CONFLICT SCENARIOS AND TRANSITIONS

Opportunities and Risks for Regions and Territories

edited by

Marco Modica
Davide Piacentino

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Part 2 – Transitions

Analysing the Energy Stocks Dynamics in European Countries Under an Energy Transition Framework

Emna Kanzari, Stefano Fricano*, Gioacchino Fazio**

Abstract

In recent years, threats to economic development due to escalating tensions related to fossil fuel use in the global energy landscape, have accelerated the need to stimulate the energy transition towards the use of renewable energy. Consequently, renewable energy, which today is seen as an important opportunity and the primary solution, has become the focus of international and local policymakers, mainly, in the developed countries that depend on fossil fuel imports such as European countries. The objective of this paper is to examine the dynamics of renewable energy in European nations by analysing the energy stock changes as a function of a set of variables mainly the production and the consumption of renewable energy. To do this, we used a Probit model considering the energy characteristics of countries as a function of their potential economic impact. The findings suggest that the increase of renewable energy proportion in the total energy supply results in a reduction in the energy stock levels in the countries studied, while greater openness to international energy markets results in an increase in energy stocks to deal with market shocks. Stretching further the analysis, the estimated parameters obtained from the Probit estimation were employed to divide the countries used in the sample into three groups based on their propensity towards a decrease in their energy stocks.

1. Introduction

In the context of energy production and consumption, the association between energy risk and fossil fuels is undeniable (Khan *et al.*, 2023). Fossil fuels, including coal, oil, and natural gas, have long been the primary sources powering the global economy (Wu, Chen, 2017). However, their dominance comes with inherent risks that span environmental, economic, and geopolitical dimensions. Firstly, the environmental risks associated with fossil fuels are manifold. Burning these fuels releases greenhouse gases, primarily carbon dioxide, into

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the atmosphere, intensifying the greenhouse effect and contributing to global climate change (IPCC, 2023).

Geopolitically, regions rich in fossil fuel reserves often experience significant geopolitical tensions and conflicts. The scramble for control over these resources has historically led to power struggles, interventions, and wars, underscoring the geopolitical risks intertwined with fossil fuel dependence.

Economically, the volatility in fossil fuel prices can destabilize national and global economies. Dependence on these exhaustible resources creates vulnerability to supply disruptions, geopolitical tensions, and market fluctuations. Furthermore, the transition away from fossil fuels towards renewable energy sources represents both an economic challenge and opportunity, with nations and industries seeking to balance energy security, affordability, and sustainability. Unlike fossil fuels, renewable energy is characterised by its abundance and not being concentrated in a specific geographic area, providing more energy independence for countries (Khan *et al.*, 2023). Many countries around the world, specifically, European countries, consume fossil energy more than they produce, which makes them heavily rely on foreign sources to meet their needs and be closely linked to the fossil exporting countries. This strong reliance can be used in some cases as a means by exporting countries to exert pressure, particularly in times of political conflicts and crises, and the tensions between Russia and the European countries are a clear and recent example of this. This crisis has highlighted Europe's over-dependence on fossil sources imports from Russia and has brought to the fore the necessity to reduce them, accelerate energy transition programs and policies, and increase the share of renewables in the energy mix, in order to obtain a more robust energy system and gain energy security (European Commission, 2022).

While fossil fuels have played a pivotal role in powering human progress, their associated risks underscore the urgent need for diversifying the global energy mix and accelerating the transition towards cleaner, renewable alternatives.

However, while renewable energies promise a sustainable future, doubts persist about their ability to fully mitigate energy risks for nations. The intermittent nature of sources like wind and solar can pose challenges to consistent energy supply, potentially leaving gaps in demand coverage. Additionally, the infrastructural demands and initial investment costs associated with renewables can be substantial, especially for developing nations. Concerns also arise regarding the scalability and storage capabilities of renewable technologies to meet growing energy demands. Hence, while renewables offer promising solutions, questions about their comprehensive role in offsetting energy vulnerabilities remain (Cergibozan, 2022).

This contribution tries to understand, through the study of the energy trends of European countries, the attitude of the various countries and whether there has been a positive effect of renewable energy on the mitigation of energy risk.

For this purpose, an analysis was developed of the trend of energy stocks in various countries over the last two decades and, which to our knowledge has never been reported in the literature, the possible interconnections with the development of renewable energy have been highlighted.

The dynamics between energy stock levels and perceived energy risk offer intriguing insights into global energy security and market sentiments. When energy stocks are abundant and surpass demand, it typically signifies a more stable energy landscape. Countries with high energy reserves, such as oil-rich nations or those with extensive renewable energy capacities, often experience reduced perceived energy risks. As the global energy landscape evolves, understanding this interplay becomes paramount for policymakers and industry stakeholders to ensure both energy resilience and public confidence.

The structure of this paper is as follows. The next section will discuss the literature review on renewable energy and energy security. In the third section, we will introduce the data and the methodology employed in the empirical work. Subsequently, we present the results and the discussion and finally, the last section summarizes and concludes.

