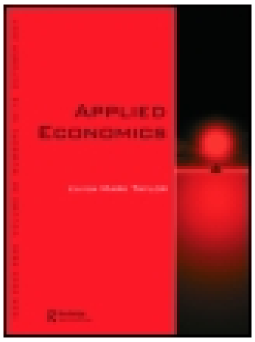

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The effect of sample size on European Union's renewable energy investment drivers

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ABSTRACT
Macroeconomic modelling results based on relatively varying sample sizes may lead to incoherent results. Such effects have not been adequately understood in the renewable energy literature regarding the European Union (EU). This study focuses on the comparison of results obtained for renewable energy investment drivers (for solar and wind energy investments) on different samples of EU countries, including all EU-27, former EU-15 and 11 high renewable investment EU countries. The study used a random effect panel data modelling approach over the period 1995–2011 for studying the impact of the levelized cost, regulation perception, carbon emissions and climatic condition on wind and solar investments over the three samples. The results demonstrate the importance of trustable regulation schemes to ensure that regulation will not have a significant negative effect on investment, showing also the need to further extend the model to include support schemes as fundamental drivers for investment.

KEYWORDS
Sample variations; electricity price modelling; regulation; renewable energy

JEL CLASSIFICATION
B23; C13; C23; Q01; Q20

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I. Introduction

Climate change issues along with economic and environmental sustainability have witnessed important discussions in the EU-2020 goals (Eurostat). Generation and supply of clean energy have also been one of the top priorities of European Union (EU). Countries such as Denmark and Belgium target 100% share of renewable energy in their total energy supply by 2050 (Lund and Mathiesen 2009; Devogelaer et al. 2013). Substantial investments and support systems in renewable energy are recommended as key requirements to fuel higher renewable energy generation (Sisodia et al. 2015a, 2015b; Sisodia, Soares, and Ferreira 2016). Additionally, it is also important to understand the main drivers of renewable investments. Sisodia and Soares (2015) presented a macroeconomic modelling of renewable energy investment determinants in EU-27, where the authors found that regulation perceptions (RG) play a significantly negative role in solar energy investments, whereas, solar and wind investments have a negative relationship with carbon emissions. However, EU-27 represents a relatively large sample; it is expected that the smaller sample size might present results that are different from those mentioned by the authors. This study focuses on the comparison of results obtained through relatively smaller sample sizes of European countries over the period 1995–2011. Hence, this study is an extension to the earlier work of the authors. For the current study, our research question is: does the investment driver for solar and wind energy varies with the varying sample sizes for the EU states? The magnitude and direction of variations in results observed through this study is interesting and offers a contribution to the literature. Additionally, as far as we know, such a comprehensive study in renewable energy investment has not been previously conducted.

Thus, taking into consideration of four main hypotheses from previous research (Sisodia and Soares 2015), we tested if the outcomes for each one are consistent across the three samples.

H1a: Higher sunshine hours lead to higher electricity generation through solar

H2a: Lower sunshine hours lead to higher electricity generation through wind

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H1b: Strong regulation perception leads to higher investment in solar

H2b: Strong regulation perception leads to higher investment in wind

Incentives given towards the adoption of green technology are supposed to be one of the instruments of climate change policies, which ultimately aim to reduce the carbon emissions. Therefore, in controlling carbon emissions, it is necessary to install a higher number of renewable energy plants. That also means that countries with higher carbon emissions should invest more in wind and solar technologies (or biomass, hydro, etc.) to meet the 2020 targets.

Wind and solar plants may contribute less towards controlling the carbon emissions if the policies support other renewable technologies like hydro or biomass. However, for the current scope, we only deal with wind and solar. Therefore, we propose two additional hypotheses (H1c and H2c) to test the dependency of solar and wind energy investments towards controlling carbon emissions.

H1c: Higher carbon emissions lead to higher investment in solar

H2c: Higher carbon emissions lead to higher investment in wind

This article is organized into the following sections: This section presents the basic introduction and the objective of the study. Section II presents a short review of the sample sizes and the influence of renewable energy directives on investments. Section III focuses on the data and methodology followed by Section IV, which deals with the macroeconomic modelling and results. Finally, Section V concludes with the policy implications.

