, 1988; Fagerberg and Godinho, 2005). By focusing on environmental innovations, one can consider the role of technological progress in mitigating climate change to be crucial (Borghesi, et al., 2015). However, we believe that a country with proven capabilities of R&D and innovation successes has a higher chance to lead in achieving a cleaner energy revolution, compared with countries with a low innovational success. On top of that, the enormous commercial potential of cleaner energy supplemented by higher financial market development should attract more energy companies to invest in this source of energy. Thus, we expect that the role of *FMD* in cleaner energy to be more profound in OCED countries that have a high level of technological innovation culture such as the U.S., Germany, the UK and Denmark and so on. This leads us to the fourth hypothesis:

H4: Ex-post higher growth in innovations drives the FMD and cleaner energy nexus.

2.5 Financial markets and the thrive for cleaner energy: Role of fossil fuels (H5)

Several socio-economic parameters hinder the process of replacing fossil fuels or the carbon-emitting energy with a cleaner energy. *First*, the world consumes about three cubic miles of oil equivalent energy per year. To generate one cubic mile of oil equivalent energy from renewable sources at current capacity, we would require 50 years of investments in building dams, nuclear power plants, windmills or solar panels (Lyman, 2016). Sadly, given the current energy consumption, production dynamics and scale economics, there is no simple way to replace carbon-emitting energy with cleaner energy. For example, major OECD economies are overwhelmingly dependent on nonrenewable energy sources. More specifically, eighty-six percent of electricity production in the U.S. comes from non-renewable energy. The figure is quite similar in other OECD countries: UK (78%), Germany (67%), France (83%), Australia (87%), Japan (85%), Turkey (72%), Belgium (88%) and South Korea (99%).

Second, the current state of the transportation sector almost completely relies on fossil fuels. In the U.S., nearly 92% of the transportation sector uses oil-based fuels, with only 5% of this sector uses renewable energy and 3% uses natural gas. Moreover, globally there is an insufficient technological progress to move countries towards using commercially viable renewable energy or solar powered vehicles. Thus, until fossil fuels become expensive (Heinberg and Fridley, 2010), the economic incentive to move away from these fuels to cleaner energy is still quite low for a country with a higher fossil fuel use. Therefore, we formulate the following hypothesis:

> *H5: The link between FMD and cleaner energy is weaker in countries with a higher reliance on fossil fuels.*

3. Data, methodology and models

3.1 Variables and measures

Using a sample of 25 OECD countries[8], we investigate the effect of financial markets on cleaner energy for the period 1980 to 2015[9]. We use three measures of cleaner energy: The first is the biomass renewable energy (*BIO*), the second is the non-biomass renewable energy (*NBIO*) and the third is the total renewable cleaner energy (*CE*), which is the sum of both bio and non-bio renewable energy. We use the logarithmic transformation of those cleaner energy measures to reduce any abnormal size effect in our estimation.

Following the prior finance literature, we use the principal component analysis of the equity market, the credit market and the broad money supply variables to construct our broad financial market development (*FMD*) measure. As a robustness check, we use separate variables for the credit market (i.e., the financial sector credit) development and for the equity market (i.e., the stock market) development since both depository and non-depository financial institutions and equity market development can have differential effects on the economic outcomes (Levine and Zervos, 1998).

In the case of the credit market, prior literature (e.g. Sadorsky, 2011) uses multiple variables including the ratio of financial system deposits to GDP, the ratio of deposit money banks' assets to GDP, and the private credit extended by deposit money banks relative to GDP. However, we argue that the deposit in the banking sector is highly correlated to banks' assets since large banks are more likely to have higher-level of deposits. Again, a bank may have a higher level of deposits, but it may have regulatory and operational constraints that makes it curtail its credit provision to potential borrowers. Moreover, bank deposits should also be highly correlated with the credit provided by the private sector. Thus, we use domestic credit

[8] We exclude countries that became an OECD member after the start of our sample except for Korea. This exclusion for Korea is made since this country has a sufficient availability of data, is one of the countries with the highest innovation rates, has the lowest fossil fuel availability, is highly dependent on imported oil and only 1% of its electricity comes from cleaner energy sources. However, our main results hold without Korea. Appendix Table A presents a list of the sample countries.

[9] Although the data for the year of 2016 are available for few countries in our sample, our choice of the sample window is purely governed by the data availability issue for the left and main right-hand side variables of all 25 countries.

to the private sector by banks and other financial institutions as a percentage of GDP as our single measure of credit market development. King and Levine (1993) show that the credit market isolates credit issued by private banks, solves the problem of overlapping in the measures, and is by far the most important indicator of credit market development.

We are aware that the bond market also plays a significant role in driving credit disbursement by mobilizing savings. However, it is possible for a cleaner energy firm to issue bonds if and only if it becomes a public limited company. Thus, equity market development represents our second disaggregated measure of financial market. The prior literature (e.g., Berger et al., 2004; Levine and Zervos, 1996) uses the ratio of stock market capitalization to GDP, the ratio of total trading volume to GDP and the stock market turnover a % of GDP. Although the trading volume activity measures the state of liquidity, while the market turnover measures operational efficiency, these are noisy measures at least in the context of our estimation. The turnover measure can incorporate the noise of market sentiment and is a potential sign of a boom and a subsequent bust in the market. However, cleaner energy requires long-term financing commitment. Hence, we consider the stock market capitalization of the listed companies as the sole measure of the equity market development[10].

We also use several control variables. We control for the living standard measure by households' per capita final consumption since a higher living standard underpinned by a higher level of purchasing power is crucial for the demand side growth of cleaner energy, which is generally more expensive than the cost of fossil fuels. A higher purchasing power also indicates a higher level of willingness on part of the citizens to pay for conserving the environment using cleaner energy. We include trade openness since Harrison (1996) argues that trade openness provides access to imported inputs including new technology, increases the

[10] We use a natural logarithmic transformation of market capitalization as our measure of equity market development since we have used market capitalization as a percentage of GDP in the principal component construction of the overall financial market development index (*FMD*). However, our result holds by using market capitalization as a percentage of GDP, as well.

size of the market faced by domestic producers, which raises the return to innovations and facilitates a country's specialization in the production of intensive research. This argument is consistent with the new growth theory (Romer, 1986; Grossman and Helpman, 1990; Levine and Renelt, 1992) that underpins the role of technology in economic growth.

We control for international oil price volatility as an inverse measure of oil price stability. We use the standard deviation of the yearly oil prices on a ten-year rolling window basis as our measure of oil price volatility. Oil as the major source of energy is a substitute for cleaner energy, and hence, a volatile international oil price may influence the economic incentive for having technological progress towards a cleaner energy since the industries that use oil as their source of energy benefit from a stable energy price. Finally, as a robustness check, we use the global financial crisis, innovation success and dependence on cheap fossil fuels, government grants and subsidies as additional variables in our models. Appendix Table B presents our definitions of the variables and sources of the data.

3.2 Cross-sectional dependence, panel unit roots and estimation *techniques*

The recent econometrics literature developed second-generation unit root tests (Bai and Ng, 2004; Moon and Perron, 2004; Pesaran, 2007) to overcome the problem of cross-sectional dependence across the units. Our sample countries are integrated through financial and trading networks. These networks raise the concern of a potential spillover effect among the countries. Thus, we employ the cross-section dependence (CD) test of Pesaran (2004) to investigate the contemporaneous correlation across the countries and assess the types of unit root and cointegration tests that best fit our data. In the Pesaran (2004), the cross-sectional independence for the CD test is the null hypothesized against the alternative hypothesis of cross-sectional dependence among the respective countries. The test follows the equation:

$$CD = \left(\frac{TN(N-1}{2}\right)^{1/2} \bar{\bar{P}}$$

where $\bar{\hat{\rho}} = \left(\frac{2}{N(N-1)}\right)\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}$ and $\hat{\rho}_{ij}$ indicates the pair-wise, cross-sectional correlation coefficient of the residuals obtained from the ADF regression. *N* and *T* indicate the cross-section and time dimensions, respectively.

After calculating the CD statistics as defined above, we estimate the following cross-sectional augmented Dickey-Fuller (CADF) regression with a time trend in the unit root test:

$$\Delta y_{it} = \alpha_i + T_i + \beta_i y_{it-1} + \gamma_i \bar{y}_{t-1} + \phi_i \Delta\bar{y}_t + \varepsilon_{it} \dots\dots\dots\dots (1)$$

Here, $t = 1, \dots, T,\ i = 1, \dots, N$ and $\overline{y}_t$ indicates the cross-sectional mean of y_{it} which is derived from $\overline{y}_t = N^{-1}\sum_{i=1}^{N} y_{it}$. The consideration of the cross-sectional mean mitigates the contemporaneous correlation among y_{it}. The null hypothesis of Equation (1) is $H_0: \beta_i = 0$ for all *i* and the alternative hypothesis is $H_a: \beta_i < 0$ for some *i*. Pesaran (2007) provides the cross-sectionally augmented panel unit root (CIPS) test statistic as:

$$CIPS(N,T) = N^{-1}\sum_{i=1}^{N} t_i(N,T)$$

where $t_i(N,T)$ indicates the t-statistic of β_i .

In our study, the main dependent variable (i.e., the generation of cleaner energy driven either by commercial or social desirability) and the main independent variable (i.e., financial market development) as well as the other control variables have a strong potential to be cross-sectionally dependent. This is because OECD countries are integrated through trade and financial globalization, neighborhood and other networking factors. Hence, we apply the common correlated effects mean pooled (CCEP) estimation approach of Pesaran (2006). This approach can deal with the cross-sectional dependence error processes as cross-correlations occur very frequently due to financial integration, spatial spillovers, omitted common factors and interactions within socioeconomic networks (Pesaran and Tosetti, 2011).

We apply the estimator that uses the mean group (MG) based on the assumption of the common correlated effect pooled (CCEP) approach that is asymptotically unbiased as *N*→∞ for both *T* fixed and *T*→∞. The CCEP is also very efficient in the presence of unobserved common effects (Pesaran, 2006). We run three different versions of CCEP addressing the potential cross-section bias: in the short-run, in the long-run and in both the short and long-run. Hence, our baseline regressions using three different measures of cleaner energy (cleaner energy (*CE*), biomass renewable energy (*BIO*), non-biomass renewable energy (*NBIO*)) are as follows:

$$CE_{jt} = a_j + d_j t + \beta_{j1} FMD_{jt-1} + \beta_{ji} Controls_{j,i,t-1} + \varepsilon_{jt} \dots\dots\dots\dots (2A)$$

$$BIO_{jt} = a_j + d_j t + \beta_{j1} FMD_{jt-1} + \beta_{ji} Controls_{j,i,t-1} + \varepsilon_{jt} \dots\dots\dots\dots (2B)$$

$$NBIO_{jt} = a_j + d_j t + \beta_{j1} FMD_{jt-1} + \beta_{ji} Controls_{j,i,t-1} + \varepsilon_{jt} \dots\dots\dots\dots (2C)$$

where j stands for the cross-sectional dimension j=1………J, time t=1………T and a_j represents the country-specific effects and $d_j t$ denotes the heterogeneous country-specific deterministic trends. *FMD* is a measure of the financial market development index as explained in the variables' definition subsection. The control variables include oil price volatility, living standard and trade openness. Note that the slope coefficients in the above models are directly related to *FMD* and other control variables in a way that represents $\beta_{j1} = \frac{\alpha_{j1}}{1-\alpha_{j1}} \dots \beta_{ji} = \frac{\alpha_{ji}}{1-\alpha_{j1}}$.