2. Literature Review on Renewable Energy and Energy Security

Energy security is a multifaceted concept that includes different dimensions. In general, the concept refers to the ability of the country to obtain energy sources uninterruptedly and affordably to satisfy its needs. Energy security contains four main dimensions namely the availability, accessibility, affordability and acceptability (Gökgöz, Güvercin, 2018). The availability of energy resources refers to the physical existence of energy, its accessibility means the ability to reach and use energy resources despite geographical and technological constraints. As for affordability, it implies access to energy at affordable and reasonable prices. Acceptability, on the other hand, is related to the use of energy with low environmental impacts (Gökgöz, Güvercin, 2018). As commonly understood and based on several studies, fossil fuel energy is highly associated with energy security risk. Firstly, because fossil fuels are finite and will be completely consumed in the long run (Holechek, *et al*., 2022). Secondly, they are not equitably distributed across countries and regions, which makes some countries heavily rely on imports from the other countries to satisfy their energy needs (Murshed, *et al*., 2020). Thirdly, over the last decades, oil, gas and natural gas prices have shown significant instability (Scholten, *et al*., 2020). Fourthly, the use of fossil fuels is strongly associated with carbon emissions and negative environmental impacts (Maji, *et al*., 2019). That said, according to previous research, renewable energy is considered an alternative to fossil fuels in different ways and can positively affect energy security (Cergibozan, 2022). Renewable energy (RE) contributes to the reduction of CO2 emissions, and it has less negative environmental impacts, making it more acceptable than fossil fuels (Bilgili, *et al*., 2016).

Additionally, despite its land and technical constraints, RE remains a better alternative to fossil fuels in terms of long-term sustainability and geographical availability, since it is characterised by its abundance all over the globe (Moriarty, Honnery, 2016). Also, renewable energy includes solar power, wind power, hydropower, geothermal energy and bio-energies. The diffusion of each of these powers generates more capacities from various sources and adds to the total energy supply of the country. According to Aslani *et al*. (Aslani, *et al*., 2012), the higher the diversification of the energy resources in a country, the higher the diversification of the energy supply and the higher the energy security of supply. The diversification of the energy system including resources with low environmental impact and available in abundance such as renewable alternatives can allow energy security as it offers new capacities with various sources, unlike the single-energy system especially that with high environmental and security supply risk such as fossil fuels, which represent a real obstacle to sustainable development and energy security achievement (Akrofi, 2021).

The diversity in the energy resources will allow countries to have more than fossil fuels in their energy mix and may be beneficial, especially for countries that do not have high fossil production and import it from foreign markets. Energy poor countries depend on external energy countries to satisfy their increasing energy demand. By doing so, they are more exposed to market risks and dependence on other countries. By employing more renewables produced domestically, energy importing countries may reduce their reliance on external suppliers and decrease their high budget expenditure (Aslantürk, Kiprizli, 2020).

It is clear that for fossil fuel importing countries, renewable energy will guarantee a secure supply from domestic production. However, when these countries decrease their imports, it can represent a challenge for the economy and budget revenues of exporting countries which heavily depend on the revenues of energy exports. For these countries, it is important to maintain their energy exports and ensure their energy security of demand (Novikau, 2022). The Organisation of the Petroleum Exporting Countries (OPEC), are the first to be affected by the reduction of their exports as they control the oil market and between 2011 and 2019, they have seen a significant decrease in their oil exports. For OPEC, ensuring the energy security of demand is as important as the security of supply (Fan *et al*., 2023).

Another aspect of energy security is the geopolitical conflicts between different countries to control the energy market. The use of fossil fuels is historically related to geopolitical tensions, wars and conflicts. Unlike fossil fuels, renewable energy is expected to reduce these tensions between countries as renewable resources such as solar, wind, hydro, ocean and geothermal are equally distributed across regions. The fact that renewable resources are available for every country will offer self-sufficiency to many countries, which will decrease the energy conflicts between them (Agaton, 2022).

As previously mentioned, renewable energy plays a significant role in ensuring energy security. Despite that, the relationship between energy security and renewable energy has not been sufficiently studied empirically in the literature.

Numerous studies examined composite energy security indicators and frameworks from various angles, including inconsistencies, measurement challenges, and methodological limitations. (Siksnelyte-Butkiene, *et al*., 2024) examined 40 different composite indicators that have been developed and used in recent years. The results indicate that many energy security indicator sets are insufficient in capturing the entirety of changes in the energy market, economy, policy, international trade, and other external factors. Despite this, many authors have reported some general considerations about some results that can be stylized. For example, analysing how renewable energy affects energy security in Lithuania, (Augutis, *et al*., 2014) employed a scenario analysis and concluded that the development of renewable energy technologies increases energy security in the country. This effect is stronger when the share of renewables in energy production does not exceed 60-70%. (Brahim, 2014) studied this relationship in the Philippines and reached the same conclusions. The Philippines has huge untapped renewable energy and by harnessing it, it is expected to offer the country more energy security and sustainability. (Lucas, *et al*., 2016) tested this nexus for 21 European Union countries from 1990 to 2013, making use of a set of indicators to proxy energy security: security of supply, sustainability and competitiveness. The results show the existence of a long-term relationship between renewable energy deployment and energy security. Based on the Long-range energy alternative planning (LEAP) system, (Aized, *et al*., 2018) identified four scenarios to discuss energy plans in Pakistan. The results suggest that the green scenario which includes renewable energy sources is the best choice that the country can adopt to have low environmental and externality costs. According to (Wang, *et al*., 2018), renewable energy can help China to enhance its energy security and reduce CO2 emissions since the country is the world's largest oil importer and the largest CO2 emitter. (Viviescas, *et al*., 2019) showed that solar PV, wind and hydropower can ensure energy security in Latin America through the complementarity of these resources and regional integration. Brazil, in particular, can be a key player in renewable energy integration as it has the strongest capacity of complementarity with other Latin American countries. In the context of Eastern Europe, Caucasus and Central Asia (EECCA) countries, (Trifonov, *et al*., 2021) made conclusions about the contribution of renewable energy to energy security through energy resource diversification. An increase in the share of renewable sources in the energy mix, the development of different renewable technologies and the structure of the energy complex played a significant role in boosting energy security. The growth of renewables share is accompanied by a reduction in energy dependency, which increases energy security in these countries. (Cergibozan, 2022) has empirically studied the nexus between renewable energy and energy security risk in 23 OECD, focusing on the effect of total renewable energy and renewable technologies separately mainly solar, wind, hydro and biomass on energy security risk. The study shows that there is a positive impact of wind, hydroelectric and total renewables together on reducing energy security risk, while the biomass and solar powers do not show a significant effect on energy security.

