The impact of policy priority flexibility on the speed of renewable energy adoption

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Abstract

The European Union (EU) National Energy and Climate Plans (NECPs) established a 32% binding renewable energy share target. Countries need to evaluate how their communication and consistency regarding renewable energy (RE) policies can aid in the increased deployment of renewables to achieve these targets. The purpose of this study is to examine whether the flexibility of policy priority has an impact on the speed of adoption of RE in 20 EU countries between 2002 to 2018.

Making use of topic modelling to extract the main ideas expressed in the EU Renewable Energy policy documents (NREAPs, NECPs and progress reports) as topics modelled by Latent Dirichlet Allocation, capturing the flexibility of policy priorities (FPP). To evaluate the impact of the FPP on RE adoption, the study applies a Sys-GMM model with economic, environmental, energy, and demographic variables.

The findings showed that RE has a positive and significant response to the adaptive narrative, indicating that changes in the policy discourse toward a RE target contribute to RE's adoption. Shifts in narrative indicate that policymakers prioritise different topics as the target of achieving increasing renewables becomes more complicated. This analysis finds evidence of a persistent effect of continuous commitment to renewables. A threshold effect is observed for greenhouse gas emissions, indicating that social awareness about climate change can only influence RE positively up to a certain level. Evidence is found that increased energy demand may be met with RES instead of traditional energy sources.

Keywords: policy priority; renewable energy; EU; flexibility

1. Introduction

The year 2020 marked a pivotal moment for climate policy to achieve the Paris agreement, aiming to reduce global greenhouse gas emissions and limit the global temperature increase to 1.5 degrees Celsius, mitigating climate change risks [1]. Globally, electricity and heat generation accounts for more than 40% of total emissions in 2018, making it a predominant contributor to climate change [2]. The low-carbon energy transition has progressed steadily since 2015, with several countries making aggressive pledges to increase clean energy production. The European Union (EU) aims to become the first climate-neutral continent by 2050, as set out by the European Green Deal, which prioritises energy efficiency with a power sector backed by renewable sources [3].

To achieve this goal, the European Commission Renewable Energy Directive established a 20% mandatory share of renewable energy sources (RES) in 2009 within total EU energy consumption, a mandate of 10% transport fuels from RES by 2020, as well as 20% improvement in energy efficiency and a 20% reduction in greenhouse gas emissions compared to 1990 levels. Each member state has an individual RES target based on starting levels and renewable potential. Procedures towards national targets are outlined in the National Renewable Energy Action Plans (NREAPs), and progress is measured and reported every two years. The 2030 ten-year National Energy and Climate Plans (NECPs) will take effect in 2021 and establish a 32% binding EU RES target and a 14% RES transport target, where 2020 country RES levels will serve as the minimum baseline [4]. Additional improvements in energy efficiency by 32.5% compared to 2005 levels and reductions in greenhouse gas emissions by 40% relative to 1990 levels are also included within the plan. Scarlat et al. [5] review the National Renewable Energy Action Plans and state that the 2030 targets would bring about long-term investor confidence in renewables. Expecting that renewables' progress could be brought to a halt with reduced investments and withdrawn support schemes by member states. Improved support schemes are necessary for increased renewable energy (RE) growth and decreased cost of technologies. However, support required needs to be stable, harmonised, and sufficient. Within the European Union and the United States "funding certainty and overall policy stability" have been identified as crucial determinants of renewable policy's success in promoting RE deployment [6]. There is scope to incorporate stakeholder input in renewable energy planning support tools, as is the case in Ireland [55]. Doing so enables informed decisions between the public and decision makers while facilitating inclusive planning and improving planning consistency. Energy planning support tools allow for data centralization, which could strengthen the production and consumption of renewable energy specifically in rural areas [56].

Countries need to evaluate which policies work the most effectively and how their communication and consistency about these policies can aid in the increased deployment of renewables. Amidst Covid-19, it is essential to remember that the "need for emission reductions remains unchanged" and apply the most effective policy and policy communication to fight against global warming [2].

Frequent policy priority changes fail to bring about the policy intent's desired results, and resources could be allocated more effectively with cohesive communication [6]. However, polices must also be flexible enough to be able to adapt to new technologies and changes in the market. Many authors have used methods such as the accumulated number of RE policies and measures (ANPM) database to measure the impact of policies on the promotion of renewable growth or investment [7; 8; 9; 10]. However, the ANPM policies and measures database merely reflects the existence of different policy measures when used in disaggregated form or the accumulated number of policies when used in aggregate form [8; 9; 10]. This variable on its own cannot inform the user of similarities or differences in policy design between countries, specific technologies, the year of implementation, duration, policy output or changes in policy priority [7]. Similarly, Mac Domhnail and Ryan [11], proposed using the growth of taxes and levies component of electricity prices (excluding VAT and excise duties) as a quantitative measure of policy support, while other studies use dummy variables [12; 13], the taxes and levies component also fails to capture unique policy traits. Consequently, studies have been done on policy stability's impact on the indented or desired outcomes [14; 6; 8]. Doubt about the nature and evolution of government policy, along with uncertainty over the current impact of government policies, hold the capacity to influence investment and increase risks for investors [15]. Regardless of current policy measures available, there is no comprehensive measure that fully captures policy effects.

There has been a recent increase in the application of using text as data within economic literature to extract meaningful information [14; 16; 17; 18; 19; 20]. One of the most compelling applications has been that of Baker, Bloom, and Davis [21] with the construction of the economic policy uncertainty index (EPU), composed from newspaper coverage frequency. Shiller [23] emphasises the vital role that narrative could play in economics, yet few economic studies attempt to quantify narrative compared to other disciplines empirically. Mobilising text as data could help us understand certain economic fluctuations and how narrative informs policy decisions and priorities. Calvo-González, Eizmendi and Reyes [14] use text-mining to measure policy volatility and its influence on long-term growth in Latin America. Their approach isolates the evolution of policy priorities, detecting changes in discourse and stability of discourse, which allows them to construct an indicator of policy volatility. The authors compile a novel dataset by extracting the policies priorities expressed through annual presidential speeches, thereby capturing the distribution of topic continuity/volatility over the sample period.

The purpose of this study is to examine whether the flexibility of policy priority has an impact on the speed of adoption of RE in 20 European Union countries between 2002 to 2018 following similar methodology to Calvo-González, Eizmendi and Reyes [14]. The flexibility of policy priorities will be captured under the umbrella policy of the NREAPs. Along with consequent progress reports, that aims to increase total energy supply with 20% RE by 2020, and the 32% RE target by 2030, that reserves the right to be adjusted upward in 2023. Several countries achieved these targets in 2018, while some countries fall just short of achieving their goals. As such we evaluate how countries policy priorities that achieve their targets differ from countries who do not.

This paper's remaining sections are structured as follows: Section 2 reviews the related literature on public policy support and its relationship with renewable energy adoption. Section 3 discusses the theoretical framework, data and methodology; Section 4 depicts and discusses our empirical results, while Section 5 concludes with policy implications.

2. Literature review

2.1 Renewable deployment measures

Bourcet [23], conducts a systematic literature review of the empirical determinants of renewable energy deployment, which allows the author to isolate trends and patterns amongst the literature. Several RE deployment measures are considered across the literature, which can be broken up into supply, consumption, installed capacity, and supply and capacity categories. These categories have been considered in absolute levels, per capita levels, the share of total energy or electricity and absolute levels and shares. While several authors state that there are two important reasons why they choose to consider the renewable energy share over other measures [9; 7; 11], namely that policy objectives are set as targets in percentage form and that as the renewable energy share increases fossil fuel shares decrease, [23] reports that the results differ widely for each choice of dependant variable. Zhao et al. [24], Kilinc-Ata [12] and Mac Domhnail et al. [11] consider the renewable share to electricity production excluding hydropower, as hydropower is considered as a mature and established renewable technology, leaving little room for further development as many countries have already reached their capacity. Given the nature of the technology, hydropower is, in most cases, no longer eligible for subsidies [12].