In Equations (2), we impose homogenous restrictions on the financial integration and the diffusion of cleaner energy in the long run, as well as heterogeneous restrictions (a_j) in the short-run. Hence, the slope coefficients $\beta_j = (\beta_{j1,}\beta_{j2,}\beta_{j3} \dots \beta_{jk})'$ are also considered as heterogeneous across the countries. We also consider the short-run dynamic adjustments of the economic shocks (the error term u_{jt}) towards the long-run equilibrium (i.e., $u_{jt} = \acute{\tau}_j f_t + \varepsilon_{jt}$.). Here $\acute{\tau}_j$ is the parameter of f_t, the vector of unobserved common shocks. Note that f_t can be either stationary or non-stationary, which does not influence the validity of our estimation (Kapetanios, 2011). In addition, the cross-sectional specific errors ε_{jt} are permissible to be serially correlated over time and weakly dependent across the countries (Cavalcanti et al., 2011). However, the regressors and the unobserved common factors must be identically distributed.

With regards to the slope coefficients of the CCEP model, Pesaran (2006) points out that $\beta_j = \beta + \omega_j$ which means that there is a common parameter β across the countries, while $\omega_j \sim IID(0, V_\omega)$. As the cross-section dependence (CD) occurs for few reasons like technology spillovers, the recent global financial crisis and local spillovers, this study applies CCEP to eliminate CD asymptotically. The estimator of CCEP is shown as $\hat{\beta}_{CCEP} = J^{-1} \sum_{j=1}^{J} \hat{\beta}_j$. In our empirical design, we view that the impact of financial markets on cleaner energy is not contemporaneous, rather it takes time for financial market development index (*FMD)* to affect cleaner energy directly or via innovations[11].

4. Results and discussion

4.1 Descriptive analysis

Table 1 presents the descriptive statistics of our variables. The sample statistics show the annual mean of cleaner energy (*CE*), biomass renewable energy (*BIO*) and non-biomass renewable energy (*NBIO*) are 59.369, 5.342 and 54.027 billion kilowatt hours (kWh). The size of *BIO* energy is significantly smaller than that of *NBIO* energy. The mean of fossil fuels output is 181.602 billion kWh. We also find that the average living standard measured by household consumption per capita is approximately $17,500, a figure that is much higher than the world's average. Considering the average value of cleaner energy, the standard deviation is very high, indicating a high heterogeneity in the cleaner energy output among the sample countries. Results in Table 1 also suggests that there is a substantial variation in the size equity and credit

[11] Prior studies (e.g., Lee, 2013; Doytch and Narayan, 2016; Paramati et al., 2017) use contemporaneous functional relation between finance and cleaner energy consumption. Although our results hold using contemporaneous functional relation (see Appendix Table C), however by following the finance and innovation literature, we avoid the contemporaneous regression governing the relation between finance and cleaner energy production.

markets among the sample countries. The nature of patents, oil price volatility, trade openness, financial market development (*FMD*) varies within a tight bound, implying that these variables have almost a homogenous nature.

[Insert Table 1 near here]

Table 2 presents the correlation matrix including the levels of significance (p-values) among the variables. Since cleaner energy comprises biomass and non-biomass, this table reveals a strong and significant positive correlations among *CE*, *BIO* and *NBIO*. Moreover, the *CE*, *BIO* and *NBIO* energy types have a relatively higher and significant positive correlation with *FMD*, equity market development and credit market development, respectively). We also find that trade openness is negatively and significantly associated with *CE*, *BIO* and *NBIO*, which is contrary to our expectations. However, the correlation makes sense since our sample countries are technologically advanced, compared to rest of the world. Hence, trade openness does not necessarily represent a technological transfer from the rest of the world to improve the technological aspect of renewable energy. Moreover, the renewable energy industry is still in its infancy stage and does not represent a significant part of the foreign trading volume. Living standard is positively and significantly associated with *CE*, *BIO* and *NBIO*. Unexpectedly, oil price volatility is negatively but weakly linked to *BIO,* which may still capture the effect of uncertainty in the oil market on cleaner energy. Overall, our univariate analysis in Table 2 provides an initial indication of a possible positive effect of *FMD* on the promotion of cleaner energy.

[Insert Table 2 near here]

Addressing the potential CD problem in a long panel time-series framework is immensely important to obtain unbiased estimators (Sadorsky, 2013). We apply the CD test developed by Pesaran (2004) to investigate contemporaneous correlations across countries. The CD test is carried out based on the average of the pair-wise correlations of the OLS residuals obtained from the individual sample country regressions in the panel. Besides, we apply the panel unit-root test to make sure that the variables do not exceed the order of integration one. The presence of the CD and I(1) or 1(0) of the respective variables is a pre-requisite for applying the CCEP approach.

We present the CD test statistics and the average cross-sectional correlations in the second and third columns of Table 3, respectively. The result of the CD test clearly shows that each variable in our study suffers from the CD problem. The third column shows that the average pair-wise cross-sectional correlation coefficients of the residuals of the regressions are very high.

Based on our findings in Columns 2 and 3 of Table 3, we apply the Pesaran (2007) CIPS (Z(t-bar)) test for the cross-section unit roots by allowing for the presence of cross-sectional dependence. These tests are estimated with a constant term in the level and in the first difference. The CIPS test results in Table 3 suggest that each series is characterized by unit-root properties. Overall, Table 3 clearly reaffirms the use of the CCEP approach as the most appropriate method for our empirical settings.

[Insert Table 3 near here]

4.2 Financial markets and cleaner energy: Main result (H1)

We investigate the effect of financial market development on cleaner energy of Hypothesis H1. Table 4 presents the results of the CCEP estimator under three scenarios: CCEP solving the problem of CD in the short run (Model 1), CCEP solving the problem of CD in the long run (Model 2), and CCEP solving the problem of CD in both the short and long run (Model 3). We focus on Model 3 to explain our results due to the presence of CD in each variable among the countries both in the short and in the long run. Our consideration of the short-run and long-run CD properties is supported by Holly et al. (2010) and Mayor and Patuelli (2012).

[Insert Table 4 near here]

We present the estimated results of Hypothesis H1 regarding the possible effect of financial market development on promoting cleaner energy in Table 4. The results in this table show that the coefficient of the error correction is negative and significant under all the three measures of cleaner energy. The negative and significant coefficient of the error correction confirms a long-run relation between cleaner energy (including biomass and non-biomass) and *FMD* through the short-run economic adjustment process. Precisely, the short-run speed of adjustment to the long-run equilibrium relation is 17.48 %, 8.56 % and 19.16 % per year for cleaner energy (*CE*), *BIO* and *NBIO*, respectively. The relatively higher degree of adjustment coefficient for *NBIO* implies a relatively higher level of the impact of financial market development on *NBIO* energy over the total *CE* and *BIO* energy. We interpret this as possible evidence of a high factor mobility and a technological flexibility in the non-biomass energy industry that are contributing a faster adjustment rate towards the long-run market equilibrium.

Table 4 shows that *FMD* significantly promote cleaner energy in the long run. This finding is consistent in both the biomass and non-biomass energy models, as well. Our long run findings coincide with the proposition of Doytch and Narayan (2016), Hsu et al. (2014) and Frankel and Romer (1999) who document the positive role of financial development in promoting innovations. Our results also reciprocate the findings of Fangmin and Zhou (2011). The finding of a positive and significant coefficient for the financial market development also supports a recent policy argument of EIA (2015) which attests that the elimination of financial barriers to the flow of funds is fundamental to the growth of cleaner energy. However, our long run result contrasts with the argument of Pástor and Veronesi (2009) and Hall and Lerner (2010) who claim that credit markets and banks would prefer certain projects over the innovative projects, and hence, financial markets may not necessarily lead to the promotion of cleaner energy. Given that *FMD* significantly impede *CE* and *NBIO* energy in the short run, we argue that the contention of Pástor and Veronesi (2009) and Hall and Lerner (2010) may be a short run phenomenon only. Overall, our result supports H1[12].

We also show that a higher living standard significantly promotes cleaner energy (total *CE*, *BIO* and *NBIO)* energy. Our result support the assertion that a higher living standard which reflects a higher purchasing power indicates a higher level of willingness of the citizens to pay for conserving the environment using cleaner energy. We also document a positive and significant coefficient of trade openness on *BIO,* while demonstrating a negative and significant impact for overall *CE* and *NBIO* in the long-run. Moreover, we find that the oil price volatility imparts a negative impact on *CE*, *BIO*, and *NBIO* both in the short run and in the long run. The negative impact of oil price volatility is only significant for *BIO* energy in the long run under the condition of short run heterogeneity and long run homogeneity. This result, however, contradicts the rational expectations theory underlying the forward-looking nature of economic agents intending to smooth their cost of energy consumption over time by paying attention to the expected future path of the oil price and the cost of production.

[12] We also check the robustness of our main result by using double clustering (cluster by year and country) regression, fully modified OLS (FMOLS), and dynamic OLS (DOLS). The results reported in Appendix Table D by using these models are consistent with our main results in this section. The double clustering technique alleviates the concern about potential cross-sectional and time-series dependence in the data (Cameron, Gelbach, and Miller, 2009; Petersen, 2009). FMOLS can alleviate any potential endogeneity and serial correlation biases (Phillips and Hansen, 1990). FMOLS also works well in finite samples. It is important to note that our regression model institutively does not suffer from the endogeneity bias. The DOLS approach is efficient in the presence of a mix order of integration in the co-integrated framework. The estimation of DOLS considers one of the I(1) variable against other I(1) and I(0) variables by including leads (p) and lags (-p) in the framework (Kejriwal and Perron, 2008; Ang, 2010). Moreover, DOLS can address any possible endogenous bias (e.g. small sample bias problems) and the results of the co-integrating vectors from the DOLS estimators are asymptotically efficient.

4.3 Credit market, stock market and cleaner energy (H1)

In this section, we decompose our measure of *FMD* into the credit market and equity market development and reassess those components' respective impacts on *CE*, *BIO* and *NBIO* energy. The results in Panel A of Table 5 show that the development of the credit market positively augments *CE*, *BIO*, and *NBIO* energy output in the long run. However, credit market development only promotes *BIO* energy in the short run.

In Panel B of Table 5, we show that the development of the equity market also promotes *CE*, *BIO* and *NBIO* energy in the long run. Equity market development also promotes *BIO* and *NBIO* energy in the short run. The coefficients of the market capitalization as a proxy for the equity market are more profound than the coefficients of the credit market development for total *CE*, *BIO*, and *NBIO* energy models. Overall results concerning the effect of decomposed measures of *FMD* signifies the commercial potentiality of cleaner energy as well as the allocative efficiency of the credit and equity markets. These results acknowledge the contention of Zyadin el al. (2014) who argue for enormous commercial potentiality, underpinned by the environment harmony of cleaner energy. Our results are also supportive of the agenda of the COP 21 Energy Day, which explicitly advocates a massive investment in cleaner energy through pursuing the financial sector to reduce CO_2 emissions.

[Insert Table 5 here]

5. Robustness checks

5.1 Alternative measures of cleaner energy[13]

Our primary measures of cleaner energy are not considered relative to the total energy production, or relative to dirty (non-renewable) energy production. Thus, *FMD* could

[13] We thank an anonymous referee for suggesting this robustness checks of our main result.

potentially have strong (or stronger) effects on non-renewable energy, as well. If so, one might argue that *FMD* is not contributing to a transition to clean energy and energy sustainability.