II. Brief literature survey

Sample sizes

Several studies have shown that small samples have a bias, whereas larger samples reduce the bias (Dietrich 2005; Gordon, Osberg, and Phipps 2005). Bali and Demirtas (2007) mention that although a very small sample size can be a serious concern in panel data modelling, increasing the number of cross-sections could reduce bias. On the other hand, Lantz (2013) and Tukey (1991) argue on the very large sample fallacy: they mention that, in most of the cases, the null hypothesis tends to be rejected. Several studies addressing the sample sizes are reported in the literature (Shevlin and Milesb 1998; Lawson and Fisher 2011; Zhou, Huang, and Shu 2014). However, the focus of this study is to check the results obtained through changing the sample sizes, without altering the methodology used by Sisodia and Soares (2015).

Influence of renewable energy directives on investments

Policies associated with regulatory frameworks play a vital role in positively or negatively affecting businesses and investments (Saltari and Travaglini 2011; Schmit, and Conrad 2011). Given that the renewable energy sector is currently a growing, dynamic field, companies and individuals would invest in this sector if it promises significant returns.

European countries are considered as favourite destinations for renewable energy sources (RES) investments research. According to Lux Research (2011), Portugal should be the second top priority for the investors of solar energy after New Jersey. Other destinations for investment are Australia, Italy and India. The companies show this interest because of the steadily rising internal rates of returns (IRR), which are expected to bring an opportunity of 400 MW business every year (Business Wire 2011). Contrary to this trend, as reported by Leete, Xu, and Wheeler (2013), investment in the renewable energy sector in the UK is declining. Investors who had previously invested in the renewable energy business now show less interest in investing further because of the unattractive regulatory policies and increased waiting time for the returns to materialize.

Recently, Boomsma, Meade, and Fleten (2012) adopted an approach for analysing the duration and time of an investment in renewable energies under various support mechanisms mainly feed-in tariffs (FIT)[1] and renewable energy certificates (REC).[2] They considered uncertainties in the model

[1]http://www.eia.gov/todayinenergy/detail.cfm?id=11471
[2]http://www.investopedia.com/terms/r/rec.asp

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and reported on investment decisions pertaining to the FIT. Their report mentions that FIT is the better policy instrument for attracting the renewable investments. In their baseline scenario, they point out, 'taking the fixed feed-in tariff as a base, the revenue required to trigger the investments was 61% higher with renewable certificates'.

Fernandes, Cunha, and Ferreira (2011), investigated real options theory approach in the energy sector investment. Copeland and Antikarov. (2003) defined real option 'as a right, but not the obligation, to take an action (e.g. deferring, expanding, contracting or abandoning) at a predetermined cost, called the exercise price, for a predetermined period – the life of the option'. This theory has been widely accepted in the energy sectors for formulation and evaluation of policies.

Furthermore, studies from non-EU countries (e.g. Aslani et al. 2012) have examined the prime criteria for private sector participation in renewable energy investment in the Middle East. They cite that, for private firms, the driving forces for investment are friendly government policies along with assured markets.

At present, however, a more adequate legal framework may be required for further adoption of the renewable energy systems. Implementing the renewable energy technologies individually by households and industries are typically expensive because of substantial installation costs associated with wind and solar RES. To avoid these high investments, most of the EU countries have adopted the FIT system for production and supply of renewable energy, and hence increased the generation of renewable energy (Eurostat). FIT is a system that allows consumers to produce and use their own electricity through roof top solar panels, and surplus energy can be supplied back to grid, where generator receives a fixed rate and a premium for generating clean energy.

Carvalho et al. (2011) point out that the EU is not only the first, but also the world's leader in the photovoltaic (PV) sector. However, because of the high installation cost, lesser investors prefer RES generation through PV.

According to the European Photovoltaic Industry Association (EPIA) 2013 report, the world's total PV capacity was 31.1 GW in 2012. Europe (not EU) accounts for 17.2 GW, almost 55% of total PV installation in the world. Germany is the top market with a PV installation of 7.2 GW. However, in Europe, electricity generation through PV is the third preferred choice, following hydro and wind, respectively. This is explained both by country's own natural resources endowments and national freedom to choose its own energy policy.