In this study, we aim to add to the literature review by focusing empirically on European countries as they are not enough discussed in the literature. In addition, we use energy stock change as a new proxy for energy security, and to the best of our knowledge, it is the first time that it has been employed in this context. Energy stocks can give information about the energy dynamics in an economy. Generally, countries that tend to increase their energy stocks are more exposed to energy security risk and aim to increase them to be protected in short-term market shocks, whilst those reserving less are likely to be surer or satisfied by their energy production.

3. Data and Methodology

3.1. Data

To discuss the dynamics of the energy stocks in Europe, we employed a set of variables that may influence them, collected from different databases mainly the International Energy Agency (see Table 1). The sample employed in this work includes variables for 20 European countries between the available time span from 1992 to 2020. We have chosen the largest 20 European countries[1] in terms of GDP.

To develop our analyses, we started by analysing some of the main variables linked to the energy trends of the various European countries considered:

- *Energy stock changes*: the difference between the initial stock levels on the first day of the year and the last day of the year of the stocks. Energy stocks are the related energy stocks held within a national territory by producers, importers,

1. The countries are as follows: Germany, United Kingdom, France, Italy, Spain, Netherlands, Switzerland, Poland, Sweden, Belgium, Norway, Ireland, Austria, Denmark, Romania, Finland, Czech Republic, Portugal, Greece and Hungary.

Table 1 – Summary of the Variables Considered in the Work (for country details see Table A.1)

Variables	*Description*	*Source*	*Mean*	*SD*	*Min*	*Max*
Energy stock changes	Expressed in Tera-joule (TJ).	IEA*	1,385.5	60020.2	-299,024.6	505,685.4
RE production	Renewable energy production in TJ.	IEA*	314,995.1	307,563	6,472.9	1889,791
Energy production	Total energy production expressed in TJ.	IEA*	2211,906	2635,305	53,244.5	1.18e+07
Energy consumption	Total energy consumption expressed in TJ.	IEA*	2416,222	2452,789	317,702.1	1.01e+07
Energy imports	Total energy imports expressed in TJ.	IEA*	2732,246	2822,925	189,065.3	1.12e+07
Energy exports	Total energy imports expressed in TJ.	IEA*	1324,720	1981,303	8989,084	32,849.5
GDP growth	Annual percentage of GDP growth.	WDI**	1.9	3.1	-11.3	24.4

Notes: * Bought from the International Energy Agency, World Energy Balances (IEA, 2023); ** The World Bank Group. DataBank, World Development Indicators (World Bank, 2023).

Source: Authors' elaborations

energy transformation industries and large consumers. A negative number refers to a stock build while a positive number shows a stock draw (IEA, 2023).

- *Renewable energy production*: is the sum of the production of renewable energy sources including wind energy, solar photovoltaic, solar thermal, hydropower, geothermal, tide energy, biogas, bio gasoline, biodiesel and municipal waste.
- *Energy production:* the total production of primary energy namely hard coal, lignite, peat, crude oil, natural gas liquids (NGLs), natural gas, biofuels and waste. It also involves nuclear, hydro, geothermal and solar as well as heat derived from heat pumps extracted from the ambient environment (IEA, 2023).
- *Energy consumption*: total consumption in end-use sectors and non-energy use excluding energy used for transformation processes and for the internal operations of energy-producing industries. It represents the deliveries made for consumers (IEA, 2023).
- *Energy imports*: the quantities that have crossed the country's national territorial borders whether customs clearance was completed or not. Coal is considered the quantities imported (excluding coal in transit) from other countries without considering the existence or the absence of an economic or customs union

between them. For oil imports, it excludes oil in transit and includes crude oil and oil products imported under processing agreements. Crude oil, natural gas and natural gas liquids (NGL) are reported based on their country of origin, while refinery feedstocks and oil products are recorded based on the country of last consignment. Additionally, imported NGL that is later exported to another country after regasification is treated as both import and export (IEA, 2023).

- *Energy exports*: the quantities that have crossed the country's national territorial borders whether customs clearance was completed or not. Coal is considered the quantities exported (excluding coal in transit) to other countries without considering the existence or the absence of an economic or customs union between them. Oil exports include the crude oil and oil products which are exported under processing agreements. For the imported oil for processing within bonded areas, when it is re-exported, it is recorded as exported from the processing country to the final destination. Additionally, imported NGL that is later exported to another country after regasification is treated as both import and export (IEA, 2023).
- *GDP growth*: refers to the annual percentage increase of Gross Domestic Product at market prices using constant local currency. The aggregates are expressed in U.S. dollars (using constant 2015 prices).