Hence, we re-estimate our main results (Table 4) taking the share of renewable energy in total energy and also controlling for the effect of the size of the economy. We apply the CCEP methodology under the conditions of short-run heterogeneity and long-run homogeneity by solving the problem of cross-sectional dependence in the short-run and long-run. Appendix table E presents the results. We find that the size of the economy has an adverse and significant effect on cleaner energy (total *CE* and *BIO*) in the long run[14]. The result is consistent with the fact that fossil fuels power economic growth in most countries. More importantly, we find that the long run positive and significant effect of *FMD* on cleaner energy (total *CE/total*, *BIO/Total*, and *NBIO/Total*) is robust to the alternative measures of cleaner energy.

Using the alternative measures of cleaner energy, we also show that the development credit market promotes *CE/Total*, *BIO/Total* and *NBIO/Total* energy in the long run. However, the development of equity market promotes *CE/Total* and *NBIO/Total* energy in the long run (see result in Appendix Table F). Consistent with our main findings in Table 5, we find that coefficients of the equity market are higher than the coefficients of the credit market development. Overall, results concerning the effect of decomposed measures of *FMD* corroborate our main findings on the positive and significant role of the credit and equity markets in alternative measures of cleaner energy.

5.2 Global financial crisis (GFC) and cleaner energy (H2)

Building on the prior literature which argues that the recent *GFC* hurt every sector, we contend that the innovation process of cleaner energy is more vulnerable to the financial crisis due to having more uncertainty associated with cleaner energy innovation. We examine this

[14] The inclusion of the size of GDP is suggested to us by an anonymous referee. The un-tabulated result shows that the effect of FMD is qualitatively the same with the exclusion of the size of the GDP.

possibility by having the *GFC* dummy for the years of 2007 and 2008. The results in Table 6 show that the *GFC* hurts the output of cleaner energy (total *CE*, *BIO*, and *NBIO*) both in the long- and short-run. The effect is significant in the case of *CE* and *NBIO only*.

Our overall result implies that the *GFC* mainly hurts total *CE* and *NBIO* through shirking the equity market access for the *CE* and *NBIO* firms. It also supports our previous findings where we document a significant positive association between the equity market and cleaner energy *CE*. Our results support the contentions of Filippetti and Archibugi (2011), OECD (2009) and Paunov (2012) who document that global economic shocks, notably the *GFC* in 2008 and onward, hurt the long-term investment, resulting in a sluggish growth of innovations. Moreover, our findings are consistent with the observation of the Sustainable Energy Finance Initiative study of 2009, which states that the adverse shock of *GFC* has reduced the flow of bank financing to renewable energy developers, thereby hurting the continued growth of the global clean energy sector as evident in the period 2004 to early 2008. Overall, our findings are consistent with the anecdotal evidence and also support Hypothesis 2 (H2).

[Insert Table 6 near here]

6. Economic mechanisms

In this section, we examine a number of economic rationale to support our findings on the relation between financial market development and cleaner energy.

6.1 Financial markets and cleaner energy: Role of the growth of carbon intensity (H3)

Recently, there are positive efforts of some countries (such as UK, Canada, Denmark, and Germany) which have a higher rate of growth in carbon intensity to meaningfully augment the role of financial markets in promoting cleaner energy. These efforts include encouraging investment in the low-carbon technologies by reforming the electricity market and providing capital for innovations in those technologies and cleaner energy. Thus, *ceteris paribus,* we assume that the countries with a higher rate of growth in CO_2 intensity are expected to make notable progress in producing cleaner energy. Thus, we re-examine our main model by clustering our sample into high growth vs. low growth carbon intensity countries based on the sample median-adjusted growth in carbon intensity.

Table 7 reports that the coefficient of *FMD* has a positive and significant effect on total *CE*, *BIO,* and *NBIO* for countries with higher growth in carbon intensities. We also find that the positive and significant effect of *FMD* on the overall cleaner energy is also significant for low carbon intensity countries, as well. However, the coefficients of *FMD* under the various definitions of cleaner energy are consistently higher in countries with a higher growth carbon intensity than in countries with a lower growth carbon intensity.

Our results show that a clear distinction between the two groups of countries captures the differences between them regarding environmental activism, public awareness and others. For instance, the UK government-adopted Climate Change Act of 2008 targets a reduction in the UK's greenhouse gas emissions by at least 80% (from the 1990 baseline) by 2050. Other countries within the OECD such as Germany, France, and Denmark are exerting a significant effort to this end, as well. The European Union (EU)-listed countries are mandated to meet by 2020 a target of 20% renewable resources in the energy supply and 10% renewable resources in energy in the transport sector to reduce carbon intensity in the EU regional market (Union, 2009). Overall, our result supports Hypothesis 3 (H3) and underpins the demand-induced growth of cleaner energy in countries with a higher growth in carbon intensity.

[Insert Table 7 near here]

6.2 Financial markets and cleaner energy: Role of innovation success (H4)

Innovation is one of the prime determinants of economic development under the neo-classical (Solow, 1956), neo-Schumpeterian and R&D-driven growth models. Regarding the environmental concern, green innovation is crucial for the mitigation of the effect of climate change (Borghesi et al., 2015). Thus, a country with proven innovation capabilities and higher innovation growth is likely to be successful in a financial markets-driven cleaner energy revolution since financial markets in those countries are accustomed to investing in innovative (risky) projects.

We test the effect of *FMD* on cleaner energy in countries with a higher and lower innovation success by classifying the sample countries into two groups based on the sample median innovation growth over the period. Table 8 reports that the long run coefficients of *FMD* are positive and significant only in countries with a higher innovation growth. Thus, our result supports Hypothesis 4 (H4). Given the enormous commercial potential for cleaner energy, our results indicate that *FMD* in countries with a higher innovation culture provides financing support for more energy companies to invest in cleaner energy[15].

[Insert Table 8 near here]

6.3 Financial markets and cleaner energy: Role of fossil fuels (H5)

The production, procurement and distribution of the entire global energy supply network are primarily based on fossil fuels. For example, in the United States, 82% of the entire energy production comes from fossil sources. Since fossil fuels are cheaper than various forms of cleaner energy, the link between the *FMD* and cleaner energy is likely to be sensitive to the

[15] We also find consistent result using renewable energy share of total energy (see Appendix Table G). Applying the CCEP methodology under the conditions of short-run heterogeneity and long-run homogeneity by solving the problem of cross-sectional dependence in the short-run and long-run we find that the role of FMD is positive significant on RE/total energy and NBIO/Total energy among countries with high innovation culture, not in countries with low innovation culture. We thank the annonomys reviewrs for this suggestion, that makes our result stronger.

availability and dependence on fossil fuels. In the USA, President Donald Trump has already announced that his administration is moving away from the COP21 declaration in Paris and is revitalizing the coal- mining industry. Taken together, we test Hypothesis 5 (H5) to uncover the effect of financial markets on cleaner energy in countries with a higher vs. a lower fossil fuel dependence grouped by the sample median growth in carbon intensity.

Table 9 reports that the coefficients of *FMD* in *CE*, *BIO* and *NBIO* models are consistently higher and statistically significant in countries with a lower dependence on fossil fuels. Our results suggest that, despite the concern for greenhouse gasses, if the private benefits of sticking to low-cost fossil fuels for fueling economic activities are higher than the social benefits to moving away from the fossil fuels to cleaner energy, then the higher dependence and availability of cheap fossil fuels may not encourage capital providers to invest in renewable energy sources. Thus, our result supports Hypothesis 5 (H5)[16].

[Insert Table 9 near here]

7. Additional robustness tests: *Alternative explanations*[17]

We examine the role of *FMD* in the cleaner energy supply function. Although capital is one of the crucial factors of production, the available technology is also critical for the supply function. The number of successful patents and the availability of fossil fuels can also be proxies for capturing the available technology. In the previous section, we indirectly account for the role of technology by running our main regression separately for sub-sample countries based on higher (lower) innovation successes and higher (lower) fossil fuel dependence. In this

[16] We also find consistent result using renewable energy share of total energy (see Appendix Table H). Applying the CCEP methodology under the conditions of short-run heterogeneity and long-run homogeneity by solving the problem of cross-sectional dependence in the short-run and long-run we find that the role of FMD is positive significant on RE/total energy and NBIO/Total energy among countries with low fosil fuel dependence.

[17] We thank an anonymous referee for suggesting this robustness checks of our main result.

section, we directly incorporate the role of technology in the cleaner energy production function.

Besides technology, government policies in the form of financial incentives for companies to invest in clean energy are also crucial in estimating the cleaner energy supply function. Since 1980, there have been 930 government policy initiatives undertaken to promote cleaner energy in our sample of the 25 *OECD* countries. Since our main empirical models do not incorporate the impact of government policies in the cleaner energy supply function, one may argue that our results may simply be picking up the effect of government policies, rather than *FMD* in the cleaner energy output function. Therefore, we control for the role of government policy initiatives and the other control variables and re-estimate the impact of *FMD* on cleaner energy. Specifically, we identify 472 policy initiatives that are related to 'subsidies and grants' in promoting the production of various forms of cleaner energy. However, since the data on the actual size of the subsidies are difficult to assemble, we use the cumulative number[18] of policy initiatives related to grants and subsidies capture the role of government subsidies in the cleaner energy production function.

The results in Table 10 show that fossil fuels have a negative (positive) and significant impact on total *CE* (*BIO* and *NBIO*) in the long run. However, the impact is negative and significant for the total *CE* and *NBIO* in the short run. Contrary to our expectations, we find that the government policy initiative does not have a significant effect on cleaner energy supply function in the long run. More importantly, we find that controlling for the available technology and financial support from the government in the form of subsidy and grants, *FMD* still has a positive and significant effect on cleaner (total *CE*, *BIO*, and *NBIO*) in the long run.

[18] We capture the effect of governments' '*grant and subsidy*' policy using the cumulative number of '*grant and subsidy*' rather than using a dummy variable for two reasons. *First*, there are a number of instances where government undertook more than one policies in a fiscal year. A dummy cannot fully capture such effect. For example, in 2009 Australia undertook 9 '*grant and subsidy*' policies to promote cleaner energy output. *Second*, since a policy is likely to bear future consequences, the use of the cumulative number of *grants and subsidies*' captures the forward-looking effect of such policies on cleaner energy output.

8. Conclusion

A robust and well-functioning financial market is significant and important for the growth of cleaner energy. It helps investors to tap into the enormous commercial potential of clearn energy and also contributes to social desires such as mitigating the challenges of inter-generational energy security and greenhouse gasses, and improving and energy efficiency and environmental sustainability. We investigate the role of *FMD* in promoting cleaner energy for 25 OECD countries using a robust methodology.

We provide several interesting findings. *First, FMD* significantly stimulates total cleaner energy, biomass and non-biomass energy production in the long run. Although both credit and equity market developments positively contribute to the cleaner energy output function, the impact is far more significant in the case of the equity market than the credit market. *Second,* the recent global financial crisis impedes cleaner energy output, particularly for the non-biomass energy output. *Third,* the positive role of *FMD* is more profound in promoting cleaner energy in a sub-sample of countries with a higher growth in carbon-intensity, a higher innovation growth/culture, and a lower dependence on fossil fuels.

Our result on the positive role of financial market (capital) in cleaner energy production function is also robust to controlling for available technology (fossil fuels, patents and trade openness), government support (subsidies and grants) and the size of the economy.