2.2 Policy variables

To date, there is not an all-encompassing measure of policy output; existing measurements are "highly variable" as it is challenging to conceptualise policy output [25]. Schaffrin et al. [25] distinguish between policy "density" and "intensity", where the former refers to the number of policy instruments and the latter to the content of the policy instrument. The IEA/IRENA policies and measures (PAMs), now referred to as the accumulated number of total policies and measures (ANPM) database is widely used to measure policy density [9; 24; 10; 8]. The ANPM database is classified in the following policy types; regulatory instruments; economic instruments; fiscal/financial incentives; tax relief; codes and standards; information and education; research, development and deployment; strategic planning; grant/subsidies; and, minimum energy performance standards [2].

Marques et al., [9] only make use of the total number of policies and selected individual policies in a separate analysis, namely incentives and subsidies which includes feed-in tariffs/premiums, regulatory instruments such as renewable energy obligations or portfolio standards and policy processes as these are the only measures being employed by the majority of their sample (EU). The authors show that the aggregate measure of all public renewable support policies shows a significant and positive sign. Isolated, only incentives and subsidies along with policy processes are significant drivers to RE, all other policy measures were tested and did not have any significance towards RE deployment. Marques et al. [9] control for a continuous commitment towards renewables by including a dummy variable that takes the value of 1 if the countries' renewable energy share is greater or equal to 10. Their results confirm the positive effect of continuous commitment.

Zhao et al. [24] find that only investment incentives and feed-in tariffs have a consistent, positive and significant impact on all types of renewable generation, whereas tax incentives, voluntary programs, production quotas and traceable certificates only have a positive effect on specific RE technologies. Zhao et al. [24] also found that policies are more effective in developed and emerging market countries compared to developing countries. Polzin et al. [10] lag all their policy variables by three years as policy instruments do not immediately impact RE investment. The authors found positive and significant effects for feed-in tariffs/premiums, tax relief, GHG emission allowances, codes and standards, where taxes and funds to sub-national governments have a negative effect, while other measures are ineffective.

Liu et al. [8] indicate that price policies (feed-in tariffs/premiums) and grants and subsidies show a significant effect within fiscal and financial incentive policies. The authors note that price policies promote renewable by providing stability for renewable energy projects while attracting social capital with the lower risk associated with investors. Tax policies were insignificant within the study, citing that possible reasons include a lack of trust from investors in policies dependent on public finance and the need for a five-to-ten-year guaranteed incentive. However, legislators are unlikely to commit longer than two years to avoid being associated with big spending programs [7]. In conjunction with market-based instruments, green certificates hold significant impact, as well as long-term policy commitment that provides a stable investment environment -strategic planning. The analysis found that aggregate policies have a much more significant impact than specific policies [8]. Liu et al. [8] also tested to see the Kyoto protocol's effect by including a dummy variable for implementation in countries for the year 2005 when the protocol came into effect and found a positive and statistically significant effect.

Mac Domhnail et al. [11] make use of an alternative measure RE policy support by using electricity taxes and levies to empirically measure the "value of policy support". The authors mention that the taxes and levies component is not limited to the support of RE, but includes capacity payments, nuclear support in selected countries, and value-added tax (VAT). To address some of the issues, the authors deducted VAT and apply the variable in its growth form. Mac Domhnail et al. [11] find a significant positive effect for the policy support proxy, indicating that an increase in the taxes and levies component of electricity prices, i.e. increases RE support, does aid in renewable electricity development.

Although results for specific policy instruments differ, overall renewable energy support policies have positively impacted RE deployment [23].

2.3 Determinants of RE

2.3.1 Economic variables

Gross domestic product (GDP) per capita provides a measurement of relative economic activity for each country, acting as a proxy/control for demand while capturing the structure and level of economic development. Majority of papers consider GDP per capita; however, the influence thereof is ambiguous. The general hypothesis is that higher income leads to more energy consumption, which includes the consumption of RE sources. Authors also expect that higher-income countries should invest more in RE technologies [23]. Marques et al. [26] found a positive effect for EU countries but the opposite effect for non-EU countries. While Cadoret et al. [27] found a negative effect for GDP per capita and GDP growth for EU countries and a positive effect for lagged GDP growth. The authors state that a possible explanation is that increased demand from increased growth might not be supplied with RE sources but rather with more flexible, easily imported or stocked energy sources such as fossil fuels. Contrarily, they postulate that GDP growth does stimulate RE investment, explained by the significance of lagged GDP growth.

Ibrahiem and Hanafy [28] found evidence for the positive trigger of economic growth, trade openness and foreign direct investment on renewable capacity expansion. Higher levels of imports and exports provides a channel for knowledge and technology acquisitions for clean energy.

Other economic variables include substitute goods for RE, such as oil, gas, and coal prices expecting that price increases in these variables should lead to decreases in fossil fuel energy production and subsequent increases in RE [26; 7; 11; 23] . Mac Domhnail et al. [11] include all of the above both at time t and lagged by four years to capture price effects and long-term infrastructure changes. The authors find a significant and positive relationship for both price and lagged oil price and a significant negative effect on lagged coal price. Since natural gas price is insignificant with their model, the authors deduced that RE is not necessarily a substitute for gas in terms of electricity production. Given long-term price effects, the authors state that a more extended lag period might be required to obtain consistent results. Coal price have a greater impact on RE capacity than natural gas price for OECD countries, with the size of the impact five times larger than that of natural gas [29]. This result highlights the degree of substitution between coal and RE in baseload electricity demand, where natural gas is targeted towards intermediate and peak-load. In the case of Iran, Mukhtarov el al. [30] found a negative relationship between oil price and CO_2 emissions on renewable energy consumption due to gains from higher oil prices.

2.3.2 Environmental variables

Many studies include CO_2 as their environmental variable, where the general thought is that higher levels of CO_2 should encourage investments into cleaner technologies. Marques et al., [9] found a negative relationship for their EU sample between 1990 and 2007, indicating that environmental concerns were not a compelling driver at the time, Papieź et al. [31] also find similar results. Whereas Cadoret et al. [27] found a positive relationship when considering a three-year lag of CO_2 for 2004-2011 in EU countries. Ibrahiem and Hanafy [28] found a significant positive relationship between CO_2 emissions and renewable energy consumption in North African countries. Romano et al. [32] consider CO_2 per capita from energy consumption and found a significant positive response when considering hydropower generation, but no effect is found when considering non-hydro RE generation. The authors state that a possible explanation is that hydropower counters the environmental impact of energy production, whereas in non-hydro production new power plants have large emissions associated with their construction. Marques et al. [26] state that a negative relationship between emissions and RE could indicate a lack of social awareness that exert political pressure towards RE's transition.

2.3.3 Energy variables

Several authors include energy consumption per capita to control for country characteristics. Authors considering EU countries find a positive relationship [9; 26], whereas authors considering a global sample with developing countries find a negative relationship implying that energy needs are most often driven by a cost-effective approach rather than an environmental concerns approach [7]. Including a proxy for energy security is a common practice when considering the EU as energy security is one of the fundamentals in EU energy policy [4]. Typically, the measurement considered is energy import dependence (ED), ED is linked to the price of natural resources. Theoretically, a decrease in energy imports should indicate larger self-sufficiency and an increase in RE deployment [23]. Evidence has found a negative relationship between ED and retail electricity prices in the EU [33]. Similarly, Marques et al. [9] found a negative relationship of ED to RE growth, stating that this result supports the "lobby effect" of traditional energy sources in countries where fossil fuels still form part of the "productive infrastructure". Authors also control for the share of fossil fuels in the energy mix by including the weight of oil, gas, coal and nuclear sources in electricity generation [11; 31]. It is expected that a higher share of fossil fuels or nuclear energy would hinder RE deployment, Mac Domhnail et al. [11] confirm this relationship.

2.3.4 Demographic variables

Aguirre et al. [7] consider population growth as a determinant of RE growth; results indicate a non-significant relationship indicative of the probability that increasing energy needs are most often met with cheaper fossil fuels similar to the relationship found when controlling for energy consumption. The authors note that this result is most likely driven by their sample, which includes China and India, where energy poverty is still very prevalent. This relationship might not hold nowadays as renewables are cost-competitive or cheaper than traditional fossil fuels [34].