3.2. Methodology

3.2.1. The Variable Selection

As already mentioned, in our analysis we focused on the stock change measure provided by the International Energy Agency for the countries considered over the last two decades. The "stock change" variable, as referenced by the International Energy Agency (IEA), pertains to the variation or alteration in the levels of energy reserves or supplies over a specified period. Specifically, in the context of the IEA's analyses and reports, the stock change provides insights into the net increase or decrease in energy stockpiles, such as oil, gas, or coal, considering factors like production, imports, exports, and consumption. A negative number refers to a stock build while a positive number shows a stock draw (IEA, 2023). Following these indications, our interest was therefore to understand in which circumstances, for each country considered, there was an increase or decrease in energy stocks. Consequently, we decided to construct a dichotomous dependent variable which, starting from the sign of the stock changes variable (*Schng*), represents the possible underlying propensity towards a decrease in energy stocks (*Schng*=1) that fall along a continuum related to the level of energy security and to test its dependence with five variables as explanatory variables as follows:

- *Energy production / Energy consumption*: the ratio between energy production and consumption used as an indicator to highlight the ability of a country to meet its energy needs by consuming what it produces. A high value indicates that the country produces more than it consumes and its domestic production satisfies its energy needs while a low ratio suggests that the country's energy sufficiency is low and may rely on foreign sources to fulfil its energy necessities.
- *Energy imports / Energy consumption*: the fraction between energy imports and energy consumption specifies the share of energy needs of a country that are met through importation compared to its energy consumption. It highlights the energy dependency on external energy imports: a low share means less dependency on international energy market and higher energy security.
- *Energy exports / Energy production*: the ratio between energy exports and energy production represents the share of the total energy production of a country that is exported to other countries. A low value implies that the country uses its produced energy domestically and it therefore has a limited economic interest on the international energy market as supplier.
- *Renewable energy production / (Energy production + Energy imports – Energy exports)*: refers to the share of renewable energy production in total energy supply. It indicates the proportion of the energy generated from renewable resources compared to overall provided energy. This represents our variable of greatest interest since it could allow us to understand the relationship between renewable energy and the mitigation of energy risk.
- *GDP growth*: we have decided to also include the variable GDP growth to take into account possible influences on economic growth which may be different for the various countries.
- *Country*: we also considered a fixed effect for each country by introducing an additional multinomial variable.

3.2.2. The Model

The research idea of this contribution is to investigate under what conditions the probability that a country's energy stocks are reduced.

Starting from what was presented above, our objective is to verify the following hypotheses:

- *H1: High capacity to meet internal energy demand through internal production can guarantee the stability of the internal market, and therefore makes high energy stocks less necessary.*
- *H2: Country's greater exposure to international energy markets leads to maintaining high energy stocks.*

Table 2 - Summary of the Variables Used in the Empirical Analysis

Variables	*Description*
Stock changes: (Schng)	Dichotomous variable referred to Energy stock changes: "0" refers to a stock build while "1" to a stock draw.
% of RE in total energy supply (REshare)	Renewable energy production / (Energy production + Energy imports – Energy exports)
Energy auto-sufficiency (EAS)	Energy production / Energy consumption
Energy demand from foreign markets (EDF)	Energy imports / Energy consumption
Energy supply to foreign markets (ESF)	Energy exports / Energy production
GDP growth (GDPg)	Annual GDP growth
Country	Multinomial variable: Germany, United Kingdom, France, Italy, Spain, Netherlands, Switzerland, Poland, Sweden, Belgium, Norway, Ireland, Austria, Denmark, Romania, Finland, Czech Republic, Portugal, Greece and Hungary

Source: Authors' elaborations

- *H3: Greater energy production from renewable sources guarantees a more secure source of supply and can induce countries to reduce energy stocks.*
- *H4: Economic growth trends can lead countries to accumulate energy stocks which can be useful in guaranteeing the growth process.*

To test the hypotheses, we decide to use a probit analysis. Probit analysis is particularly appropriate when trying to estimate the effects of one or more independent variables on a binomial dependent variable. Probit regression assumes that the relationship between the predictors and the probability of the response variable can be modelled using the cumulative distribution function (CDF) of a normal distribution. In other words, probit regression assumes that the probability of the response variable being equal to 1 can be modelled using a normal probability density function and that the values of the predictor variables determine the mean and standard deviation of the distribution (Hong, *et al*., 2022). We use probit regression to model the relationship between the binary variable *Schng* and the predictor variables of Table 2 and its general specification is as indicated in the following equation:

$$Pr\ \left(Schng_{it} = 1\right) = \varnothing\left(\beta_0\, REshare_{it} + \beta_1 EAS_{it} + \beta_2\, EDF_{it} + \beta_3\, ESF_{it} + \beta_4 GDPg_{it} + u_i + \varepsilon_{it}\right) \quad [1]$$

Where $Schng_{it}$ is the binary dependent variable for country *i* and year *t*, [Equation 1] refers to the cumulative distribution function of a standard normal distribution, β_0, β_1, β_2, β_3, β_4, are the coefficients to be estimated, u_i, indicates the country fixed effects and ε_{it} is the random error.