Furthermore, Kost, Flath, and Möst (2013) examined this phenomenon at the country level, analysing the Spanish market for concentrated PV, where investment decision is not only relied upon the capacity installation, but also on the storage capacity of the plant. They analysed the economic value of concentrated PV in Spanish market under wholesale market price and local FIT. In that market, there was a limited incentive for storage even for thermal power. They developed a framework that gives optimal layout decision and the operation of concentrated solar power (CSP) plants. In another recent study, Avila-Marin, Fernandez-Reche, and Tellez (2013) analysed different renewable energy plants for their cost effectiveness. Specifically for solar plants, they mention that the larger plant size can be cost effective through improved economies of scale.

Panel data modelling

Menegaki (2011) adopted a similar approach to develop an empirical understanding of the causal relationship between economic growth and renewable energy through panel data over the period 1997–2007 in EU-27, using random effect modelling. Observation suggests that there is no relationship between RES consumption and economic growth. More recently, Lee (2013) used a fixed effects panel data model to investigate the contribution of foreign direct investment (FDI) net inflows on clean energy use, carbon emissions and economic growth using a panel data of G20 countries over the period 1971–2009. He observed that FDI plays a positive role in economic development, but leads to higher carbon emissions. Similarly, Chakraborty and Mukherjee (2013) studied 10 years of panel data (2000–2010) from 114 countries to understand the relationship among environmental performance index, export and FDI. Export and FDI were found to be negatively associated with an environmental performance index. Thus, the study revealed a serious concern at

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the nexus between environmental sustainability and economic growth.

Cambini and Rondi (2009) investigated the relationship between investment and regulation through panel data of EU-27. The outcome shows that regulation is negatively associated with private and public firms' incentives to invest. Instead of the ordinary least square method, they used a two-stage least squares (TSLS) and generalized method of movements (GMM) approach. TSLS is widely used in econometrics to estimate parameters in systems of linear simultaneous equations and to solve problems of omitted-variables bias in single-equation estimation (Angrist and Imbens 1995); whereas, the GMM estimator is typically used to correct for bias caused by endogenous explanatory variables (Xang and Fan 2003).

Another empirical study by Sadorsky (2012) related to modelling of renewable energy company risk suggested a negative association of sales growth to business risk. This study used panel data on 52 companies over the period 2001–2007.

In another study, Ni, Kresl, and Li (2014) conducted a panel data study over the period 1990–2009 to understand the competitiveness among 25 cities in China. The objective of this study was to put forth the policy perspective concerned with the economic development of China. The result suggests that cities situated in the north of China are developing at a faster pace leading to higher economic contributions from north. This region attracts cheap labours and may require institutional reforms. Saenz de Miera, Gonzalez, and Vizcaıno (2008) empirically studied the interaction of RES in electricity and the price of wind energy in the electricity market in Spain and found that as the amount of wind energy fed into the grid increased, the final price to end consumers decreased.

On the other hand, Moreno, López, and García-Álvarez (2012) studied the panel data of EU-27 over the period 1998–2008 and proposed that as the renewable share of electricity supply significantly increases, the household price to final consumers increases. They also identified carbon emissions as an additional variable influencing household electricity prices. The cleaner the energy is, the higher the price of electricity because technological, operation and regulatory costs are involved in the production of green energy. In the more recent article, DelRío and Arancón (2012) analysed the features of econometric research on RES determinants (in articles published from 2006 to 2010). The main objective of their study was to find the relationship between administrative barriers and onshore wind investments. The results suggest that administrative barriers negatively influence wind investments.

III. Data and methodology

This section explains the methodology adopted to obtain the results empirically from modelling the EU-27 sample data concerning the factors that affect wind and solar energy generation. This study uses a panel data methodology for testing the reliability of investment determinants and hypotheses on varying sample sizes put forth by Sisodia and Soares (2015).