Bourcet [23] states that socio-demographic variables regarding citizens' narrative and attitude towards renewables have rarely been explored. Empirically exploring citizen's narrative is limited through a lack of data availability; however, survey data is available for 2019 examining citizens attitude towards EU energy policy conducted by the European Commission [35]. The survey recorded the percentage of answers given by the respondents on the most important priority of EU energy policy in their opinion were “shifting away from fossil fuels towards renewables to combat climate change” was the most popular narrative amongst 17 Member states mostly in Northern, Western and Southern Europe, and a tied response in Croatia. Secondly, eight countries mainly from Eastern Europe indicated “more competitive energy prices for consumers”, following that “ensuring nuclear energy is safe and secure” from Slovakia and “decreasing energy consumption across the EU” from Czechia. Citizens 55+ years, placed a larger emphasis on energy prices similarly respondents that received below 15 years of education, where 15-24 years olds prioritised the shift away from fossil fuels, similar to respondents still studying or finished education after the age of 20. While “supporting developing countries towards moving to clean energy systems” and “securing secure energy imports from the EU” is not amongst the priorities of member state citizens [35]. Anune and Golombek [36] indicated that in Eastern and Central Europe, coal is the primary energy source. Consequently, these countries were not pleased with the EU 2020 RE targets and the narrative of the respondents seem to convey this sentiment further.

2.3.5 Political/ Institutional variables

Cadoret et al. [27] consider the influence of political factors on RE growth in the EU, findings include a significant positive influence of government quality and higher RE deployment amongst left-wing parties considering a three-year policy delay. The analysis included a proxy for the manufacturing industry's lobbying effect and confirmed a negative relationship. Highlighting that the manufacturing industry is energy-intensive and reluctant to accept increased electricity prices that tend to accompany renewable deployment, along with a general opposition to environmental regulations. Rahman and Sultana [37] found that and increase in institutional quality led to an RE consumption in the long-run for emerging economies. Similar results are found for an increase in government effectiveness, which covers the quality of public and civil service, independence from political pressure, policy formulation quality and the implementation and commitment to such policies.

2.4 Overview- Sample and methodologies

Studies investigating determinants of renewable deployment start as early as 1971, most studies consider the period after 1990 characterised by increased RE deployment, further development in technology, and the falling cost of RE technology in more recent [38, 23]. Diverse country groups have also been considered in the analysis, Marques et al. [39] , Marques and Fuinhas [26], Marques et al. [9], Cadoret and Padovano [27], Nicolini and Tavoni [40] , Papież et al. [31], and Mac Domhnail and Ryan [11] consider European countries. While Polzin et al. [10], Liu et al. [8], Aguirre and Ibikunle [7] investigate OECD countries, Zhoa et al. [24] conducted a study on developed, developing and emerging market countries, Narbel [41] considered a panel of developed and developing countries while Samant et al. [42] consider Turkey, Brazil, India and China.

The bulk of studies reviewed employ panel data econometric techniques to determine the impact that their selected variables have on RE's deployment. Marques et al. [39] and Aguirre and Ibikunle [7] apply fixed effects (FE), random effects (RE) and fixed effects with vector decomposition (FEVD) estimation techniques, however [11] criticises the use of FEVD stating that the method produces misleading results and questions whether the method produces robust coefficient estimates of time-invariant variables. Instead, the authors apply a hybrid mixed-effects model that allows effective estimation of variables that varies within and between countries but does not estimate time-invariant variables [11]. Marques and Fuinhas [9] and Aguirre and Ibikunle [7] employ a panel corrected standard error (PCSE) estimation, quantile regression [26], Poisson pseudo-likelihood estimation [24] and two-step estimation techniques such as least squares dummy variable (LSDV) estimator [27], are also among the techniques employed. Dynamic panel estimation techniques include system and difference general method of moments (GMM) [26; 38]. Papież et al. [31] conduct a cross-sectional analysis for 1995 and 2014 respectively; the authors apply classical principal component analysis (PCA) to capture correlations between different sources of renewable energies and the main contributors towards the energy mix of their sample years. Following the results of the PCA, the least absolute shrinkage selection operator (lasso) method is applied which works well with small samples where the number of control variables exceeds the sample size [31;43].

3. Methodology and data

3.1. Theoretical framework

Following Calvo-González, Eizmendi and Reyes [14], this study makes use of topic modelling to extract the main ideas expressed in the EU Renewable Energy policy documents (NREAPs, NECPs and progress reports) as topics modelled by Latent Dirichlet Allocation [44]. To adequately assess the impact of the flexibility of policy priority (FPP) on RE adoption, this study makes use of economic, environmental, energy, and demographic variables, identified as determinants of RE in Marques and Fuinhas [26].

To examine the relationship between policy priority and RE adoption, our model takes the form expressed in equation (1)

$$CRES_{i,t} = \beta_0 + \beta_1 CRES_{i,t-1} + \beta_2 FPP_{i,t} + \beta_3 GHGPC_{i,t} + \beta_4 EnergyPC_{i,t} + \beta_5 SOil_{i,t} + \beta_6 SGas_{i,t} + \beta_7 SCoal_{i,t} + \beta_8 SNuclear_{i,t} + \beta_9 ED_{i,t} + \beta_{10} GDP_{i,t} + \beta_{11} Oilp_{i,t} + \beta_{12} Gasp_{i,t} + \beta_{13} Coalp_{i,t} \quad (1)$$

The dependent variable is the contribution of renewables to energy supply *(CRES)*. Our main variable of interest is the flexibility of policy priority *(FPP)*, our control variables are confirmed determinants of RE growth identified by Marques and Fuinhas [26], and are as follows; greenhouse gas emissions per capita *(GHGPC)* opposed to CO_2 per capita as used by [26] due to a lack of data available for our sample length; per capita energy use *(EnergyPC)*; the share of oil, gas, coal and nuclear in as a percentage of electricity generation *(SOil, SGas, SCoal, SNuclear)*; import energy dependency *(ED)*; gross domestic product *(GDP)*; and the global price of oil gas and coal *(Oilp, Gasp, Coalp)*.

This analysis employs RE share over other possible RE measures because policy targets are set in percentages, the target set in the NREAP and NECP is 20% RES in 2020 and 32% in 2030. The assumption is that when the RE share increases, fossil fuel shares are decreasing. Marques et al. [26] also use *CRES*; another reason concerns the latest data availability up till 2018. CRES's lagged value is used to determine the persistent effect of continuous commitment to renewables, where a positive relationship is to be expected.

Topic models are a form of a probabilistic model within natural language processing (NLP) used to extract the main topics within a text corpus [44]. A notable advantage of the algorithm is that it does not require manual specification of the document's topic set classification. Instead, it uses “modelling assumptions and properties of the texts” to determine topics and match documents to the discovered topics [14]. Latent Dirichlet Allocation (LDA) will be used on European Union Renewable Energy policy documents to extract policy flexibility. Blei et al. [44] describe Latent Dirichlet Allocation (LDA) as a computational linguistic model capable of extracting a set number of topics from a corpus of text data. These topics are generated by a three-level hierarchical Bayesian model that models a collection of items as a finite mixture over underlying, or latent, topics. The text from the documents is converted into a term-frequency inverse document-frequency sparse matrix before processed in LDA. This refers to tokenising the text data and finding the “most descriptive words” to be modelled into topics. The change in topics over time, and over countries can be considered a proxy for policy flexibility *(FPP)* [14]. Therefore, *FPP* will act as a measure of cross-country differences of topics over time within the proposed policy, reflecting the discourse and objectives of each country and the evolution of renewable policy with the European Union. Calvo-González et al. [14] has shown a link between policy priority flexibility and long-term economic growth in Latin America.

To proxy for environmental concerns and considering that EU energy policy also targets emission reductions, this study includes greenhouse gas emissions per capita *(GHGPC)*, where we expect a positive relationship, bearing in mind a possible threshold effect. A positive effect indicates that higher emissions levels generate political pressure to increase RES, where a negative effect indicates climate insensitivity. However, [23] reports that a negative effect is observed when a European sample and the RES opposed to RE per capita is considered. Therefore, a negative relationship could be considered a threshold effect, where, after a certain level of emissions RE may not meet demand immediately. Energy consumption per capita *(EnergyPC)* is included to investigate the effect of increased energy consumption on RE deployment. To account for the lobby effect of traditional more mature energy technologies, the weight of fossil fuels such as oil, gas, and coal, along with nuclear generation are considered. The hypothesis is that an increase in these variables will negatively impact RE deployment [7]. Alongside traditional electricity generators' lobby effect, one must account for energy import dependency *(ED)*. We expect higher values of ED to negatively impact RE deployment contra to the expectations of [26]. Marques et al. [26] suggest that higher values of *ED* would prompt countries to invest more in RE to ensure energy security, however, the negative relationship between *ED* and retail electricity prices is possibly a result of low-cost fossil fuel imports [33]. Therefore, countries with low-cost, high energy import dependency are less likely to incur additional investment in RE sources to become self-sufficient.