4. Results and Discussion

Although the general purpose of this analysis is to verify the various hypotheses of the model, the main objective of this study is to understand what effect has a greater production of renewable energy on changing the amount of energy stocks owned annually by each country, in particular, we intend to perceive whether a greater production of renewable energy can increase the probability that the stock decrease and therefore obtain a value of "1" for the dependent variable. To do so, we developed a Probit analysis using Mathematica® on our data and the fitting results are shown in Table 3.

As can be noticed from the results, both variable Energy auto-sufficiency (EAS) and variable GDP growth (GDPg) are not significant in our analysis, whereas the variables related to the external market relationship namely the energy demand from foreign markets (EDF) and the energy supply to foreign markets (ESF), especially the variable measuring the amount of renewable energy produced in relation to all available energy (REshare), are significant.

The lack of significance of the variable Energy auto-sufficiency (EAS) would seem to *deny Hypothesis H1* and, at first glance, it might appear uninteresting. In our opinion, however, it is very significant and reflects an important signal of the energy behaviour of the various countries. In fact, it tells us that the "current" ability to satisfy internal demand with internal production does not seem to sufficiently "ensure" the country systems. This aspect is indeed intriguing and has also been emphasized by several analyses (Dyatlov, *et al.*, 2020), which underscore the fact that in certain countries where new initiatives for diversifying energy supply have been initiated, they stem from concerns regarding the lack of long-term guarantees offered by the current production capacity.

For the variables related to the external market relationship, it is interesting to note that the sign of the coefficients associated with the interaction with the external market is negative for both variables (-1.79274 and -0.757505): this confirms that greater exposure to international energy markets induces individual countries to keep high values of energy stocks instead of reducing them in order to contain the risk that may arise from price volatility. *This affirmation verifies our Hypothesis H2*.

Indeed, when there is a price spike in the international market, energy importing countries (for example: Germany, Italy, France, Netherlands, United Kingdom and

Table 3 – Empirical Results

Probit Results Cox&Snell PseudoR2 = 0.3132 Pearson ChiSquare = 638.5 Dependent variable: Stock changes				
	Estimate	*Standard Error*	*z-Statistic*	*P-Value*
REshare	3.079	1.566	1.966	0.049
EAS	-0.106	0.186	-0.572	0.567
EDF	-1.793	0.510	-3.517	0.001
ESF	-0.757	0.288	-2.634	0.008
GDPg	-0.020	0.018	-1.151	0.249
Country effect				
Austria	0.883	0.606	1.458	0.145
Belgium	1.631	0.662	2.465	0.014
Czech Republic	0.840	0.504	1.668	0.095
Denmark	1.447	0.616	2.349	0.019
Finland	0.927	0.626	1.480	0.139
France	1.470	0.578	2.540	0.011
Germany	1.917	0.563	3.403	0.001
Greece	2.036	0.687	2.964	0.003
Hungary	1.190	0.541	2.198	0.028
Ireland	1.772	0.552	3.207	0.001
Italy	1.748	0.553	3.157	0.001
Netherlands	2.730	0.941	2.901	0.004
Norway	-0.524	2.058	-0.255	0.799
Poland	0.710	0.456	1.558	0.119
Portugal	0.947	0.610	1.550	0.121
Romania	1.031	0.484	2.128	0.033
Spain	1.728	0.646	2.673	0.007
Sweden	0.759	0.678	1.118	0.263
Switzerland	1.315	0.566	2.322	0.020
UK	1.286	0.524	2.453	0.014

Note: * The time span considerate in the analysis is 1992-2020.

Source: Authors' elaborations

Spain (IEA, 2023)) try to use their reserves of energy to stabilise domestic prices and for them it is important to have an abundant energy stock to better respond to the market. For these countries, it is important also to diversify their energy mix and include alternative resources as a hedge against price volatility and market pressures. In the opposite case, energy exporting countries tend to accumulate stocks to be able to respond promptly in case of a spike in external market demand. This dynamic is well recognized within the EU and over the years multiple initiatives have been put in place to address the volatility of the energy market. As a matter of fact, to ensure a consistent and stable energy supply across member states, the EU has established directives regarding energy emergency stock levels (Directive 2009/119/CE) (European Union, 2009b). These directives mandate that member countries maintain a minimum level of oil and petroleum product reserves equivalent to at least 90 days of average daily net imports or 61 days of average daily inland consumption, whichever is greater. Furthermore, the EU specifies that these emergency stock levels should be accessible and deployable within a short notice period. Member states must also regularly report their stock levels to the European Commission, ensuring transparency and adherence to the established norms. The rationale behind these directives is multifaceted. Firstly, it aims to mitigate the potential impacts of sudden energy supply disruptions, whether due to geopolitical tensions, natural disasters, or other unforeseen events. Secondly, it underscores the EU's commitment to ensuring energy security, promoting stability in energy markets, and safeguarding the interests of both consumers and businesses. Also, energy prices started rising in the EU well before the invasion of Ukraine and the Commission reacted to growing pressure to act by adopting guidance to Member States in the form of a Communication in October 2021 entitled "Tackling rising energy prices: a toolbox for action and support".

The positive sign of the parameter linked to the portion of renewable energy out of the total available energy (Reshare) *confirms the Hypothesis H3* and responds to the question to which this contribution refers. In fact, it shows how a greater percentage of available renewable energy is more likely to lead to a reduction in energy stocks. It is useful to remember in this case how this result is in line with European directives regarding the energy transition towards renewables.