The current methodology is an attempt to understand the trends in RES and associated variables on EU-27, and to compare the EU-27 results with those for EU-15[3] and EU-11.[4] The dependent variables used in the study were solar investments (RES-S) and wind investments (RES-W) over the specified period. The five independent variables were levelized cost of generation through solar (LS) and wind (LW), regulations perceptions[5] (RG), carbon emissions (CE) and annual sunshine hours (ASH). RES-S and RES-W were considered to represent yearly installation of solar and wind generation capacities. Data for RES-S, RES-W and CE was gathered from Eurostat. The RG values, obtained from World Bank,[6] represent overall regulatory perceptions; however, for this study we assumed that RG also

[3]EU-15 comprises the member countries in the European Union prior to the accession of 10 candidate countries on 1 May 2004. EU-15 comprises then the following countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and United Kingdom.

[4]The EU-11sample was selected by the authors and was based on the countries that generated highest renewable energy in the year 2013 and included Austria, Denmark, Finland, France, Germany, Italy, Netherland, Poland, Italy, Spain and Sweden.

[5]Regulatory quality (RG) is a world governance indicator taken from World Bank database. It reflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.

[6]http://info.worldbank.org/governance/wgi/index.aspx#faq

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represents electricity regulation perceptions. ASH was taken from climate database of EU.

Levelized cost[7] associated with electricity generation (although it may be subsidized) is an important consideration in the model of an empirical investment. This is particularly significant because businesses looking to invest in the electricity sector are also looking at levelized costs of available options (e.g. wind, solar, biomass, nuclear) (see Gross, Heptonstall, and Blyth 2007; VGB Report 2011). Therefore, this study applies a revised model that provides additional information on other associated variables through panel data modelling. Thus, it intends to contribute to the body of current scientific knowledge on the solar and wind energy investment drivers.

Levelized cost of electricity generation through wind and solar were taken from World Energy Outlook. According to EIA (2013), levelized costs are associated with competitiveness of generating electricity from different sources. The main inputs for calculating the levelized costs are capital costs, fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs and an assumed utilization rate for each plant type. Levelized cost is considered to be an important factor in investment decisions associated with the implementation of the renewable energy projects (Hernandez-Moro and Martínez-Duart 2013), because generation of energy from renewable sources is considered to be an expensive operation for businesses (Borenstein 2011). Levelized cost of electricity generation is also used as an input variable by Ohunakin, Oyewola, and Adaramola (2013) for energy modelling.

EU-11 and EU-15 samples were assumed to be homogeneous in nature. Data obtained from Eurostat and World Bank databases were sorted on the basis of EU-15 and EU-11 countries over the period 1995–2011. Multicollinearity and heteroscedasticity were tested. Results of Hausman test suggested the use of random effect modelling. For further detail regarding the conceptual framework and methodological approach, see Sisodia and Soares (2015).

IV. Modelling and results

We used the following OLS panel data regression to test our hypotheses

$$Y_{it}(\mathrm{RES}-\mathrm{S}) = \beta_0 + \beta_1 * \mathrm{LS} + \beta_2 * \mathrm{CE} + \beta_3 * \mathrm{ASH} + \beta_4 * \mathrm{RG} + U_{it} \quad (1)$$

$$Y_{it}(\mathrm{RES}-\mathrm{W}) = \beta_0 + \beta_1 * \mathrm{LW} + \beta_2 * \mathrm{CE} + \beta_3 * \mathrm{ASH} + \beta_4 * \mathrm{RG} + U_{it} \quad (2)$$

where i = 1, &, 27, t = 1995, &, 2011 and β_0 parameters denote country effects which are included in the model in order to take account of any possible country-specific factors that may have an influence on prices beyond the explanatory variables included. The disturbance/noise of this model is denoted by U_{it} and is assumed to be independent and identically distributed random variables with mean zero and variances $\sigma 2u$. We formulated six model versions across the three sample sizes for the two dependent variables.