Our findings have key policy implications. *Firstly*, a healthy flow of finances is an important step in the production of cleaner energy, which has ramifications for environmental sustainability in the long run. Thus, smoothing the availability of finances to renewable energy firms should be a key priority for governments in order for those firms to be able to increase cleaner energy production and address the threat of increasing greenhouse gases and achieve inter-generational energy security. Given that the role of government grants and subsidies in the cleaner energy estimates is not significant in the long run, we argue that the government role should not come in the form of command or direct financial support incentives, rather it should come in the form of market-based initiatives for promoting private investments. Since the equity market plays a more significant and positive role in cleaner energy output, regulators should provide a market-based support by, for example, easing the process of stock market-listing requirements for cleaner energy firms to allow sufficient fund procurements for these firms.

Secondly, since cleaner energy is a socially desirable private good, governments should provide tax credits to investors in stocks of cleaner energy firms. This should encourage the socially faithful investors and others to invest more funds in the stocks of companies that produce cleaner energy. *Finally*, government policies should reduce the economic incentives to use, produce and invest in fossil fuels through measures like increased carbon tax, stringent usage guidelines for producing and using fossil fuels, while providing increased governmental support for cleaner energy initiatives.

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Table 1: Descriptive statistics.

Variables	N	Mean	5%	Median	95%	SD	Skew.
CE (BKW)	*900*	*59.369*	*0.369*	*24.531*	*337.160*	*96.837*	*2.721*
BIO (BKW)	*900*	*5.342*	*0.000*	*1.013*	*22.716*	*12.291*	*3.968*
NBIO (BKW)	*900*	*54.027*	*0.171*	*21.120*	*306.494*	*89.031*	*2.664*
CE/Total	*900*	*0.180*	*0.014*	*0.153*	*0.396*	*0.124*	*0.334*
BIO/ Total	*900*	*0.017*	*0.000*	*0.008*	*0.070*	*0.024*	*2.523*
NBIO/ Total	*900*	*0.165*	*0.005*	*0.128*	*0.395*	*0.125*	*0.451*
Credit market	*900*	*91.002*	*27.740*	*84.660*	*181.030*	*46.566*	*0.719*
Equity market	*900*	*51.189*	*0.000*	*38.114*	*145.578*	*50.465*	*1.505*
FMD	*900*	*0.525*	*-1.511*	*0.101*	*3.930*	*1.648*	*0.953*
Living standard	*900*	*17451.67*	*5064.89*	*17003.85*	*29903.75*	*7054.768*	*0.221*
Trade openness	*900*	*74.374*	*24.615*	*62.425*	*166.236*	*49.564*	*2.826*
Oil price vol.	*900*	*17.533*	*5.200*	*20.130*	*27.480*	*7.863*	*-0.413*
Patents	*900*	*8.240*	*4.310*	*8.242*	*12.638*	*2.580*	*-0.917*
Fossil fuels (BKW)	*900*	*181.602*	*0.028*	*32.213*	*639.296*	*477.543*	*4.393*
GDP size	*900*	*26.894*	*23.850*	*26.794*	*29.368*	*1.523*	*-0.350*

Note: Table 1 presents the descriptive statistics of the variables in actual (raw) values for the 25 OCED countries over the period 1980 to 2015.

Table 2: Correlation matrix.

Variables		1	2	3	4	5	6	7
Cleaner energy (CE)	1							
Biomass (BIO)	2	0.672[a]						
Non-Biomass (NBIO)	3	0.994[a]	0.594[a]					
CE/Total	4	0.160[a]	-0.161[a]	0.196[a]				
BIO/ Total	5	-0.102[a]	0.160[a]	-0.133[a]	0.078			
NBIO/ Total	6	0.176[a]	-0.189[a]	0.218[a]	0.987[a]	-0.086		
FMD	7	**0.368[a]**	**0.434[a]**	**0.341[a]**	-0.034	0.203[a]	-0.068	
Living standard	8	**0.158[a]**	**0.169[a]**	**0.149[a]**	-0.106[a]	0.208[a]	-0.140[a]	0.344[a]
Trade openness	9	**-0.284[a]**	**-0.211[a]**	**-0.279[a]**	0.012	0.470[a]	-0.066	0.026
Credit market	10	**0.320[a]**	**0.421[a]**	**0.290[a]**	0.005	0.189[a]	-0.027	0.889[a]
Equity market	11	**0.298[a]**	**0.242[a]**	**0.290[a]**	-0.066	0.207[a]	-0.100	0.561[a]
Oil price vol.	12	0.007	-0.023[a]	0.011	0.0437	-0.053	0.0522	-0.0787
Patents	13	0.447[a]	0.437[a]	0.426[a]	-0.217[a]	-0.142[a]	-0.193[a]	0.377[a]
Fossil fuels	14	0.704[a]	0.844[a]	0.650[a]	-0.238[a]	-0.052[a]	-0.229[a]	0.378[a]
GDP size	15	0.536[a]	0.553[a]	0.507[a]	-0.434[a]	-0.132[a]	-0.412[a]	0.416[a]
		8	9	10	11	12	13	14
Trade openness	9	0.142[a]						
Credit market	10	0.351[a]	-0.013					
Equity market	11	0.274[a]	0.263[a]	0.391[a]				
Oil price vol.	12	-0.121[a]	-0.007[a]	-0.0589	-0.290[a]			
Patents	13	0.158[a]	-0.344[a]	0.347[a]	0.204[a]	0.002		
Fossil fuels	14	0.121[a]	-0.285[a]	0.377[a]	0.240 [a]	-0.030	0.441[a]	
GDP size	15	0.306[a]	-0.461[a]	0.361[a]	0.275[a]	-0.048	0.568[a]	0.570[a]

Note: Table 2 shows the correlation matrix for the respective variables of the 25 OCED countries over the period 1980 to 2015. Along with the correlation coefficients, the table also contains the significance levels (p-values), where a, b and c measure the 1%, 5%, and 10% significance levels, respectively.

Table 3: Cross-sectional dependency (CD) and panel unit root tests

Variable	CD-test	abs(corr)	CIPS (Level)	CIPS (1st difference)
Cleaner energy (CE)	80.31[a]	0.773	-1.888	-3.312[a]
Biomass (BIO)	81.87[a]	0.788	-1.510	-2.507[a]
Non-Biomass (NBIO)	67.81[a]	0.652	-2.005	-3.182[a]
CE/Total	19.46[a]	0.445	1.406	-4.268[a]
BIO/ Total	60.59[a]	0.635	-1.777	-4.062[a]
NBIO/ Total	23.63 [a]	0.522	-1.415	-4.263[a]
FMD	81.80[a]	0.794	-1.936	-2.379[a]
Living standard	96.90[a]	0.932	-0.690	-2.998[a]
Trade openness	71.13[a]	0.710	-1.903	-2.384[a]
Credit market	58.62 [a]	0.583	-1.662	-2.194[b]
Equity market	43.85 [a]	0.561	-1.789	-2.999[a]
Fossil Fuel	31.28[a]	0.608	-1.823	-2.586[a]
GDP Size	100.51[a]	0.967	-1.913	-3.260 [a]
Patents	4.04 [a]	0.501	-2.174[a]	-3.628[a]

Note: Table 3 shows the results of the cross-sectional dependency (CD) test of Pesaran (2004) and the panel unit-root test of the Pesaran (2007) CIPS of the respective variables of the 25 OCED countries over the period 1980 to 2015. The second and third columns of the table represent the CD statistics and the average correlations among the cross sections, respectively. Whereas the fourth and fifth columns represent the CIPS (Z(t-bar)) statistics for the level and 1st difference forms of the variables, respectively. The symbols a, b, and c measure the 1%, 5% and 10% significance levels, respectively.

Table 4: Role of financial markets development (*FMD*) in cleaner energy output.

	Cleaner Energy (CE)			Biomass Energy (BIO)			Non-Biomass Energy (NBIO)		
Variables	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Error Correction	-0.2904[a]	-0.1998[a]	-0.1748[a]	-0.1021[b]	-0.0889[b]	-0.0856[b]	-0.3198[a]	-0.2155[a]	-0.1916[a]
	(-5.15)	(-3.33)	(-3.46)	(-2.34)	(-2.21)	(-1.96)	(-5.23)	(-3.60)	(-3.84)
Long run estimates									
FMD $_{t-2}$	**0.0455[a]**	**0.2743[a]**	**0.1334[a]**	**0.1145[a]**	**0.0788[c]**	**0.1579[a]**	**0.0366[a]**	**0.2109[a]**	**0.1904[a]**
	(3.27)	**(8.42)**	**(6.32)**	**(3.52)**	**(1.78)**	**(5.34)**	**(2.85)**	**(9.30)**	**(9.08)**
Oil price vol. $_{t-1}$	0.0020[b]	0.0001	-0.0008	0.0041[b]	0.0005	-0.0111[a]	0.0015	-0.0001	-0.0013
	(2.04)	(0.02)	(-0.36)	(2.11)	(0.12)	(-3.93)	(1.60)	(-0.06)	(-0.47)
Living standard $_{t-1}$	0.4494[a]	-0.7149[a]	0.0165[a]	1.0542[a]	0.9385[a]	1.7862[a]	0.3800[a]	0.0184[a]	0.0178[a]
	(9.06)	(-3.88)	(3.41)	(6.94)	(2.76)	(7.29)	(7.83)	(3.01)	(3.38)
Trade openness $_{t-1}$	0.0013	-0.0111[a]	-0.0111[a]	0.0238[a]	0.0200[a]	0.0211[a]	-0.0007[c]	-0.0141[a]	-0.0127[a]
	(1.25)	(-5.45)	(-4.31)	(11.34)	(5.06)	(6.97)	(-1.65)	(-5.40)	(-4.47)
Short run estimates									
Δ FMD	-0.0581[b]	-0.0246	-0.0708[b]	0.0209	0.0148	0.0161	-0.0700[b]	-0.0422	-0.0808[a]
	(-2.39)	(-0.88)	(-2.47)	(0.82)	(0.74)	(0.69)	(-2.55)	(-1.39)	(-2.79)
Δ Oil price vol.	0.0008	0.0021	-0.0031	0.0011	0.0015	-0.0014	0.0005	0.0019	-0.0028
	(0.42)	(0.98)	(-1.15)	(0.57)	(0.97)	(-0.78)	(0.27)	(0.75)	(-1.06)
Δ Living standard	0.1458	0.1532	0.1082	0.1226	0.4763[a]	0.1424	0.1066	-0.0402	-0.0048
	(1.02)	(1.00)	(0.73)	(0.46)	(2.71)	(0.52)	(0.80)	(-0.25)	(-0.03)
Δ Trade openness	-0.0020	0.0007	-0.0027	0.0031	0.0031[c]	0.0025	-0.0035	0.0015	-0.0040
	(-0.83)	(0.59)	(-1.01)	(1.61)	(1.73)	(1.29)	(-1.37)	(1.18)	(-1.39)
Constant	-0.1969[b]	1.5864[a]	1.0462[a]	-0.9706[b]	-0.4946[b]	0.1015	-0.0102	0.2126[a]	0.8077[a]
	(-2.11)	(3.41)	(3.76)	(-2.37)	(-2.15)	(1.58)	(-0.11)	(3.06)	(4.27)
Countries	25	25	25	25	25	25	25	25	25
Observations	850	850	850	850	850	850	850	850	850

Note: Table 4 presents the results of the impact of *FMD* on cleaner energy in our sample of the 25 OECD countries for the period 1980 to 2015. We use three different measures of cleaner energy: total cleaner energy, biomass energy and non-biomass energy, which is the difference between cleaner energy and biomass energy. Our financial development variable is generated by the principal component analysis of the domestic credit provided to the private sector, equity market capitalization and broad money supply. We use the Pesaran (2006) Common Correlated Effect mean Pool (CCEP) methodology under the condition of short-run heterogeneity and long-run homogeneity by solving the problem of cross-sectional dependence in the short-run (Model 1), in the long-run (Model 2), and the short-run and long-run (Model 3). The significance levels of the coefficients are denoted by a, b, c for the 1%, 5%, and 10%, respectively. The t-statistics are in parentheses. Columns 1, 2, and 3 represent Model 1, Model 2 and Model 3, respectively.