Gross Domestic Product *(GDP)* is widely used as a measure of relative income and economic development across countries. Theory suggests that countries with higher income will have higher levels of energy demand and consequently, higher levels of RE deployment. The thinking is that higher-income countries can mobilise finances for RE investment [23]. However, Cadoret et al. [27] observe a negative effect for EU countries, while confirming a positive effect for lagged GDP growth. As such, we expect to see a positive effect of GDP on RES. The prices of substitute goods for RE, namely the coal, oil and gas price are included. Theory suggests that an increase in these prices should lead to a decrease in fossil fuel consumption and consequently, increase RE consumption [23; 11]. Similarly increases in RE deployment could safeguard countries against oil and gas price volatility as well as improve energy security [7].

3.2. Topic model methodology

This analysis employed an LDA topic model which discovers the latent topics and their frequency within each document. The advantage of this type of model is that there are few restrictions imposed by the user, of which the number of topics to discover is one. LDA employs a "bag-of-word" assumption, indicating that the order in which terms occur is not important but rather the frequency of each term. An essential assumption within LDA is that documents are generated with a "probabilistic generative process" that is latent or hidden. The function of LDA is to estimate this structure by "working through the generative process in reverse" [14]. LDA estimates the generative process parameters that make up the corpus of text by making use of the observed terms within each document.

This study employs the generative process described in Calvo-González, Eizmendi and Reyes [14] (pg 7-10) to generate our *FPP* measure see Blei et al., [44] for the full model derivation.

Furthermore, Collapsed Gibbs sampling algorithm where posterior samples are iteratively generated through loops of "each variable to sample from its conditional distribution" and holding other variable values fixed is applied. Since the algorithm is launched with random values, starting version does not resemble the true posteriors, but later converges to approximate true posteriors. Approximating topic proportions and the distribution over words requires "a sequence of samples of topic assignments for each word" [14]. The values of variables are retained, and one remains fixed, which allows words to be the only observable variable for each iteration. The topic assignment of that word is updated while the others remain unchanged. The algorithm randomly assigns each word in the document to a subset of K topics, and from there on, it is improved upon with each iteration. The iterative process is repeated many times until the topics converge to close approximations of their true values.

3.3. LDA implementation

Before conducting the LDA, several issues with the documents had to be addressed. Firstly, each document has to be machine-readable text, and secondly, each document should be in English for comparability purposes. Many older documents were scanned, and text could not be identified, these documents were converted into readable text using optical character recognition (OCR). Other documents were only available in French and google translate was used to translate these texts into English; a random sample of each converted documents was drawn to confirm accuracy. Thirdly, the documents had to be cleaned from stop words and punctuation to improve topic discovery.

Gibbs sampling requires parameter specification of per-topic distributions β and per-document topic distributions α, following Calvo-González et al. [14] we used $\beta = 0.1$ and $\alpha = 50/t$ where t is the number of topics. To determine the optimal number of topics, two measures can be used "perplexity" and "coherence". Calvo-González et al. [14] makes use of perplexity, which is widely used in language model evaluation and measures the model's ability to predict unseen data. Lower perplexity scores indicate better models and are measured as a log-likelihood ratio. However, Chang et al. [45] indicate that likelihood measures like perplexity are often not correlated with human judgement and propose that coherence be used to deliver human interpretable topics. This study will make use of the c_v coherence measure, which measures how well statements support each other. c_v produces values between 0 and 1, where higher scores indicate better coherence.

To estimate the LDA, the sample is partitioned randomly where 90% of documents were used as a training set and the other 10% of documents used as a test set. LDA is then implemented iteratively with a different number of topics $I \in \{1, \ldots, 30\}$ for each iteration. The coherence score is calculated and used to evaluate how accurately the model predicts the data. Calvo-González et al., [14] compute policy volatility by using the three topics with the highest proportions in their base year, which is 1940, and taking the change in these topic proportions up till 2010. While this measurement is valid for longer sample size, our sample is significantly shorter. The focus of this analysis is to see changes in topic distribution over the whole sample rather than the three most prevalent topics in the base year. After the topic distributions were identified, the Euclidean distance is used to calculate our *FPP* measurement as proposed by van Schoor and Viegi [46].

$$FPP(D) = \left[euc(d_1, d_2) = \sqrt{\sum_{i=1}^{I} \left(d_{2_i} - d_{1_i}\right)^2} \quad \cdots \quad euc(d_{N-1}, d_N) = \sqrt{\sum_{i=1}^{I} \left(d_{N_i} - d_{N-1_i}\right)^2} \right] \quad (2)$$

Where I is a set of topics identified, in our case, the optimal number of topics is 14, where $I \in \{1, \dots, 14\}$. N depicts the document number, and D represents the document-topic distribution for all documents in the sample, d_{2_1} represents the distribution of topic 1 in document 2, similarly d_{1_1} represents the distribution of topic 1 in document 1. As such, $euc(d_{n-1}, d_n)$ measures the Euclidean distance between topic distributions of document n and $n-1$.

3.4. Econometric methodology

This study estimates a dynamic panel System Generalised Method of Moments (Sys-GMM) approach proposed by Arellano and Bover [47] /Blundell and Bond [48] from 2002 to 2018 for a sample of 20 EU countries. Given our relatively small sample size and that $\mathrm{N} > \mathrm{T}$, Sys-GMM is to our knowledge the most appropriate econometric technique. Due to the nature of our question, the existence of endogeneity is expected. Another potential issue is time and cross-sectional specific effects, to address this issue, the data is time demeaned, and forward orthogonal deviations are applied to eliminate cross-sectional effects. In applying forward orthogonal deviations, otherwise known as Helmert's transformation, it is possible to include lags of the regressor that is no longer correlated with the transformed error term as valid instruments in the [47] Sys-GMM estimation [49]. Sys-GMM addresses the issue of endogeneity and heterogeneity while producing efficient and consistent results [50]. The Hansen test [51] will be applied to test the validity of the instrument; the Arrelano-Bond

(1991) test for first-order autocorrelation AR(1) as well as for second-order autocorrelation AR(2) will also be applied.

The estimation will take the following form:

$$CRES_{it} = \delta CRES_{i,t-1} + \beta \boldsymbol{X'}_{\boldsymbol{it}} + d_t + \eta_i + \varepsilon_{it} \quad (3)$$

Where $y_{i,t}$ is a NT x 1 vector of the endogenous dependent variable, in our case *CRES*. $\boldsymbol{X'_{it}}$ is a NT x k vector of all the independent variables outlined in equation (1), apart from the lagged dependent variable and β represents a k x N vector of all the slope coefficients η_i and d_t represent country- and time-specific effect respectively, while ε_{it} represent the idiosyncratic error terms (Marques et al., 2011).

3.4.1 Data

The analysis is conducted for 20 EU member countries, Austria, Belgium, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden and the United Kingdom. The data utilised in this evaluation were obtained from the OECD Factbook, the OECD extended world energy balances, the European Commission, Eurostat, the World Bank development indicators and BP statistical review. See Table 5 for data definition and respective sources. Table 1 below summarises the descriptive statistics for all variables used in this analysis for 2002-2018. Our sample is driven by the availability of NREAPs and progress report documents that are available for 2002, 2003, 2005, 2007, 2009, 2009-2010, 2011-2012, 2013-2014, 2015-2016 and 2018. Given that each progress report covers two years, FPP values were interpolated with the assumption that the countries position did not change in those years.