The commitment of Europe to its energy shift is not related to recent conditions and the development of renewable energy has been at the core of its energy policy for many years. Between 2001 and 2009, the European Union adopted a set of initiatives to impose on its countries the increase of renewable sources used to produce energy, to raise the share of renewables in electricity production (Directive 2001/77/EC), to adopt renewable fuels including biofuels in the transport sector (Directive 2003/30/EC) and other renewable resources in different sectors such as heating and cooling (Directive 2009/28/EC) (European Union, 2001; 2003; 2009a). In 2018, another action known as the Renewable Energy Directive suggested that by 2030, at least 32% of the energy produced in the EU has to be generated from renewables.

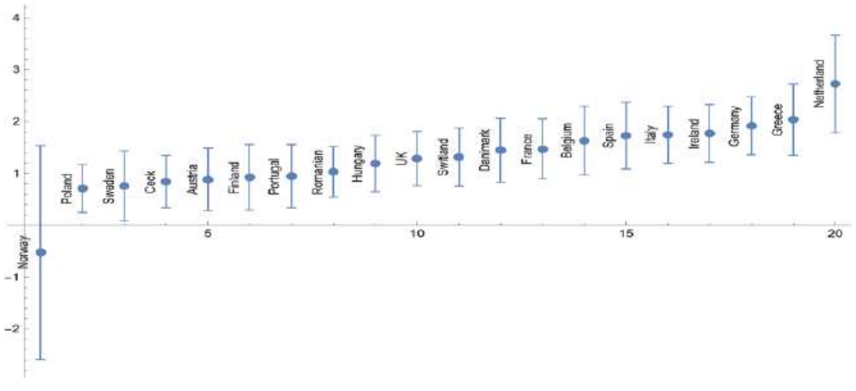
Finally, the findings of our analysis do *not confirm Hypothesis H4*. In this case, however, the result could be connected to the variability of the data which could lead to a distortion of the result. To investigate this possibility and evaluate the robustness of the results, we first repeated the analysis on a subsample relating to narrower time windows and replacing the variable GDP growth by GDP growth per capita. The results confirmed what was obtained before and led to deeper reflections on whether there is indeed a mechanism that can link the growth dimension, possibly with different indices, to that of energy security.

5. Country Fixed Effects

The results deriving from the contribution of country fixed effects also deserve careful discussion. Considering the country fixed effects, it is noteworthy how the parameters related to the country fixed effects are positive, except in the case of Norway for which the parameter, although the estimate has a very large standard error, takes on a negative value (see Figure 1).

This negative value is explained by the fact that, within our panel data, Norway is a unique case in which the value of energy production is much higher than

Figure 1 – The Estimated Parameters for Each Country (u_i)



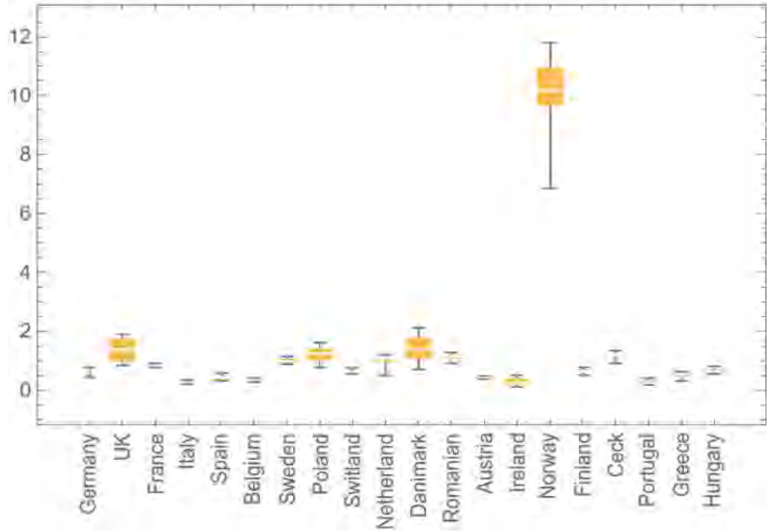
Source: Authors elaborations on values u_i

domestic demand (approximately 5 times the average value of the other countries in our sample, see Figure 2) and in this case, the level of energy risk appears to be considerably low, likely not linked to stock levels at all.

Norway is a remarkable and unique example of energy self-sufficiency in renewable energy and it is more energy secure than almost any other country. Between 1995 and 2020, Norway registered a power surplus and became one of the most energy independent countries, being the world's fifth largest petroleum exporter and seventh largest hydropower producer (Hansen, Moe, 2022).

Excluding Norway, we can identify three distinct groups of countries depending on the parameter values through the definition of some merely symbolic thresholds. The first group of countries is made up of six countries namely Poland, Sweden, Czech Republic, Austria, Finland and Portugal, for which the estimated best fit parameter takes on a value less than 1; for these countries, we can define a general low propensity towards a decrease in stocks. For the countries of a second group which is composed of Romania, Hungary, Denmark, France, UK and Switzerland, the estimated value of the parameter varies within a range of 1 and 1.5; for these countries, we can define a general moderate propensity towards a decrease in stocks. Finally, for the countries belonging to the last group, the estimated parameters are greater than 1.5 with a maximum value of approximately 2.7 for the Netherlands. These countries have a greater propensity

Figure 2 – Energy Auto-sufficiency for Each Country



Source: Authors elaborations

to decrease energy stocks probably because of a progressive transition towards the diversification of energy sources. This last result is interesting and deserves further analysis which could provide useful indications at a macroeconomic level on the nature of any exogenous or endogenous causes that may be at the basis of this variability.