Table 5: Credit market development, equity market development, and clearer energy output.

Panel A: Credit market development and cleaner energy output.

	Cleaner Energy (CE)			Biomass Energy (BIO)			Non-Biomass Energy (NBIO)		
Variables	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Error Correction	-0.3141[a]	-0.2417[a]	-0.2595[a]	-0.0823[b]	-0.0544	-0.0634	-0.3361[a]	-0.3233[a]	-0.3575[a]
	(-5.37)	(-3.71)	(-4.44)	(-2.06)	(-1.43)	(-1.56)	(-5.74)	(-5.22)	(-6.00)
Long run estimates									
Credit market$_{t-2}$	**0.0009[b]**	**0.0053[a]**	**0.0042[a]**	**0.0011**	**-0.0079[a]**	**0.0024[a]**	**0.0023[a]**	**0.0011[a]**	**0.0016[a]**
	(2.44)	**(8.36)**	**(7.45)**	**(1.28)**	**(-6.22)**	**(2.74)**	**(8.45)**	**(3.29)**	**(4.35)**
Oil price vol. $_{t-1}$	0.0008	0.0014	-0.0000	0.0045[c]	0.0030	-0.0029	0.0005	0.0004	0.0001
	(0.89)	(0.80)	(-0.03)	(1.84)	(1.10)	(-1.33)	(0.58)	(0.32)	(0.13)
Living standard $_{t-1}$	0.4292[a]	0.0143	0.0213[b]	1.2419[a]	1.7156[a]	1.5871[a]	0.0686[a]	0.0656[a]	0.0556[a]
	(8.33)	(1.31)	(2.23)	(8.52)	(6.13)	(5.80)	(3.18)	(3.17)	(2.74)
Trade openness $_{t-1}$	0.0032[a]	-0.0051[b]	-0.0009[c]	0.0254[a]	-0.0202[a]	0.0126[a]	0.0004[a]	-0.0004[c]	-0.0002
	(3.75)	(-2.45)	(-1.82)	(9.79)	(-4.21)	(3.58)	(2.75)	(-1.86)	(-0.77)
Short run estimates									
Δ Credit market	-0.0002	-0.0005	-0.0000	0.0021[c]	0.0015	0.0024[b]	-0.0013	-0.0012	-0.0013
	(-0.16)	(-0.56)	(-0.03)	(1.83)	(1.46)	(2.19)	(-1.29)	(-1.04)	(-1.40)
Δ Oil price vol.	0.0005	0.0020	-0.0002	0.0006	0.0022	-0.0014	0.0019	0.0031	0.0010
	(0.22)	(0.86)	(-0.07)	(0.31)	(1.30)	(-0.99)	(0.75)	(1.50)	(0.39)
Δ Living standard	0.1030	0.1549	0.0888	0.1800	0.4067[b]	0.2222	-0.0030	-0.0858	-0.0319
	(0.75)	(1.12)	(0.73)	(0.67)	(2.21)	(0.81)	(-0.02)	(-0.53)	(-0.20)
Δ Trade openness	-0.0027	0.0006	-0.0028	0.0021	0.0022	0.0013	-0.0044[c]	0.0007	-0.0045[c]
	(-0.99)	(0.51)	(-0.98)	(0.99)	(1.45)	(0.71)	(-1.71)	(0.52)	(-1.70)
Constant	-0.2001[c]	0.2517[a]	0.3864[a]	-0.9228[b]	-0.8678	0.0377	0.8517[a]	0.7809[a]	0.9087[a]
	(-1.84)	(3.16)	(3.64)	(-2.11)	(-1.40)	(0.89)	(4.86)	(4.67)	(4.82)
Countries	25	25	25	25	25	25	25	25	25
Observations	850	850	850	850	850	850	850	850	850

Panel B: Equity market development and cleaner energy output.

	Cleaner Energy (CE)			Biomass Energy (BIO)			Non-Biomass Energy (NBIO)		
Variables	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Error Correction	-0.3036[a]	-0.2405[a]	-0.3165[a]	-0.0839[b]	-0.1049[b]	-0.1016[b]	-0.3294[a]	-0.3117[a]	-0.3479[a]
	(-5.24)	(-4.63)	(-5.35)	(-2.19)	(-2.33)	(-2.28)	(-5.17)	(-4.84)	(-5.46)
Long run estimates									
Equity market $_{t-2}$	**0.0275[a]**	**0.0633[a]**	**0.0274[a]**	**-0.1031[a]**	**0.2094[a]**	**0.2588[a]**	**0.0282[a]**	**0.0167[b]**	**0.0269[a]**
	(3.27)	**(6.16)**	**(3.71)**	**(-4.49)**	**(5.15)**	**(7.08)**	**(3.54)**	**(2.24)**	**(3.56)**
Oil price vol. $_{t-1}$	0.0024[b]	0.0022	0.0015	0.0046[b]	-0.0047	-0.0125[a]	0.0024[b]	0.0008	0.0027[c]
	(2.57)	(0.85)	(1.00)	(2.19)	(-1.50)	(-5.08)	(2.50)	(0.63)	(1.82)
Living standard $_{t-1}$	0.4674[a]	0.0574[b]	0.0714[c]	1.3428[a]	0.4132	1.0159[a]	0.4200[a]	0.0838[b]	0.0666[c]
	(10.35)	(2.57)	(1.79)	(11.96)	(1.54)	(4.01)	(9.12)	(2.30)	(1.91)
Trade openness $_{t-1}$	0.0034[a]	-0.0011	0.0016	0.0205[a]	0.0016	0.0020	-0.0002	-0.0006[a]	-0.0009[b]
	(4.01)	(-0.81)	(1.61)	(7.96)	(0.50)	(0.68)	(-0.45)	(-2.61)	(-2.52)
Short run estimates									
Δ Equity market	0.0151	0.0127	0.0171	0.0101	0.0111	0.0262[c]	0.0189[c]	0.0098	0.0208[c]
	(1.48)	(1.21)	(1.62)	(0.86)	(0.86)	(1.72)	(1.65)	(0.90)	(1.79)
Δ Oil price vol.	-0.0015	0.0031[c]	-0.0005	0.0017	0.0021	-0.0002	-0.0019	0.0029[c]	-0.0016
	(-0.75)	(1.76)	(-0.25)	(0.93)	(1.46)	(-0.16)	(-0.91)	(1.75)	(-0.74)
Δ Living standard	0.0356	0.0449	-0.0496	0.1078	0.4114[b]	0.1027	-0.0400	-0.0840	-0.1323
	(0.21)	(0.27)	(-0.27)	(0.46)	(2.21)	(0.40)	(-0.22)	(-0.50)	(-0.69)
Δ Trade openness	-0.0008	0.0009	-0.0018	0.0018	0.0023[c]	0.0021	-0.0029	0.0009	-0.0034
	(-0.35)	(0.85)	(-0.81)	(0.84)	(1.93)	(1.11)	(-1.16)	(0.70)	(-1.35)
Constant	-0.3107[a]	-0.1334	0.5131[a]	-0.9656[b]	-0.0953	0.1726[c]	-0.1744[c]	0.4408[a]	0.6359[a]
	(-2.85)	(-1.34)	(3.85)	(-2.27)	(-1.52)	(1.80)	(-1.81)	(3.65)	(4.30)
Countries	25	25	25	25	25	25	25	25	25
Observations	850	850	850	850	850	850	850	850	850

Note: Table 5 presents two panels. Panel A presents the effect of the credit market development (*CRD*) and panel B presents the effect of the equity market development (*MCAP*) on cleaner energy output in our sample countries, using three different measures of cleaner energy output: total cleaner energy, biomass energy, and non-biomass energy. We use the CCEP methodology under the conditions of short-run heterogeneity and long-run homogeneity by solving the problem of cross-sectional dependence in the short-run (Model 1), in the long-run (Model 2), and the short-run and long-run (Model 3). The significance levels of the coefficients are denoted as a, b, c for the 1%, 5%, and 10%, respectively. The t-statistics are in parentheses. Columns 1, 2 and 3 represent Model 1, Model 2 and Model 3, respectively.

Table 6: Effect of the financial crisis on cleaner energy output.

	Cleaner Energy (CE)			Biomass Energy (BIO)			Non-Biomass Energy (NBIO)		
Variables	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Error Correction	-0.2902[a]	-0.1953[a]	-0.2857[a]	-0.0060	-0.0496[b]	-0.0680[b]	-0.3116[a]	-0.3209[a]	-0.3373[a]
	(-4.91)	(-3.19)	(-4.99)	(-0.50)	(-2.33)	(-2.11)	(-4.75)	(-4.51)	(-5.07)
Long run estimates									
Financial crisis $_{t-2}$	**-0.0433**	**0.1391[c]**	**-0.1174[a]**	**-2.5555[a]**	**0.0300**	**-0.0583**	**-0.1417[a]**	**-0.0972[a]**	**-0.1232[a]**
	(-1.17)	**(1.69)**	**(-3.81)**	**(-4.71)**	**(0.13)**	**(-0.63)**	**(-3.92)**	**(-4.82)**	**(-4.70)**
Oil price vol. $_{t-1}$	0.0018[c]	-0.0001	0.0032[a]	0.0911[a]	0.0188[b]	0.0122[a]	0.0037[a]	0.0031[a]	0.0025[a]
	(1.90)	(-0.02)	(3.11)	(6.21)	(2.06)	(3.09)	(4.87)	(4.24)	(3.19)
Living standard $_{t-1}$	0.4873[a]	-0.2230	-0.1695	1.0918[b]	-0.1943	-1.0792[a]	0.3541[a]	-0.1529[c]	0.0794[c]
	(11.35)	(-1.36)	(-1.61)	(2.55)	(-1.56)	(-3.11)	(8.18)	(-1.91)	(1.83)
Trade openness $_{t-1}$	0.0030[a]	-0.0065[a]	-0.0005[a]	0.0663[a]	-0.0036	-0.0065	-0.0001	-0.0006[a]	-0.0005[a]
	(3.41)	(-2.68)	(-2.60)	(6.68)	(-0.44)	(-1.55)	(-0.56)	(-4.57)	(-3.02)
Short run estimates									
Δ Financial crisis	-0.0220	-0.0072	-0.0334[b]	0.0004	-0.0499[a]	-0.0023	-0.0382[c]	-0.0419[c]	-0.0388[c]
	(-1.45)	(-0.47)	(-2.13)	(0.02)	(-3.97)	(-0.10)	(-1.83)	(-1.93)	(-1.89)
Δ Oil price vol.	0.0001	0.0011	0.0018	-0.0003	0.0035[b]	0.0002	0.0009	0.0035[b]	0.0006
	(0.03)	(0.59)	(1.11)	(-0.21)	(2.02)	(0.07)	(0.51)	(2.49)	(0.35)
Δ Living standard	0.1042	0.0525	-0.0379	-0.1299	0.4639[b]	-0.1901	0.0616	-0.0837	-0.0147
	(0.82)	(0.39)	(-0.27)	(-0.37)	(2.47)	(-0.53)	(0.46)	(-0.63)	(-0.11)
Δ Trade openness	-0.0021	0.0008	-0.0032	0.0026	0.0022	0.0007	-0.0040	0.0019	-0.0043
	(-0.81)	(0.65)	(-1.23)	(1.12)	(1.59)	(0.31)	(-1.29)	(1.38)	(-1.36)
Constant	-0.3076[a]	0.7633[a]	0.9791[a]	-0.0463	-0.7119[b]	0.7295[b]	0.0134	1.0539[a]	0.6936[a]
	(-3.03)	(3.72)	(4.22)	(-0.29)	(-2.22)	(2.02)	(0.14)	(4.27)	(3.97)
Countries	25	25	25	25	25	25	25	25	25
Observations	850	850	850	850	850	850	850	850	850

Note: Table 6 presents the results of the impact of the global financial crisis (*GFC*) on the growth of cleaner energy in our sample countries. This financial crisis is a dummy taking the value 1 from 2007 to 2008, and zero otherwise. We use the CCEP methodology under the conditions of short-run heterogeneity and long-run homogeneity by solving the problem of the cross-sectional dependence in the short-run (Model 1), in the long-run (Model 2), and the short-run and long-run (Model 3). The significance levels of the coefficients are denoted as a, b, c for the 1%, 5%, and 10%, respectively. The t-statistics are in parentheses. Columns 1, 2, 3 represent Model 1, Model 2 and Model 3, respectively.