***Table 1**: Descriptive statistics*

Variable	Obs	Mean	Std. Dev.	Min	Max
cres	340	11.992	9.193	1.3	43.02
FPP	340	.206	.296	0	1.196
ghgpc	340	11082.647	4215.72	5400	30700
energypc	340	3997.432	1571.705	2121	10411.21
soil	340	2.996	4.468	.007	30.848
sgas	340	22.2	19.095	.165	76.279
scoal	340	25.983	21.699	0	94.207
snuclear	340	21.557	22.923	0	78.382
ed	340	55.457	26.711	-50.6	98.61
gdp	340	8.381e+11	1.006e+12	3.900e+10	3.900e+12
oilp	340	80.114	29.417	35.56	126.45
gasp	340	7.445	2.512	3.21	11.6
coalp	340	78.546	26.858	31.65	147.67

Table 2 represents the correlation between all variables; we can see the correlation between all variables used in this study. Except for the gas price and oil price, the correlation coefficients suggest the absence of multicollinearity between explanatory variables. The level of correlation between the dependent and explanatory variables is very weak.

***Table 2**: Correlation Matrix*

Variables	CRES	FPP	GHGPC	EN_PC	SOIL	SGAS	SCOAL	SNUC	ED	GDP	OILP	GASP	COALP
CRES	1.000												
FPP	0.004	1.000											
GHGPC	-0.384	0.034	1.000										
ENERGYPC	0.027	0.024	0.754	1.000									
SOIL	-0.136	-0.018	-0.096	-0.357	1.000								
SGAS	-0.421	0.023	0.488	0.245	0.184	1.000							
SCOAL	-0.279	0.052	-0.006	-0.411	0.130	-0.287	1.000						
SNUCLEAR	-0.037	-0.034	-0.325	0.094	-0.364	-0.465	-0.332	1.000					
ED	-0.190	-0.106	0.213	0.150	0.293	0.370	-0.444	-0.071	1.000				
GDP	-0.186	0.004	-0.193	-0.135	0.036	0.039	-0.017	0.134	-0.033	1.000			
OILP	0.057	0.118	-0.063	-0.023	-0.161	0.033	-0.031	-0.007	0.015	0.010	1.000		
GASP	0.075	0.136	-0.080	-0.035	-0.180	0.032	-0.041	-0.009	0.022	0.014	0.958	1.000	
COALP	0.058	0.075	-0.051	-0.010	-0.157	0.061	-0.058	-0.011	0.029	0.020	0.755	0.767	1.000

Table 3: *Variable description and source*

Variable	Description	Source
cres	Contribution of renewables to energy supply (as a percentage of total primary energy supply)	OECD Factbook (2009) and (2015) ; Extended world energy balances (2020)
ghgpc	Greenhouse gas emissions (kg/capita)	Eurostat (2020)
ed	Import dependency of energy (%)	Eurostat (2020)
energy_pc	Per capita energy consumption (kgOe/capita)	Eurostat (2020)
gdp	GDP (constant 2010 US$)	World Bank World Development Indicators (2020)
scoal	Ratio of electricity generation from coal sources to gross electricity production (%)	Eurostat (2020)
sgas	Ratio of electricity generation from natural gas sources to gross electricity production (%)	Eurostat (2020)
soil	Ratio of electricity generation from oil sources to gross electricity production (%)	Eurostat (2020)
snuclear	Ratio of electricity generation from nuclear sources to gross electricity production (%)	Eurostat (2020)
coalp	US dollars per tonne - Northwest Europe marker price	BP statistical review of World Energy 2019
gasp	US dollars per million Btu - German import price	BP statistical review of World Energy 2019
oilp	2019 US dollars per barrel - Oil: Crude oil prices	BP statistical review of World Energy 2019

4. Empirical results

Table 3 represents the top probability terms defining each topic across different relevance scores (λ). Topic 1 mainly has to do with green certificates, renewable obligations, and a guarantee of renewable origin and renewable quotas, all of which refer to a certain minimum share of renewable energy share within the energy mix. Figure 1 shows the evolution of topic proportions in Belgium (see all other countries topic distributions in the Appendix), where topic 1 has a significant distribution across the sample. The topic peaks coincide with five Green Certificate schemes that Belgium enforced in 2001, two in 2002, 2003 and 2004. The last three are still in force, one covering national jurisdiction and the others enforced on the state or provincial levels in Flanders and Brussels [2]. Belgium has the highest topic 1 distribution across the sample, although Italy holds the highest number of green certificates. However, only two are currently in force which coincides with the years of which topic 1 prevalence is depicted in the figure. Belgium has seen limited growth in CRES from 2002 and stood at 7.76% in 2019; there are still ways to go until the 13% 2020 target is met. However, it is a highly energy-dependent country and imported more than 80% of its energy needs in 2019. It is also to be noted that the country holds limited renewable potential similar to that of Cyprus [52].

Table 4: *Top probability terms defining each topic across different λ scores*

Topic 1	Topic 2	Topic 3	Topic 4	Topic 5	Topic 6	Topic 7
Green certificate Green guarantee Quota Grant Installation Production	Mobility Housing Climate Bicycle Commuter Building Renovation transport	grid aid ethanol tax origin license	Thermal Production Installation Thermoelectric Condominium Micro-production Methanisation Mainland	Biofuel Biogas Wood Waste Manure Environmental	Effort share Timeline Ambition Resilience Poverty Upskill Interlinkage	Projection Scenario Modelling Simulation Baseline Pipeline Patent
Topic 8	**Topic 9**	**Topic 10**	**Topic 11**	**Topic 12**	**Topic 13**	**Topic 14**
Generate Power Operator Plant Capacity Install Activity	Scheme Agreement Offshore Denmark Obligation	Wind power Hydroelectric Hydropower Hydroelectrical Rainfall	Regulate Permit Body Authorisation Publicise	Myenergy Heating Cooling Biodiesel Price Support	Developer Installer Qualification Designing Retail premise Training Fulfilment renewable	Tender Funding Federal Expansion Bid Law Network

The narrative change with the introduction of the 2009 NREAP is visible in most except for the United Kingdom (UK) and Ireland. The UK and Ireland have similar levels of RES and saw similar levels of RES growth since 2002. The prevalence of topic 9 is extensive and continues in importance throughout the sample, as seen in Figure 2. Topic 9 is slightly ambiguous but covers Offshore Denmark, a networking company that provides Danish companies with the opportunity to export energy, oil, gas, and renewables. The term could also refer to offshore wind farms that Ireland has made a significant investment in, and offers feed-in premiums to the offshore wind [4].