6. Conclusion

In the present study, we were interested in examining how an extensive production and use of renewable energy may affect the energy stocks dynamics in an economy. We mainly focused on 20 European countries as Europe is one of the most exposed regions to energy security risks. The European Union's economy is reliant on fossil fuels, which account for nearly three-quarters of its total energy consumption. Fossil energy is largely imported: the EU's share of global fossil fuel demand stands at 8%, compared to its share in global production of 0.5% for oil and 1% for gas, respectively.

Using a panel sample for the period between 1992 and 2020, we applied a Probit estimation model considering the sign of energy stock change as the binary dependent variable and the share of renewable energy in total energy supply as the main independent variable. We included also other energy related variables: the energy auto-sufficiency and two variables related to the external market relationship which are the energy demand from foreign markets and the energy supply to foreign markets.

We tested the relationship between all variables in the model and we concluded that whether the country is an energy supplier or demander, the exposure to foreign energy markets is highly linked to energy security risks as the coefficients of the energy demand and supply are both negative, which means that those countries tend to increase their stocks to overcome the market risks.

On the other hand, the share of renewable energy in the total supply is significant and positive, suggesting that countries having an important share of renewables in their energy supply are likely to decrease their energy stocks as they are not much exposed to market fluctuations. Expectations of a demand decrease can heighten uncertainty about the future returns on fossil fuel investments, thereby reducing their volume. A decline would manifest in reduced supply and increased prices. However, other supply channels might lead to price decreases. For instance, producers might opt to expedite the exploitation of their reserves, resulting in increased supply and decreased fossil fuel prices. Similar effects – namely, increased investments and reduced costs – might also arise from technological innovations related to fossil fuels, such as carbon capture and storage.

So, renewable energy appears to be an important solution for European countries to gain energy independence and security and considering that, they should improve energy policies and implement renewable plans to accelerate their transition towards green powers.

In this work, we have provided an overview of energy dynamics in European countries focusing on their energy stocks in relation to renewable energy deployment. However, there is a potential for future research to extend our analysis to add other countries beyond Europe. In order to focus on different geopolitical contexts, we aim to provide a better understanding of global energy stocks and the energy transition landscape at the international level.

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Sommario

Dinamica delle scorte energetiche in Europa: un'analisi nel contesto della transizione energetica

Negli ultimi tempi, il crescente rischio energetico dei paesi dovuto alle tensioni geopolitiche internazionali ha accentuato le problematiche relative all'uso di combustibili fossili e le ripercussioni sulle economie hanno spinto verso una rapida transizione verso *fonti energetiche sostenibili come le rinnovabili. La produzione di energia da fonti rinnovabili è diventata una indubbia priorità, specialmente nei paesi avanzati come quelli europei che sono, ancora oggi, fortemente dipendenti dai combustibili fossili, nell'idea di attenuare il rischio energetico. Una maggiore produzione di energia rinnovabile dovrebbe consentire infatti all'economia europea di affrontare più agevolmente un rincaro dei prezzi energetici e una restrizione dell'offerta dei combustibili fossili. Tuttavia, le energie rinnovabili presentano anch'esse svantaggi, quali l'intermittenza nella produzione e il fabbisogno di materie prime necessarie per la costruzione degli impianti. Questo articolo si propone di analizzare il ruolo delle energie rinnovabili in Europa, studiando, attraverso un modello Probit, come le varie dinamiche energetiche dei paesi possano influenzare le riserve di energia dai vari paesi. I risultati mostrano che un incremento nell'uso di energie rinnovabili porta a ridurre le riserve energetiche, di contro una maggiore presenza nei mercati globali può aumentarle. Infine, basandosi sui risultati ottenuti, i paesi sono stati classificati in tre categorie secondo la loro tendenza a ridurre o meno le riserve energetiche.*

Appendix

Table A.1 – Means, Maximum and Minimum Values for Each Variable for Each Country, 1992-2020