Table 1 shows the statistical results over the three sample sizes (EU-11)

The values observed for LS across the three samples (MV 1, 3 and 6) were consistent but not statistically significant. For LW, the values observed for MV2 and MV4 were noticed to be significant, whereas, for MV6, the LW values were not significant. The reason for the variation in the results for EU-11 might be high government incentives through support systems that may have supported the wind investment relative to solar (Renewables 2014). The EU-11 sample majorly consists of countries that have high GDP per capita, therefore, its comparison with other two samples could yield different results. For countries with less GDP, technologies that are cheaper to produce electricity are more preferred to generate electricity. The non-significance of LW and LS could also suggest that investors are mostly focused on the rewards than on levelized costs of solar and wind generation. This also could mean that the rewards through FIT and feed-in premium are already planned by each country's government taking into account the levelized costs. Additionally, in EU-11 sample, we have dealt with samples that are

[7]EIA Report (2013) levelized cost as: 'Levelised cost of electricity (LCOE) is often cited as a convenient summary measure of the overall competitiveness of different generating technologies.... For technologies such as solar and wind generation that have no fuel costs and relatively small variable O&M costs, LCOE changes in rough proportion to the estimated capital cost of generation capacity'.

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Table 1. Statistical results of the modelling through six model versions (MV).

		EU-27				EU-15				EU-11			
		RES-S		RES-W		RES-S		RES-W		RES-S		RES-W	
		MV 1		MV 2		MV 3		MV 4		MV-5		MV-6	
Price variables	LS	−0.002				0				0.0004			
	LW			−0.044	*			−0.042	***			−0.0128	
Economic variables	CE	−1.513	*	−9.748	*	−6.236	*	−49.688	*	−3.005	**	−19.556	*
Other variables	ASH	8.129	*	−6.699	**	−0.175		−9.15	*	−0.662	**	−9.0198	*
	RG	−0.916	***	−2.231		−1.285	***	−3.463		−0.654		−2.3269	
R-squared		0.034		0.128		0.238		0.455		0.107		0.2168	
Adjusted *R*-squared		0.021		0.116		0.22		0.443		0.0759		0.1896	
F-statistic		2.685		11.261		13.632		36.531		3.4434		7.9591	
Prob(*F*-statistic)		0.032		0		0		0		0.0107		0	

*Significant at 1% level.
**Significant at 5% level.
***Significant at 10% level.

pro wind investors (example: Denmark and Germany). For instance, LW is not as important for Denmark because the selection of technology is based on natural endowment. In summary, the major concern is overall trend that suggest wind power generation to be significantly and negatively related to levelized cost and investment for the EU. The non-significance of levelized cost for solar power can be explained by the existing support schemes that can overcome the impact of levelized costs on the willingness to invest.

CE values across all the six model versions were found to be consistently negative and significant. That means in all the possible cases, when investment in RES increases, the carbon emissions decrease, which is normally expected and also aligned with the EU-2020 goals. The results from hypothesis H1c and H2c seem to point to the non-acceptance as a negative relation between CE and both wind and solar investment was found, this could mean that the model could not find evidence that countries with higher carbon emissions would tend to invest more on RES. Contrarily, the trend is that countries with lower carbon emissions are in fact higher RES investors.

As for ASH, the result on EU-15 was seen inconsistent and insignificant for ASH in the MV3. For the EU-27, the results point to a positive relation between ASH and investment is solar power, which is consistent to the expected one. The negative relation obtained for EU-11 and even for EU-15, although in this case not significant, cannot be explained by the characteristics of the technology, as higher sunshine hours would mean a higher power output and consequently higher expected return and theoretically resulting in higher investment. In fact, once more the effect of support schemes can be much relevant leading to higher investments in countries with low ASH but better incentives. For example, Germany and Denmark, being cold countries with 1500 and 1650 h of ASH, respectively, have very high levels of solar energy generation. In 2013, Germany had the highest PV capacity in the world (Renewables 2014). As for the negative relation between ASH and investment in wind power, comes mainly from the high support given to wind power even in countries with low sunshine hours, as is the case of North European countries. Concerning hypotheses H1a and H2a, the results are then not fully consistent. H1a can be considered accepted for the EU-27 but not for EU-11 and EU-15. H2a is accepted for the three cases, meaning that the model could find evidence that investment in wind power tends to be higher in countries with lower sunshine hours.