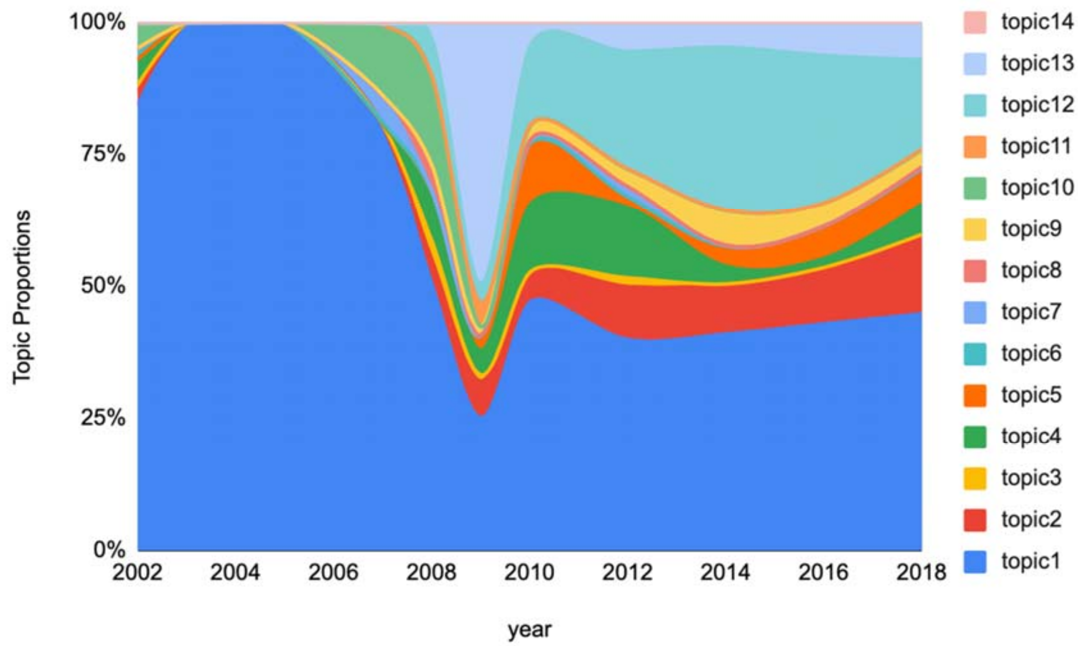


Figure 1*: Evolution of document topic proportions in Belgium*

The UK hold the biggest share of offshore wind capacity in the European market, at 8GW capacity, followed by Germany, Denmark, Belgium and the Netherlands, evident from the topic distributions depicted by the graphs. Topic 10 covers wind but mainly hydropower; most countries see a decrease in the prevalence of topic 10 in 2009. However, Austria, Denmark, Germany, Poland Slovakia, and Sweden see an increase. These countries have also seen steady growth in their hydropower capacity over the years. Topic 12 increases in 2009; this topic has to do with '*MyEnergy*' and consumer-directed energy efficiency interventions. *MyEnergy* is a consumer-directed platform, to help consumers view their energy usage and improve efficiency. Along with Finland and Austria, Sweden and Denmark have seen some of the most significant CRES growth from 2002 till 2018 and hold the highest shares in the sample. As we can see from figure 2, their topic distributions are rather similar, emphasising topics 5, 10, and 12, where topic 5 speaks to biofuels and biowaste.

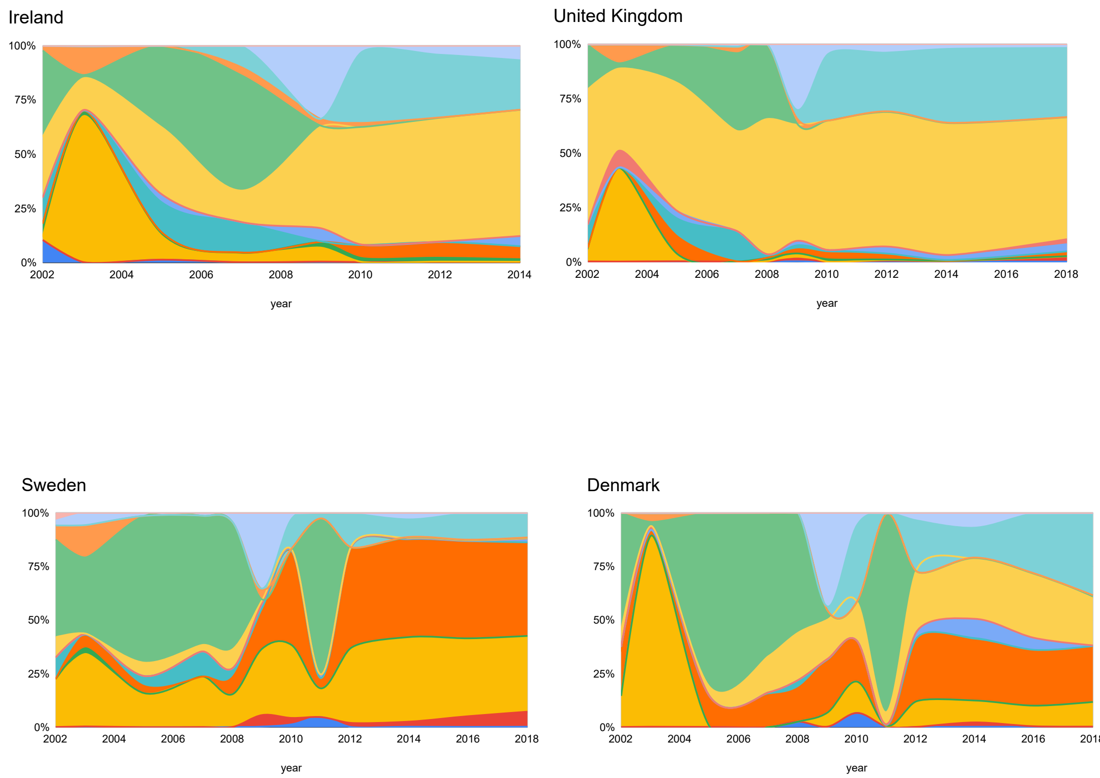


***Figure 2**: Evolution of document topic proportions in Ireland, the United Kingdom, Sweden and Denmark*

Germany holds a fairly unique topic distribution and is one of the only countries to speak about topic 14, covering a funding aspect and network expansion. The increase in prevalence corresponds to the 2018 Electricity Grid Action Plan policy, aiming to optimise exiting grids and acceleration grid expansion. Topic 2, which speaks to commuting and building efficiency, is relatively consistent over the sample, corresponding to the KfW-Programme Energy-Efficient Rehabilitation, which involves modernisation measures for residential buildings [2]. Germany consistently speaks about topics 10 and 12, where topic 12 increases sharply in 2012 and references' biodiesel', Germany enacted a biofuels quota act in 2010 set at 6.25%.

Table 4 represents the econometric results from Sys-GMM application, where Model 1 serves as a baseline model to replicate the results of Marques et al. [26] and Model 2 includes the FPP measurement. The Hansen test [51], confirms instrument validity, and the null-hypothesis of the absence of second-order autocorrelation for both models cannot be rejected.

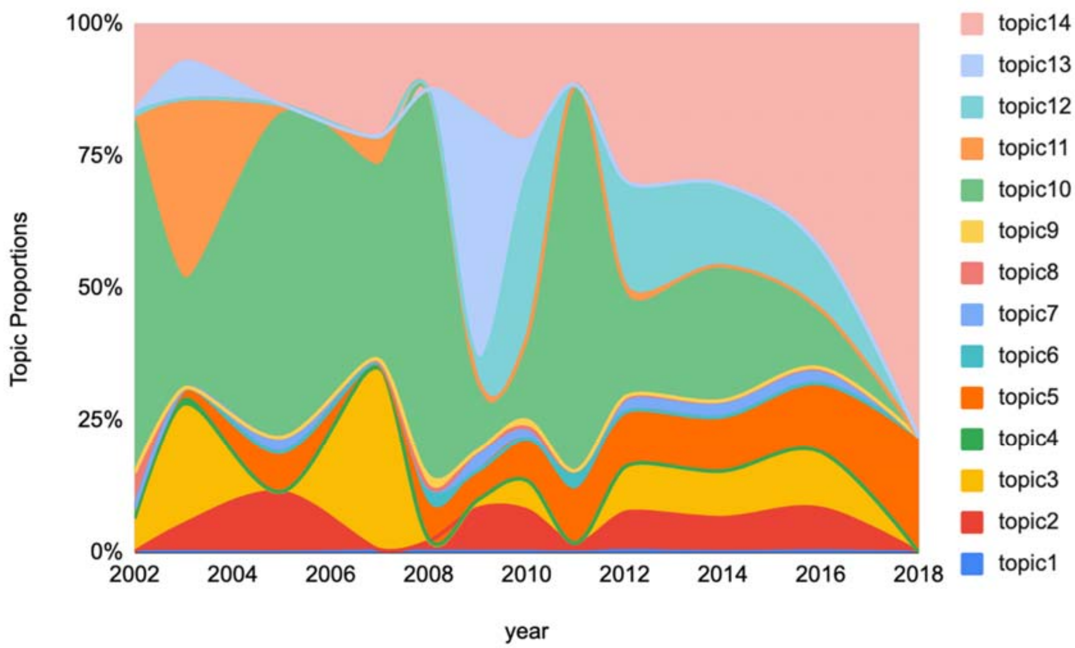


Figure 3: *Evolution of document topic proportions in Germany*

Rendering the results from both models valid. The topic model's coherence score identifying 14 topics as the best performing model is 0.3789, which is reasonably well considering our documents' length. Marques et al. [26] investigate the period 1990 to 2006 with 24 European countries, whereas this study looks into the period 2002 to 2018 for 20 European countries. Continuous commitment to renewables is positive and statistically significant and does not differ much in magnitude from Marques et al. [26]. However, when the *FPP* measure is included, the coefficient becomes slightly smaller. Nonetheless, expectations of a positive relationship between current and previous levels of renewables are confirmed. The persistence effect of continuous commitment shows that continued policy support for RE promotes the adoption of RE.