Country	*Stock Changes*			*RE Production*			*Energy Production*		
	Mean	*Min*	*Max*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
Germany	35533.24	-299024.56	230432.07	889759.80	212248.20	1889790.86	5631431.57	4045733.32	7794023.35
United Kingdom	32111.97	-189247.91	505685.45	223079,62	42508,99	687714,96	8019592.47	4475511.6	11790263.1
France	-11157.87	-200575.33	111877.43	782264.38	628825.96	1055806.65	5473429.82	4684462.68	5819910.04
Italy	-3172.76	-192781.76	108653.60	628411.99	267144.20	1041004.5	1304292.75	1059992.10	1539343.67
Spain	-1470.39	-112848.62	146928.44	451452.99	213876.79	782052.62	1370295.01	1262357.83	1476089.45
Netherlands	-10158.01	-130001.61	79869.94	110159.18	31235.60	285080.4	2502314.30	1140495.89	3131350.43
Switzerland	5454.36	-8083.34	33920.87	186301.86	148891.66	222543.95	493938.67	428023.93	546670.34
Poland	-22646.66	-174511.70	107385.04	243028.85	56753.99	511632.02	3317894.88	2422563.99	4349069.12
Sweden	-975.15	-130211.99	85704.60	618617.40	460277.40	843279.82	1387885.65	1227354.37	1553774.74
Belgium	-2810.82	-38128.32	52077.03	63726.51	13626.99	160860.68	571013.93	449307.59	668976.98
Norway	-5813.92	-77460.81	87054.75	503857.47	417834.6	598466.83	8474639.51	5002329.67	9915020.44
Ireland	154.88	-35402.38	32082.92	22268.14	6472.88	65062.29	110821.51	53244.49	209159.47
Austria	-490.87	-106493.13	48323.23	314649.08	208927.20	423223.28	434727.35	340643.30	530130.61
Denmark	686.72	-60236.89	50851.56	99858.92	43192.80	167538.39	836706.95	385790.01	1308726.17
Romania	686.72	-56424.16	44198.21	186934.47	66291.60	255210.11	1209539.53	937327.64	1693785.98
Finland	13481.56	-96320.47	86167.02	348173.19	212674.80	481268.64	665241.38	467634.47	822591.19
Czech Republic	3663.24	-57943.72	76867.1	112152.82	47757.60	207227.28	1345075.91	991379.58	1723507.64
Portugal	-39.65	-20675.7	36688.47	182488.86	119287.40	248591.90	186882.37	123080.42	254419.45
Greece	-1511.89	-44166.38	80826.56	76185.11	46249.60	118028.34	381334.85	190709.95	438622.11
Hungary	-5629.39	-112442.57	55202.35	76032.36	33065.80	138750.96	499688.54	428578.15	614946.28

Country	*Energy Consumption*			*Energy Imports*			*Energy Exports*		
	Mean	*Min*	*Max*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
Germany	9616169.22	8955070.99	10135123.5	9964868.57	7919295.25	11216628	1511259.9	710480.72	2540401.8
United Kingdom	5807995.05	4774851.22	6341465.98	4881078.31	3104474.73	6971992.56	3885570.34	2724007.82	5421132.12
France	6563809,61	5777900	7064125.17	6554297.00	5339183.53	7521777.14	1229611.23	837947.30	1597543.16
Italy	5246566.60	4498109.71	5915407.07	6784612.46	5485335.58	8044942.00	1068024.79	729799.49	1396980.02
Spain	3455625.24	2544476.15	4266733.92	4661820.36	3048456.62	5720997.07	690293.11	297735.99	1364112.66
Netherlands	2477465.78	2256918.86	2732261.54	6216008.06	4224289.29	8625565.11	4903683.55	3480540.25	6728642.18
Switzerland	801591.571	720001.98	860696.83	739525.93	622273.34	816843.38	131700.77	89426.68	155482.19
Poland	2745054.45	2397955.33	3288439.32	1611228.10	859578.28	2685069.76	796306.88	534684.20	997873.19
Sweden	1422507.98	1329976.47	1542490	1325529.89	1128871.98	1528932.62	552312.85	386824.74	879647.40
Belgium	1663156.63	1349099.61	1789743.39	3168257.77	2536660.13	3677122.83	1118945.44	818630.14	1591070.99
Norway	831533.29	713074.75	892610.18	294733.26	189065.29	486669.92	7584920.65	4228435.85	8989083.78
Ireland	430105.84	315729.31	527161.21	521790.81	318495.04	651536.89	56365.67	29223.38	84344.58
Austria	1052063.49	827662.7	1173748.57	1103656.98	778687.09	1376803.65	226950.78	50892.09	580660
Denmark	595417.28	544055.92	633771.08	682594.19	554451.77	790773.02	678043.2	301536.05	1019341.73
Romania	622981.56	428061.04	1140236.95	622981.56	428061.04	1140236.95	190878.44	97066.80	268182.39
Finland	1028966.93	924270.43	1114229.47	1010840.6	818682.39	1199666.3	269816.70	72406.69	427749.99
Czech Republic	1134482.02	1054246.48	1380791.49	835274.10	640385.40	1003808.03	357424.49	231256.94	610281.28
Portugal	722629.43	560793.61	856631.20	961445.60	721658.89	1165965.91	160392.93	70342.80	335110.89
Greece	736263.40	606827.97	913908.24	1215049.63	836994.25	1630832.22	384446.08	139887.56	860732.97
Hungary	776817.49	712677.17	866180.12	772270.39	532831.37	1219840.96	167677.61	51796.30	440835.93

Source: Authors' elaborations

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The Conference of the Italian Regional Science Association (AISRe), held in September 2023 in Naples, allowed scholars and policy makers to debate on the global issue of conflicts and transitions that are involving many regional economies worldwide, especially in the Euro-Mediterranean area. This book, collecting some contributions that were presented during the conference, aims at increasing the understanding of how regions are navigating and responding to the complex array of challenges they face in a rapidly changing world. The book considers a broad specification of conflicts that are closely related to the idea of exogenous shocks and consequent transitions interpreted as adaptation strategies to those shocks. The book is structured in two parts. The first part presents seven papers dealing with 'conflicts' of different nature such as regional disparities and cohesion, respect of law and social norms, occupational safety and health, urban congestion, gendered sectoral segregation, natural disasters. The second part of this book presents eight papers focuses on different types of 'transitions' related, for example, to climate change and environment, energy, digitalization and innovation. The book, even if does not cover all global conflicts and local responses comprehensively, however it provides useful insights to the debate on how regions are confronting the profound and often unexpected changes brought about by disruptive challenges.

FrancoAngeli
La passione per le conoscenze