Table 7: Financial markets development and cleaner energy: Role of carbon intensity.

	High growth in carbon intensity			Low growth in carbon intensity		
Variables	CE	BIO	NBIO	CE	BIO	NBIO
Error Correction	-0.2196[a]	-0.1119[c]	-0.2209[a]	-0.3061[a]	-0.1317[b]	-0.3548[a]
	(-3.00)	(-1.75)	(-3.06)	(-2.69)	(-2.45)	(-2.87)
Long Run						
FMD $_{t-2}$	**0.1149[a]**	**0.1361[a]**	**0.1466[a]**	**0.0511[b]**	**0.0550**	**0.0228**
	(5.16)	**(3.94)**	**(5.83)**	**(2.49)**	**(1.07)**	**(1.13)**
Oil price vol. $_{t-1}$	0.0004	-0.0043	-0.0012	0.0033	-0.0266[a]	0.0037[c]
	(0.18)	(-1.26)	(-0.44)	(1.55)	(-7.43)	(1.73)
Living standard $_{t-1}$	0.0151[a]	1.6217[a]	0.0154[b]	-0.0896	-2.4530[a]	-0.3596[c]
	(2.75)	(6.19)	(2.55)	(-0.38)	(-10.22)	(-1.66)
Trade openness $_{t-1}$	-0.0111[a]	0.0103[b]	-0.0123[a]	-0.0077[a]	-0.0059[a]	-0.0099[a]
	(-3.86)	(2.40)	(-3.81)	(-3.18)	(-4.41)	(-4.70)
Short Run						
Δ *FMD*	-0.1186[b]	0.0211	-0.1285[a]	-0.0245	0.0057	-0.0392
	(-2.58)	(0.61)	(-2.76)	(-0.71)	(0.20)	(-0.89)
Δ Oil price vol.	-0.0078[b]	-0.0042[c]	-0.0081[c]	0.0042	0.0024	0.0057[c]
	(-2.00)	(-1.95)	(-1.90)	(1.35)	(1.11)	(1.87)
Δ Living standard	0.2147	0.0207	0.2781	0.1186	-0.3159	-0.1891
	(1.50)	(0.06)	(1.43)	(0.36)	(-0.98)	(-0.66)
Δ Trade openness	0.0003	0.0028	-0.0001	-0.0072[b]	0.0008	-0.0109[a]
	(0.14)	(1.46)	(-0.02)	(-2.30)	(0.30)	(-2.81)
Constant	1.2455[a]	0.0153	1.2438[a]	1.0883[a]	3.2888[b]	1.2579[a]
	(3.21)	(0.40)	(3.27)	(2.68)	(2.43)	(3.02)
Countries	14	14	14	11	11	11
Observation	476	476	476	374	374	374

Note: Table 7 presents the results of the impact of financial markets development on cleaner energy output in the sub-samples of the high carbon intensity and low carbon intensity status. We use the CCEP methodology that assumes the short run heterogeneity and long-run homogeneity and solves the problem of CD both in the short-run and long-run. The significance levels of the coefficients are denoted as [a, b, c] for the 1%, 5%, and 10%, respectively.

Table 8: Financial markets development and cleaner energy: Role of innovation growth.

Variables	High innovation			Low innovation		
	CE	BIO	NBIO	CE	BIO	NBIO
	(1)	(2)	(3)	(1)	(2)	(3)
Error Correction	-0.2274[a]	-0.1097[c]	-0.2234[a]	-0.1050	-0.1250[b]	-0.3528[a]
	(-2.87)	(-1.68)	(-2.81)	(-1.24)	(-2.53)	(-3.09)
Long run estimates						
FMD_{t-2}	**0.1075[a]**	**0.1334[a]**	**0.1238[a]**	**-0.0024**	**0.0586**	**0.0192**
	(4.86)	**(3.83)**	**(5.03)**	**(-0.03)**	**(1.15)**	**(0.96)**
Oil price vol. $_{t-1}$	0.0004	-0.0042	-0.0010	-0.0290[a]	-0.0264[a]	0.0038[c]
	(0.19)	(-1.19)	(-0.40)	(-3.62)	(-7.41)	(1.80)
Living standard $_{t-1}$	0.0158[a]	1.6537[a]	0.0173[a]	1.8195[b]	-2.4403[a]	-0.3177
	(2.86)	(6.29)	(2.85)	(2.06)	(-10.19)	(-1.50)
Trade openness $_{t-1}$	-0.0107[a]	0.0094[b]	-0.0114[a]	-0.0528[a]	-0.0059[a]	-0.0090[a]
	(-3.74)	(2.07)	(-3.58)	(-3.29)	(-4.43)	(-4.44)
Short run estimates						
Δ FMD	-0.1300[a]	0.0049	-0.1415[a]	-0.0110	0.0285	-0.0461
	(-2.68)	(0.15)	(-2.86)	(-0.45)	(0.82)	(-1.12)
Δ Oil price vol.	-0.0084[b]	-0.0046[b]	-0.0089[c]	0.0006	0.0023	0.0057[b]
	(-1.99)	(-2.05)	(-1.89)	(0.15)	(1.18)	(2.09)
Δ Living standard	0.2477[c]	0.0409	0.3178	-0.0412	-0.3184	-0.1823
	(1.66)	(0.10)	(1.59)	(-0.13)	(-1.08)	(-0.70)
Δ Trade openness	0.0006	0.0031	0.0003	-0.0085[b]	0.0007	-0.0099[a]
	(0.22)	(1.48)	(0.10)	(-2.15)	(0.30)	(-2.76)
Constant	1.3520[a]	0.0214	1.4429[a]	-0.4331	3.0992[b]	1.0915[a]
	(3.03)	(0.61)	(2.95)	(-1.19)	(2.51)	(3.24)
Countries	13	13	13	12	12	12
Observation	442	442	442	408	408	408

Note: Table 8 presents the results of the impact of *FMD* on cleaner energy output in the sub-samples of the high innovation and low innovation growth countries in our sample. We use the CCEP methodology that assumes short run heterogeneity and long-run homogeneity and solves the problem of CD both in the short-run and long-run. The significance levels of the coefficients are denoted as [a, b, c] for the 1%, 5%, and 10%, respectively. The t-statistics are in parentheses.

Table 9: Financial markets development and cleaner energy output: Role of fossil fuels.

Variables	High fossil fuel			Low fossil fuel		
	CE	BIO	NBIO	CE	BIO	NBIO
	(1)	(2)	(3)	(1)	(2)	(3)
Error Correction	-0.2302[b]	-0.1644[b]	-0.2485[a]	-0.2021[a]	-0.1053[b]	-0.4622[a]
	(-2.53)	(-2.17)	(-2.84)	(-4.05)	(-2.49)	(-4.56)
Long Run						
FMD **$_{t-2}$**	**0.0293**	**-0.0192**	**-0.0030**	**0.2035[a]**	**0.1371[a]**	**0.0364[b]**
	(0.63)	**(-0.48)**	**(-0.07)**	**(6.79)**	**(3.89)**	**(2.15)**
Oil price vol. $_{t-1}$	0.0028	-0.0053[b]	-0.0017	0.0013	-0.0031	0.0032
	(0.97)	(-2.51)	(-0.51)	(0.34)	(-0.87)	(1.64)
Living standard $_{t-1}$	0.1886	-0.1867	0.0982	0.0228[a]	1.5754[a]	0.0631[b]
	(1.06)	(-0.62)	(0.63)	(2.91)	(6.02)	(2.20)
Trade openness $_{t-1}$	-0.0077[a]	0.0143[a]	-0.0034[c]	-0.0125[a]	0.0076[c]	-0.0061[a]
	(-2.58)	(4.44)	(-1.92)	(-2.98)	(1.66)	(-4.05)
Short Run						
Δ *FMD*	-0.0823[b]	0.0344	-0.0998[b]	-0.0316	-0.0083	-0.0378
	(-2.06)	(1.04)	(-2.43)	(-1.37)	(-0.26)	(-1.17)
Δ. Oil Price Vol.	-0.0007	0.0003	-0.0004	-0.0007	-0.0018	0.0018
	(-0.21)	(0.13)	(-0.12)	(-0.25)	(-0.71)	(0.68)
Δ. Living Standard	0.2906[c]	-0.4217	0.0812	-0.2341	0.3213	0.0166
	(1.72)	(-1.21)	(0.47)	(-1.11)	(0.80)	(0.07)
Δ. Trade Openness	0.0003	0.0040	-0.0012	-0.0052	0.0015	-0.0065[c]
	(0.13)	(1.25)	(-0.40)	(-1.07)	(0.74)	(-1.74)
Constant	-0.3308[c]	0.1663[c]	0.2770[b]	0.7355[a]	0.0230	0.5019[a]
	(-1.66)	(1.90)	(2.44)	(4.34)	(0.67)	(3.06)
Countries	14	14	14	11	11	11
Observation	476	476	476	374	374	374

Note: Table 9 presents the results of the impact of *FMD* on cleaner energy output in the sub-sample of the high fossil fuesl and low fossil fuels dependent countries within our sample. We use the CCEP methodology that assumes short run heterogeneity and long-run homogeneity and solves the problem of CD both in the short-run and long-run. The significance levels of the coefficients are denoted as [a, b, c] for the 1%, 5%, and 10%, respectively. The t-statistics are in parentheses.