Model 2 shows a positive and highly significant response from CRES to our flexibility of policy priority *(FPP*) measure. The positive relationship indicates adaptive narrative of policy discourse to an increasingly complex problem. Specific policies that were in force may have ended, leaving no need to discuss them further or new policies came into play. Policies that did not yield results might have been adapted. From the evolution of topic proportion graphs, one can see a change in the narrative with the introduction of the 2020 goals, transitioning from the 2010 goals. Flexibility in the RE discourse captured in the documents, in this sample has a positive effect on RE supply.

In model 1 a negative and significant relationship with per capita emissions (GHGPC) can be observed, the coefficient is slightly larger than that of Marques et al. [26] and model 2 approaches the magnitude of Marques et al. [26]. Confirming expectations, a certain threshold effect where the emissions level would not be a positive driver for RE is observed. Energy use per capita holds a positive and significant relationship in both models in a similar magnitude to Marques et al. (2011), although slightly smaller in model 2. Indicating that increased energy consumption could be met with increased RE. Only the oil share of the traditional electricity sources shows a positive and significant relationship in model 1, which is not in line with expectations of a negative relationship and contra the results of Marques et al. [26]. Oil is primarily used in transportation and heating. The only fraction is used in electricity plants; however, power plants that use oil are primarily coal-fired, furthering expectations of a negative relationship with RE. In model 2 where we control for *FPP*, this relationship is still positive but no longer significant. Indicating that changes in narrative towards clean energy rendered the relationship between the oil share and RES insignificant, a possible reason could be that 'oil' did not feature as a prominent topic across the documents. The share of oil in the electricity share is small compared to other sources and anticipating climate action, several oil companies have transitioned into the clean energy market in Europe. However, the share of gas and coal confirms a negative and significant relationship in model 2, which is in line with the lobbying effect's expectations.

Similarly, a significant negative relationship is confirmed with the share of nuclear sources in the electricity mix. Due to the low carbon nature of nuclear energy, lower RE deployment is expected. Energy dependency holds a negative and significant relationship, slightly more prominent in magnitude than Marques et al. [26]. This confirms the expectation that countries with higher energy dependency, which is primarily from fossil-fuels are less likely to invest in RE to increase energy security. GDP has a negative but significant relationship in both models, albeit very small. This relationship points to a possible renewable energy Kuznets curve (RKC) relationship, where the levels of RE increase up to a certain point of GDP and then decrease [53]. Marques et al. [26] found no significant relationship between CRES and fossil fuels' prices. In model 1, oil, gas, and coal price is statistically significant, where oil shows a negative, gas a positive and coal a negative relationship. Higher prices of these substitute goods should theoretically lead to lower use thereof and consequently increase RE's share. In model 2, only the price of coal and gas have significant relationships. For our sample and for our timeframe, a substitute effect of gas to RE can be observed, significant increases in the price of gas was observed between 2008 and 2013. There is a negative response from RE to coal price; it is worth noting that [32] point out that the price producers pay and market prices differ, and that electricity demand is inelastic to price variations in raw materials. However, since energy infrastructure investment decisions based on price volatility are not enacted immediately, lagged prices should be considered in the future when more data is available.

Table 5: *Results of Sys-GMM*

	Model 1	Model 2
L.cres	0.656***	0.440**
	(0.152)	(0.197)
FPP		**0.833*****
		(0.159)
ghgpc	-0.00256**	-0.000997**
	(0.00105)	(0.000433)
energypc	0.00595**	0.00229*
	(0.00247)	(0.00111)
soil	0.188**	0.0320
	(0.0882)	(0.0640)
sgas	0.0268	-0.152**
	(0.0310)	(0.0603)
scoal	0.0594	-0.119**
	(0.0769)	(0.0416)
snuclear	-0.149***	-0.181**
	(0.0460)	(0.0636)
ed	-0.0172	-0.0398**
	(0.0221)	(0.0162)
gdp	-1.10e-12*	-7.12e-13*
	(5.32e-13)	(3.46e-13)
oilp	-0.0263**	-0.0132
	(0.0102)	(0.00795)
gasp	0.377***	0.222*
	(0.126)	(0.109)
coalp	-0.0119***	-0.00869**
	(0.00327)	(0.00331)
Constant	-39.57	-287.2
	(150.5)	(190.5)
Observations	320	320
No. of instruments	22	31
AR1 (p-value)	0.0497	0.0710
AR2 (p-value)	0.766	0.101
Hansen-J (p-value)	0.612	0.635

Standard errors in parentheses * p<0.10, ** p<0.05, *** p<0.010

5. Conclusion and Policy implications

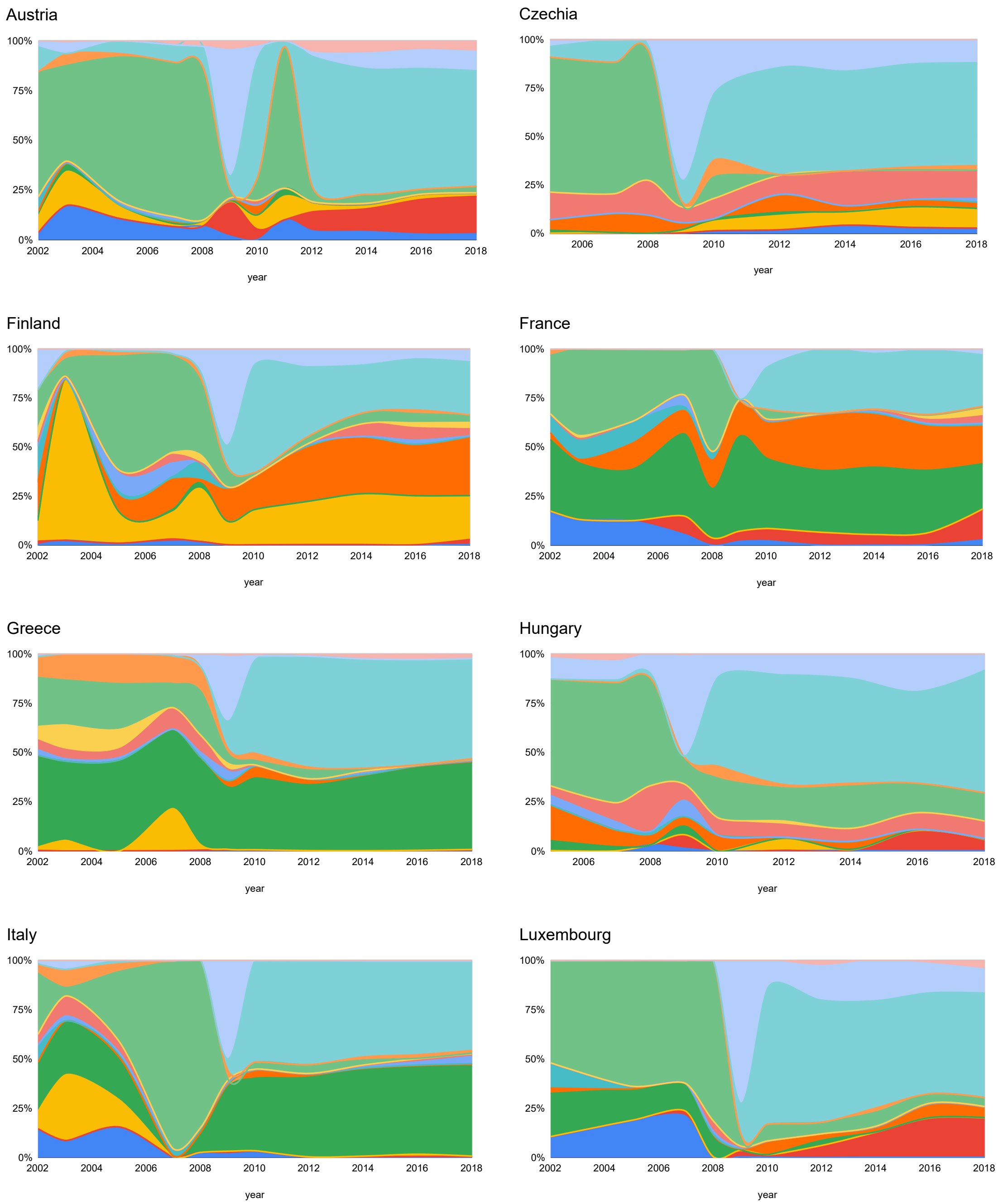
This study's primary purpose is to investigate the effect of changes in policy discourse presented by the umbrella policy of the NREAPs and consequent progress reports on RE's adoption in the 20 European countries between 2002 and 2018. Using text as data, our contribution to the literature provides a flexibility of policy priority *(FPP)* measurement that captures changes in policy prevalence across these documents. To properly test the impact of the flexibility of policy priority measure, we replicated the results of Marques et al. [26] who identified drivers of RE with an updated timeframe but limited to the years for which documents were available and conducted separate models excluding and including the *FPP* measure. This study found that RE has a positive and significant response to the adaptive narrative, indicating that changes in the policy discourse towards a RE target contribute to RE's adoption. Shifts in narrative indicate that policymakers prioritise different topics as the target of achieving increasing renewables becomes more complicated. Overall countries prioritised topic 10, which covers hydropower up till 2008 with a resurgence in 2011. At that time, Europe had 57 policies in place directed at hydropower and hydropower has been a steady source of electricity generation for the European Union [2]. Countries also saw an increase in the prevalence of topic 12, which contains consumer-directed energy efficiency interventions in 2008 and steady distribution of topic 8 advocating for capacity expansion.