The RG variable is only significant for solar power for EU-27 and EU-15, but a general trend can be observed for all models and for both solar and wind, which is a negative relationship between regulation and investment. Although the results should be looked with caution as RG does not reflect actual regulation level of the electricity sector, the results seem to point to the general idea that higher regulation can be seen as a policy risk factor reducing the investors interest for the sector. For the particular case of solar power and the non-significance of the results for EU-11, one possible explanation could be that the countries in EU-11 samples might have stronger support policies for wind and solar power generation than the EU-27 and EU-15 countries (refer to ECOFYS Report 2014). For example, the countries such as Sweden, Denmark, Germany and Finland which are part of the EU-11 have highest RG perceptions, whereas the EU-27 include countries such as Bulgaria, Hungary, Greece and Romania that have very weak RG perceptions. Furthermore, the countries in EU-11 have developed countries that are into solar and wind investments for few decades now, thus defining that the regulations in energy are widely accepted and trusted by investors, whereas, in other samples, strong regulations could affect investors in negative way.

Finally, concerning hypotheses H2a and H2b, although the results are not statistical significant across the six models, the final conclusions lead to the non-acceptance of both hypotheses as stronger regulation perception tends in facto to lead to lower investment in RES. The rejection of H2a is statistically demonstrated for EU-15 and EU-27.

V. Conclusion and strategy

Through this study, we have put forth the issue of varying samples in the macroeconomic approach, which to a large extent defines the limitations of such studies. We have used a random effect panel data modelling approach to capture the effect of variables under the study over the period 1995–2011. The results allowed drawing already some conclusions on the factors affecting investment in renewables in the part years in EU. However, it became also evident that other aspects are severely conditioning the model performance and results as these are strongly affected by external factors and in particular to the existence of different support schemes. These turn difficult to find consistent relationships between investments and what would be evident driving factors for investors in a full competitive market, as is the case of resources availability directly affecting ASH and depending only on the climatic conditions. The same goes for levelized cost as its importance for the investors becomes quite reduced when RES incentives are available.

As for regulation, the general view is that stronger regulation perception does not necessarily lead to higher interest by the investors. Although it must highlighted that regulation perception of the economy does not reflect the effective regulation of the electricity sector and of RES, the results show how regulation can lead to less interest from private investors. This does not mean that regulation should be avoided or reduced; it rather shows that these measures must be clearly defined, accepted and considered to be trustable to have a positive or at least non-negative effect on investment. This is particularly evident on the case of less developed technologies, as is the case of solar, for which support schemes combined with a stable and trustable regulatory regime are key factors for enhancing investment.

Regarding the research question 'does the investment driver for solar and wind energy vary with the varying sample sizes for the European Union states?' the following conclusions can then be drawn: (1) carbon emissions impact are negatively related to RES investment for all the considered EU sample sizes; (2) levelized cost presents in general a negative relationship with RES investment for all the sample sizes but the significance of this relationship changes with the selected EU sample size, which can be explained by the important role played by RES support schemes; (3) sunshine hours can be positively or negatively related to RES investment depending on the EU sample size, demonstrating once more the importance of RES support schemes to overcome technical and climatic barriers to investment; (4) regulation perception presents in general a negative relationship with RES investment but the significance of this relationship changes with the selected EU sample size and is particularly evident for solar power, demonstrating that regulation can still be seen as obstacle to investment.

Though increasingly important, development of renewable energy across the world faces a number of barriers: (1) cost, (2) market share and (3) government's policy. Renewable energy has a higher cost and price than traditional energy sources. This is the biggest obstacle to its commercialization, distribution and the production cost of renewable energy is higher than that of fossil fuels with the similar technology. Therefore, high cost of renewable energy weakens its competitive ability. Moreover, the current development of renewable energy is under small scale (compared to conventional sources) with significant uncertainty and lack of sufficient promotional mechanism and solutions from local government.

For policymakers, it may be worthwhile to consider the relative incentives provided for different RES technologies like wind, solar, hydro, biomass

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and other forms of RES, depending upon the country's natural endowments in each sector. It is also equally important to ensure matching demand for the energy produced. We propose a policy framework for homogeneous countries in our next study but recognize the need to expand the model including other variables related to support schemes implemented in different countries through the analysed years. Furthermore, developing nations, such as India, at the nascent stage in energy development research (Sisodia et al. 2015b) could also use this article to analyse regulation parameters. We propose further research in developing nations context.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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