Table 10: Additional tests- *Alternative explanation*

Variables	Cleaner Energy	Biomass Energy	Non-Biomass Energy
	(1)	(2)	(3)
Error Correction	-0.1421[a]	-0.0869[b]	-0.1111[a]
	(-3.12)	(-2.09)	(-6.20)
Long run estimates			
FMD $_{t-2}$	**0.1000[a]**	**0.0575[c]**	**0.2253[a]**
	(4.34)	**(1.93)**	**(2.85)**
Oil price vol.$_{t-1}$	-0.0010	-0.0187[a]	-0.0003
	(-0.32)	(-5.89)	(-0.03)
Grant and subsidy$_{t-1}$	0.0402	-0.0876	-0.1468
	(0.26)	(-1.38)	(-0.45)
Fossil fuels $_{t-1}$	-0.3016[a]	0.3672[a]	0.1366[c]
	(-4.70)	(3.38)	(1.68)
Patents $_{t-1}$	0.0136	-0.0168	-0.0235
	(1.07)	(-0.71)	(-0.75)
Living standard $_{t-1}$	-0.0100	1.1802[b]	0.0115
	(-1.22)	(2.57)	(0.22)
Trade openness $_{t-1}$	-0.0033	0.0235[a]	-0.0010
	(-1.31)	(7.70)	(-0.31)
Short run estimates			
Δ *FMD*	-0.0586[b]	0.0376[c]	-0.0252
	(-2.19)	(1.66)	(-1.30)
Δ Oil price vol.	-0.0031	0.0002	-0.0001
	(-1.26)	(0.11)	(-0.02)
Δ Grant and subsidy$_{t-1}$	-0.0291[c]	0.0158	0.0060
	(-1.72)	(0.94)	(0.24)
Δ Fossil fuels $_{t-1}$	-0.5453[a]	0.1925	-0.1510[a]
	(-5.16)	(0.63)	(-7.10)
Δ Patents $_{t-1}$	-0.0675	-0.0142	0.0011
	(-0.72)	(-0.17)	(0.28)
Δ Living standard	-0.0897	-0.0866	-0.0058
	(-0.60)	(-0.31)	(-0.40)
Δ Trade openness	0.0010	0.0002	0.0002
	(0.43)	(0.07)	(0.17)
Constant	0.4270[a]	0.4160[c]	0.0439
	(3.60)	(1.94)	(0.05)
Countries	25	25	25
Observation	850	850	850

Note: Table 10 contains three Panels that present several additional robustness checks of our main result. Panel A shows the results of the impact of *FMD* on alternative measures of cleaner energy. Our alternative measures represent the ratio of total cleaner energy, total biomass energy, and total non-biomass to total energy output during the year. Panel B presents the contemporaneous effect of *FMD* on various measures of cleaner energy. Panel C presents the impact of *FMD* on various measures of cleaner energy controlling for a government grant and subsidy for cleaner energy, the patent culture of the country, and production of fossil fuels. We use the CCEP methodology that assumes the short run heterogeneity and long-run homogeneity and solves the problem of CD both in the short-run and long-run. The significance levels of the coefficients are denoted as [a, b, c] for the 1%, 5%, and 10% levels, respectively. The t-statistics are in parentheses.

Appendices

Appendix A: List of countries in the sample.

Sample countries	Date Joined	Sample countries	Date Joined
Australia	7-Jun-71	Korea, Rep.	12-Dec-96
Austria	29-Sep-61	Luxembourg	7-Dec-61
Belgium	13-Sep-61	Netherlands	13-Nov-61
Canada	10-Apr-61	New Zealand	29-May-73
Denmark	30-May-61	Norway	4-Jul-61
Finland	28-Jan-69	Portugal	4-Aug-61
France	7-Aug-61	Spain	3-Aug-61
Germany	27-Sep-61	Sweden	28-Sep-61
Greece	27-Sep-61	Switzerland	28-Sep-61
Iceland	5-Jun-61	Turkey	2-Aug-61
Ireland	17-Aug-61	United Kingdom	2-May-61
Italy	29-Mar-62	United States	12-Apr-61
Japan	28-Apr-64		

Appendix B: Variable definition.

Variable	Definition	Source
Cleaner energy measures		
Cleaner energy (*CE*)	Net energy generation (Billion Kilowatt-hours) from various renewable sources, including hydroelectric, includes geothermal, solar, tides, wind, biomass, and biofuels.	International Energy Statistics (EIA, 2017).
Biomass energy (*BIO*)	Net generation (Billion Kilowatt-hours) from the extract of organic material including plants, animals, garbage, landfill gas and other sources.	EIA, 2017.
Non-biomass energy (*BIO*)	Net generation (Billion Kilowatt-hours) from various sources including hydroelectric, includes geothermal, solar, tides, wind and other sources.	EIA, 2017.
CE/Total	Net cleaner energy generation (Billion Kilowatt-hours) to total energy generation from all sources.	EIA, 2017.
BIO/Total	Net biomass energy generation (Billion Kilowatt-hours) total energy generation from all sources.	EIA, 2017.
NBIO/Total	Net cleaner energy generation (Billion Kilowatt-hours) to total energy generation from all sources.	EIA, 2017.
Financial market development measures		
Financial market development index (*FMD*)	A principal component constructs using domestic credit provided by private financial sector, banking sector, equity markets and broad money supply.	WDI, 2017.
Domestic credit to private sector (*CRD*)	Financial resources provided in the form of loans, purchases of non-equity securities, and trade credits and other accounts receivable, claims for repayments by private sectors financial corporations such as banks, finance and leasing companies, money lenders, insurance corporations, pension funds and foreign exchange companies.	WDI, 2017.
Market capitalization of listed companies (*MCAP*)	The sum of the product of share price times the number of shares outstanding for all listed domestic companies.	WDI, 2017.
Baseline control and other variables		
Carbon intensity	CO_2/GDP at purchasing power parities.	WDI, 2017.
Fossil fuel	Net energy generation (Billion Kilowatt-hours) from fossil formed in the Earth's crust from decayed organic material represented by petroleum, coal, and natural gas.	WDI, 2017.
Grant and subsidy	Cumulative total number of government's economic policy initiatives that provide grant and subsidy to various stakeholder working to promote cleaner energy.	EIA, 2017.

Innovation growth (*INOGR*)	Annual growth rate of the total number of patent applications by residents and non-residents through the patent cooperation treaty procedure or with a national patent office for exclusive rights for an invention.	WDI, 2017.
Living standard	Living standard is measured by household final consumption expenditure per capita, i.e., market value of all goods and services, including durable products, purchased by households excluding purchases of dwellings but including imputed rent for owner-occupied dwellings and including payments and fees to governments to obtain permits and licenses (at constant 2010 US$).	WDI, 2017.
Oil price volatility (*OPV*)	Ten years rolling standard deviation of international crude oil price in US$.	Macro Trends, 2017.
Patents	Annual total number of patent applications by residents and non-residents.	WDI, 2017.
Size	Size is measured as the natural logarithm of gross domestic product (at constant 2010 US$).	WDI, 2017.
Trade openness (*TO*)	Trade is the sum of exports and imports of goods and services measured as a share of output.	WDI, 2017.

Appendix C:
Contemporaneous impact of financial markets development on cleaner energy output.

Variables	Cleaner Energy	Biomass Energy	Non-Biomass Energy
	(1)	(2)	(3)
Error Correction	-0.2871[a]	-0.1137[a]	-0.3210[a]
	(-5.13)	(-3.12)	(-4.98)
Long run estimates			
FMD $_{t-1}$	**0.0345[c]**	**0.3919[a]**	**0.0432[b]**
	(1.75)	**(8.06)**	**(2.28)**
Oil price vol. $_{t-1}$	0.0051[a]	-0.0064[b]	0.0039[b]
	(3.09)	(-2.04)	(2.32)
Living standard $_{t-1}$	0.4399[a]	-0.0582	0.1254[b]
	(4.11)	(-0.18)	(2.16)
Trade openness $_{t-1}$	0.0047[a]	-0.0162[a]	-0.0001
	(2.96)	(-5.21)	(-0.22)
Short run estimates			
Δ FMD	0.0170	0.0151	0.0262
	(0.72)	(0.43)	(0.97)
Δ Oil price vol.	0.0024	0.0016	0.0019
	(1.18)	(0.87)	(0.84)
Δ Living standard	0.0895	-0.0947	0.0818
	(0.64)	(-0.36)	(0.54)
Δ Trade openness	-0.0025	-0.0006	-0.0051[c]
	(-0.85)	(-0.33)	(-1.75)
Constant	-1.6765[a]	-0.4843[a]	-0.1867
	(-4.64)	(-3.10)	(-1.60)
Countries	25	25	25
Observation	875	875	875

Appendix D:
Long run impact of FMD on cleaner energy output- Alternative econometric approaches.

Variables	Double Clustering			DOLS			FMOLS		
	RE	BIO	NBIO	RE	BIO	NBIO	RE	BIO	NBIO
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
FMD $_{t-2}$	**0.230[c]**	**0.279[a]**	**0.220[c]**	**0.326[a]**	**0.364[a]**	**0.305[a]**	**0.237[c]**	**0.282[a]**	**0.225**
	(1.93)	**(3.05)**	**(1.73)**	**(13.05)**	**(20.12)**	**(11.59)**	**(1.65)**	**(2.71)**	**(1.45)**
Living standard $_{t-1}$	0.177	0.082	0.167	0.197[a]	0.108[a]	0.183[a]	0.034	-0.033	0.028
	(1.43)	(0.99)	(1.38)	(5.15)	(3.91)	(4.55)	(0.16)	(-0.21)	(0.12)
Oil price vol.$_{t-1}$	-0.002	-0.017	0.001	0.007	-0.004	0.009[c]	-0.033	-0.024	-0.031
	(0.001)	(0.001)	(0.002)	(1.38)	(-0.98)	(1.81)	(-1.17)	(-1.19)	(-1.04)
Trade openness $_{t-1}$	-0.019[a]	-0.007[a]	-0.019[a]	-0.017[a]	-0.006[a]	-0.018[a]	-0.017[a]	-0.005	-0.017[a]
	(-6.76)	(-3.79)	(-5.62)	(-22.25)	(-10.15)	(-22.14)	(-3.80)	(-1.62)	(-3.54)
Constant	2.520[b]	0.739	2.487[b]	2.214[a]	0.365	2.228[a]	4.258[c]	2.171	4.114[c]
	(2.32)	(1.00)	(2.35)	(5.83)	(1.33)	(5.57)	(1.93)	(1.37)	(1.73)
Adjusted R-square	0.469	0.442	0.441	0.455	0.416	0.435	0.121	0.203	0.119
Year fixed effect	Yes	Yes	Yes	No	No	No	No	No	No
Countries	25	25	25	25	25	25	25	25	25
Observation	875	875	875	875	875	875	874	874	874

Appendix E:
Financial markets development and alternative measure of cleaner energy

Variables	CE/Total	BIO/Total	NBIO/Total
	(1)	(2)	(3)
Error Correction	-0.4203[a]	-0.1388[a]	-0.2274[a]
	(-5.58)	(-2.95)	(-4.27)
Long run estimates			
FMD $_{t-2}$	**0.0028[b]**	**0.0016[b]**	**0.0051[a]**
	(2.16)	**(2.22)**	**(7.82)**
Oil price vol.$_{t-1}$	-0.0003[c]	-0.0001	0.0000
	(-1.71)	(-1.31)	(0.32)
GDP size$_{t-1}$	-0.0185[a]	-0.0389[a]	0.0093
	(-4.79)	(-8.26)	(1.12)
Living standard $_{t-1}$	-0.0003	0.0470[a]	-0.0394[a]
	(-0.57)	(8.12)	(-4.63)
Trade openness $_{t-1}$	-0.0000	0.0006[a]	-0.0006[a]
	(-0.26)	(8.61)	(-5.20)
Short run estimates			
Δ *FMD*	-0.0041	0.0014	-0.0072[c]
	(-0.66)	(1.08)	(-1.71)
Δ. Oil price vol.	0.0002	-0.0000	-0.0003
	(0.66)	(-0.51)	(-1.06)
Δ. GDP size	-0.0425	0.0008	0.0328
	(-0.81)	(0.07)	(0.75)
Δ. Living standard	0.0472	0.0056	0.0053
	(1.37)	(0.87)	(0.26)
Δ. Trade openness	0.0001	0.0000	-0.0003
	(0.13)	(0.54)	(-0.72)
Constant	1.8973[a]	0.0111[c]	0.0936[a]
	(5.61)	(1.82)	(4.28)
Countries	25	25	25
Observation	850	850	850

Appendix F:

Credit market development, equity market development, and alternative measure of cleaner energy.