Furthermore, this analysis finds evidence of a persistence effect of continuous commitment to renewables. The is a threshold effect regarding greenhouse gas emissions for this sample and timeframe, where the intuition is that social awareness about climate change can only influence RE positively up to a certain level. There is evidence that increased energy demand may be met with RES instead of traditional energy sources; a possible explanation could be the merit-order effect associated with RE. Traditional energy sources, specifically gas, coal and nuclear, impede the adoption of RE. While nuclear energy is a low carbon and a means to reduce emissions and meet SDG 7, public safety concerns are a significant deterrent. Policymakers should adapt the narrative of nuclear power and address public safety concerns. We find that energy import dependency hinders RE adoption. Highly energy-dependent countries will not necessarily opt for RE to increase energy security as the renewable potential is fairly low. Reliance on imported gas subsequently undermines energy security gains from RE [54]. The is the possibility of an RKC relationship between RE and GDP is observed, where developed countries with higher levels of GDP are still in the stage of development where they are consuming relatively more fossil fuels than RE [53]. Increases in the price of gas decrease the use thereof and hold a positive relationship with RE.

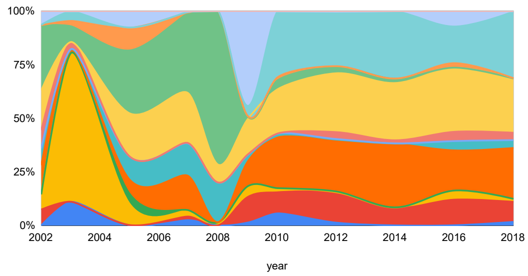
A limitation of our measure of policy priority flexibility is the inability to fully extract each policy's peculiarities outlined within the NREAPs and NECPs without analysing each original policy document individually. While our measure is surely not all-encompassing of each member states accumulated renewable energy policy communication, the documents lay out a clear plan outlining which policies the individual member state will use to achieve their nation legally binding renewable energy target for 2020 as well as whether policy deliverables were met. As such, our contribution to the literature provides a measure of renewable energy policy priority flexibility to be used as a complement rather than a substitute for existing policy indicators [14].

Appendix

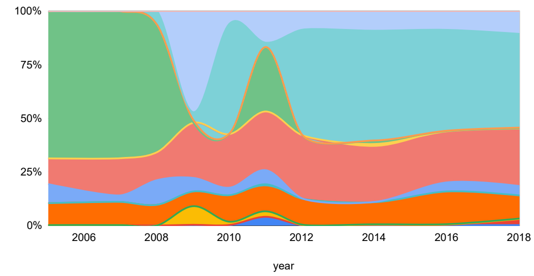
Figure 4: *Evolution of topic proportions*



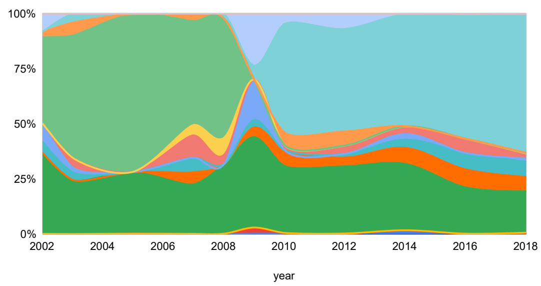
Netherlands



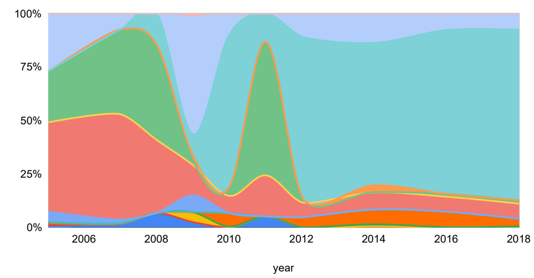
Poland



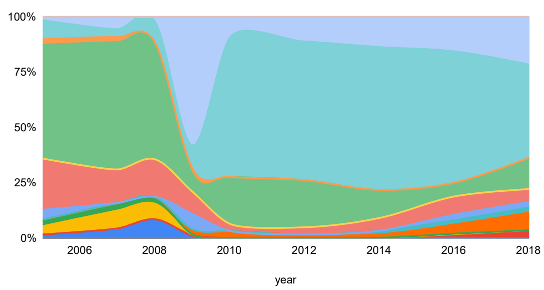
Portugal



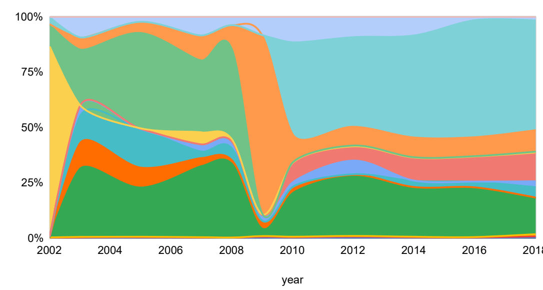
Slovakia



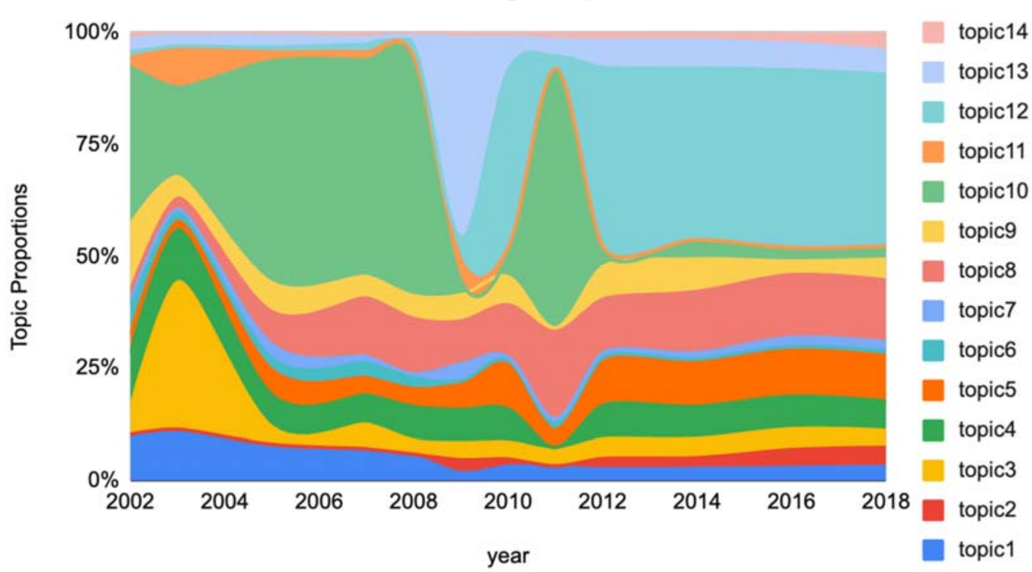
Slovenia



Spain



Evolution of all countries average topic distributions



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