Variables	CE/Total		BIO/Total		NBIO/Total	
	(1)		(2)		(3)	
Error Correction	-0.4487^{a}	-0.4487^{a}	-0.1768^{a}	-0.1768^{a}	-0.3002^{a}	-0.3002^{a}
	(-5.41)	(-5.41)	(-3.68)	(-3.68)	(-4.35)	(-4.35)
Long run estimates						
Credit market $_{t-2}$	**0.0001^{c}**		**0.0001^{c}**		**0.0002^{a}**	
	(1.86)		**(1.74)**		**(3.65)**	
Equity market $_{t-2}$		**0.0022^{b}**		0.0011		**0.0032^{a}**
		(2.42)		(1.31)		**(2.89)**
Oil price vol.$_{t-1}$	-0.0000	-0.0001	0.0000	-0.0000	-0.0001	0.0003
	(-0.13)	(-0.87)	(0.33)	(-0.45)	(-0.43)	(1.52)
GDP size$_{t-1}$	0.0236^{b}	-0.0104	-0.0170^{a}	-0.0168^{a}	-0.0068	-0.0332^{b}
	(2.41)	(-1.04)	(-4.66)	(-5.69)	(-1.16)	(-2.25)
Living standard $_{t-1}$	-0.0674^{a}	-0.0154	0.0199^{a}	0.0186^{a}	0.0014	0.0480^{b}
	(-4.50)	(-1.12)	(4.79)	(5.24)	(0.84)	(2.40)
Trade openness $_{t-1}$	-0.0004^{a}	-0.0000	0.0003^{a}	0.0002^{a}	-0.0003^{a}	-0.0002
	(-4.74)	(-0.36)	(6.55)	(7.22)	(-2.65)	(-1.14)
Short run estimates						
Δ Credit market $_{t-2}$	-0.0000		-0.0000		-0.0001	
	(-0.11)		(-0.51)		(-1.03)	
Δ Equity market		0.0046^{c}		-0.0004		0.0026^{b}
		(1.88)		(-1.58)		(2.24)
Δ. Oil price vol.	-0.0001	-0.0000	-0.0000	-0.0000	-0.0003	-0.0003
	(-0.20)	(-0.12)	(-0.10)	(-0.19)	(-1.06)	(-1.07)
Δ. GDP size	0.0008	-0.0017	0.0009	0.0010	0.0406	0.0293
	(0.02)	(-0.04)	(0.09)	(0.10)	(0.95)	(0.71)
Δ. Living standard	0.0297	0.0425	0.0039	0.0087	0.0101	0.0074
	(0.84)	(1.07)	(0.73)	(1.14)	(0.48)	(0.34)
Δ. Trade openness	0.0000	0.0001	0.0001	0.0001^{c}	-0.0002	-0.0001
	(0.00)	(0.27)	(1.18)	(1.84)	(-0.50)	(-0.33)
Constant	0.2281^{a}	0.4977^{a}	-0.0323^{a}	-0.0434^{a}	0.6321^{a}	0.8782^{a}
	(5.05)	(5.26)	(-3.83)	(-3.76)	(5.04)	(4.36)
Countries	25	25	25	25	25	25
Observation	850	850	850	850	850	850

Note: Appendix Table F presents the effect of the credit market development (*CRD*) and the effect of the equity market development (*MCAP*) on alternative measure of cleaner energy output in our sample countries. Our alternative measures represent the ratio of total cleaner energy, total biomass energy, and total non-biomass to total energy output during the year. We use the CCEP methodology under the conditions of short-run heterogeneity and long-run homogeneity by solving the problem of cross-sectional dependence in the short-run and long-run. The significance levels of the coefficients are denoted as a, b, c for the 1%, 5%, and 10%, respectively. The t-statistics are in parentheses.

Appendix G:
Financial markets development and cleaner energy: Role of innovation growth.

Variables	High innovation			Low innovation		
	CE/Total	BIO/Total	NBIO/Total	CE/Total	BIO/Total	NBIO/Total
	(1)	(2)	(3)	(1)	(2)	(3)
Error Correction	-0.4131[a]	-0.1960[a]	-0.3925[a]	-0.1960[a]	-0.0710	-0.2683[b]
	(-3.41)	(-2.63)	(-3.72)	(-2.63)	(-1.62)	(-2.30)
Long run estimates						
FMD $_{t-2}$	**0.0043[a]**	**0.0013**	**0.0029[c]**	0.0003	0.0008	0.0006
	(10.24)	**(0.63)**	**(1.78)**	(0.63)	(0.58)	(0.58)
Oil price vol. $_{t-1}$	0.0000	0.0001	-0.0007[b]	0.0001	-0.0003	-0.0011[a]
	(0.36)	(1.45)	(-2.48)	(1.45)	(-0.85)	(-3.71)
GDP size$_{t-1}$	0.0177[c]	-0.0245[a]	-0.0244[a]	-0.0245[a]	0.0043	0.0574
	(1.77)	(-8.83)	(-4.01)	(-8.83)	(0.22)	(1.21)
Living standard $_{t-1}$	-0.0234[a]	0.0167[a]	-0.0002	0.0167[a]	-0.0905[a]	0.0655[b]
	(-3.96)	(4.65)	(-0.26)	(4.65)	(-3.28)	(2.02)
Trade openness $_{t-1}$	-0.0004[a]	0.0003[a]	-0.0003	0.0003[a]	0.0003[c]	-0.0007[b]
	(-3.81)	(6.87)	(-1.38)	(6.87)	(1.70)	(-2.20)
Short run estimates						
Δ FMD	0.0072	0.0006	-0.0152[b]	0.0006	0.0026	0.0011
	(0.71)	(1.06)	(-2.55)	(1.06)	(1.02)	(0.18)
Δ Oil price vol.	0.0006	0.0001	-0.0003	0.0001	-0.0001	-0.0002
	(1.22)	(0.95)	(-0.78)	(0.95)	(-0.67)	(-0.56)
Δ GDP size	-0.1173	-0.0108	-0.0040	-0.0108	0.0040	-0.0111
	(-1.32)	(-0.99)	(-0.06)	(-0.99)	(0.22)	(-0.14)
Δ Living standard	0.0754	0.0095	0.0245	0.0095	-0.0084	0.0372
	(1.08)	(1.60)	(1.18)	(1.60)	(-0.95)	(1.10)
Δ Trade openness	-0.0005	0.0000	0.0006	0.0000	0.0001	-0.0008
	(-0.73)	(0.29)	(1.35)	(0.29)	(1.14)	(-1.45)
Constant	0.1526[a]	0.1696[a]	3.4187[a]	0.1696[a]	-0.3261	1.3100[b]
	(2.72)	(2.60)	(3.74)	(2.60)	(-1.62)	(2.31)
Countries	13	13	13	12	12	12
Observation	442	442	442	408	408	408

Note: Appendix Table G presents the results of the impact of *FMD* on cleaner energy output in the sub-samples of the high innovation and low innovation growth countries in our sample. We use the CCEP methodology that assumes short run heterogeneity and long-run homogeneity and solves the problem of CD both in the short-run and long-run. The significance levels of the coefficients are denoted as [a, b, c] for the 1%, 5%, and 10%, respectively. The t-statistics are in parentheses.

Appendix H:

Financial markets development and cleaner energy output: Role of fossil fuels.

Variables	High fossil fuel			Low fossil fuel		
	CE/Total	BIO/Total	NBIO/Total	CE/Total	BIO/Total	NBIO/Total
	(1)	(2)	(3)	(1)	(2)	(3)
Error Correction	-0.3612[a]	-0.0176	-0.2386[b]	-0.4843[a]	-0.2206[a]	-0.3056[a]
	(-3.24)	(-0.52)	(-2.58)	(-4.19)	(-2.63)	(-3.88)
Long run estimates						
FMD $_{t-2}$	0.0009	-0.0012	0.0035[c]	**0.0043[a]**	**0.0006**	**0.0048[a]**
	(0.53)	(-0.33)	(1.76)	**(10.17)**	**(1.33)**	**(8.03)**
Oil price vol. $_{t-1}$	-0.0002	0.0017[a]	-0.0005[c]	0.0000	-0.0001[b]	0.0001[c]
	(-0.76)	(4.17)	(-1.94)	(0.31)	(-2.04)	(1.76)
GDP size$_{t-1}$	-0.0247	-0.1052[a]	-0.0466[a]	0.0167[c]	-0.0175[a]	0.0344[b]
	(-1.48)	(-2.85)	(-3.10)	(1.66)	(-2.97)	(2.36)
Living standard $_{t-1}$	0.0060	0.0700[a]	0.0557[b]	-0.0238[a]	0.0176[a]	-0.0314[a]
	(0.23)	(2.66)	(2.52)	(-4.07)	(3.98)	(-3.72)
Trade openness $_{t-1}$	-0.0000	-0.0015[a]	-0.0001	-0.0004[a]	0.0002[a]	-0.0006[a]
	(-0.07)	(-3.00)	(-0.56)	(-4.12)	(4.87)	(-4.32)
Short run estimates						
Δ FMD	-0.0055	0.0018	-0.0105	-0.0027	0.0002	-0.0043
	(-0.48)	(1.13)	(-1.38)	(-0.82)	(0.28)	(-1.11)
Δ Oil price vol.	-0.0002	-0.0000	-0.0003	0.0006	0.0001	-0.0001
	(-0.50)	(-0.32)	(-0.83)	(1.42)	(1.03)	(-0.35)
Δ GDP size	-0.0231	0.0046	0.0383	-0.0800	0.0087	0.0006
	(-0.32)	(0.27)	(0.78)	(-1.03)	(0.63)	(0.01)
Δ Living standard	0.0918	0.0052	0.0293	-0.0049	-0.0051	-0.0132
	(1.59)	(0.58)	(0.89)	(-0.27)	(-0.54)	(-0.92)
Δ Trade openness	0.0004	0.0000	0.0001	-0.0004	0.0001	-0.0007
	(0.82)	(0.41)	(0.21)	(-0.53)	(0.69)	(-1.08)
Constant	0.1526[a]	0.1696[a]	3.4187[a]	0.2157[a]	-0.0054[b]	0.1639[a]
	(2.72)	(2.60)	(3.74)	(4.39)	(-2.36)	(3.67)
Countries	14	14	14	11	11	11
Observation	476	476	476	374	374	374

Note: Appendix Table H presents the results of the impact of *FMD* on cleaner energy output in the sub-sample of the high fossil fuel and low fossil fuels dependent countries within our sample. We use the CCEP methodology that assumes short run heterogeneity and long-run homogeneity and solves the problem of CD both in the short-run and long-run. The significance levels of the coefficients are denoted as [a, b, c] for the 1%, 5%, and 10%, respectively. The t-statistics are in parentheses.