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Climate Change and Energy Security: The Dilemma or Opportunity of the Century?

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Climate Change and Energy Security: The Dilemma or Opportunity of the Century?

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Abstract

This paper investigates the connection between climate change and energy security in Europe and provides empirical evidence that these issues are the two faces of the same coin. Using a panel of 39 countries in Europe over the period 1980–2019, the empirical analysis presented in this paper indicates that increasing the share of nuclear, renewables, and other non-hydrocarbon energy and improving energy efficiency could lead to a significant reduction in carbon emissions and improve energy security throughout Europe. Accordingly, policies and reforms aimed at shifting away from hydrocarbons and increasing energy efficiency in distribution and consumption are key to mitigating climate change, reducing energy dependence, and minimizing exposure to energy price volatility.

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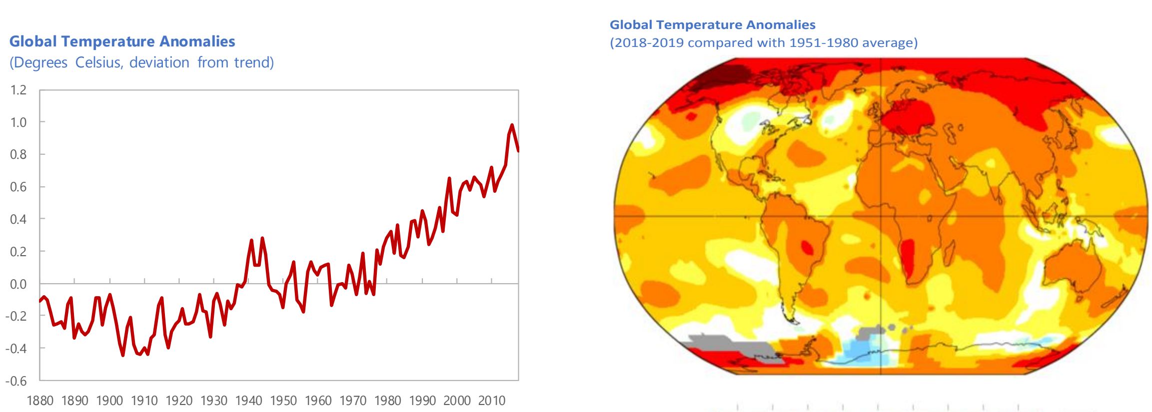
I. Introduction

Climate change is accelerating rapidly, with a narrow possibility to escape its worst environmental and socioeconomic consequences. The global average surface temperature has already increased by about 1.1 degrees Celsius (°C) compared with the preindustrial average during 1850–1900, amplifying the frequency and severity of climate shocks across the world (Figure 1). The risk of extreme weather events, such as heat waves, wildfires, droughts, flooding, and severe storms, is projected to increase over the next century, as the global mean temperature continues to rise by as much as 4°C over the next century (IPCC 2007, 2014, 2019; 2021). According to the latest assessment, if greenhouse gas (GHG) emissions remain on the current growth path, global warming is projected to reach 4-6°C by 2100—an unprecedented shift with greater probability of larger and irreversible environmental changes unseen in millions of years that threaten devastation in swathes of the natural world and render many areas unlivable. Although 189 countries have committed to reduce carbon dioxide (CO_2) emissions by 30 percent in 15 years until 2030, global CO_2 emissions continued to increase since the 2015 Climate Accord by 2.3 percent to 36.3 billion metric tons in 2021—the highest level in history.

Geopolitical tensions are a stark reminder that energy security remains a critical challenge for Europe. Besides the death toll, human misery, and destruction of physical capital, Russia's invasion of Ukraine has unsettled global energy markets and interrupted the flow of oil and natural gas to Europe due to international sanctions on Russia. The price of crude oil has increased from an average of $68 per barrel in 2021 to as high as $124 in 2022, while the price of natural gas in Europe jumped to a record high of €345 per megawatt-hour, which is the oil equivalent of $600 per barrel (Figure 2). At the same time, price volatility has hit new heights as a result of the uncertain output of renewable assets and a tight supply-and-demand balance in the European power system. Although it is still too early to know how events might unfold, the crisis will likely result in long-lasting changes in energy supply networks and energy sources in the generation of electricity. Similar to the emergence of energy security—uninterrupted access to affordable energy—as a policy concept after the first oil shock of the 1970s, the latest bout of geopolitical tensions in Europe has rekindled policy discourse on the macro-critical importance

Figure 1. Global Climate Change



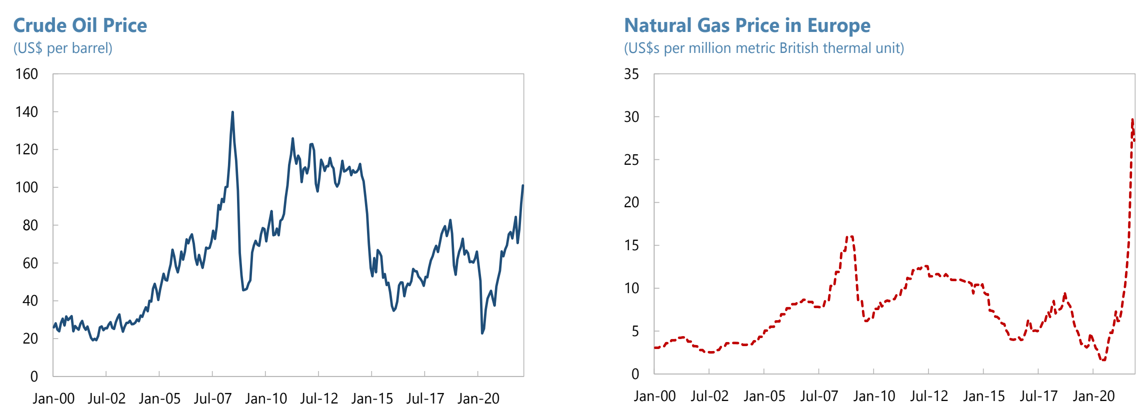
Source: NOAA.

of ensuring an adequate supply of energy at a stable and reasonable price. While it appears like a dilemma, strengthening energy security and addressing climate change are the two faces of the same coin. Policies and structural reforms aimed at reducing dependence on fossil fuels would therefore deliver not only a significant reduction in CO_2 emissions, but also help improve energy security throughout Europe.

Changing the energy matrix and improving energy efficiency could bring a significant reduction in CO_2 emissions and strengthen energy security. Moving away from fossil fuels is certainly necessary to mitigate climate change, and that requires global CO_2 emissions to peak by 2025 and reach net zero by 2050. Unfortunately, the current pace of CO_2 emissions is still not consistent with the goals of the Paris agreement (IPCC, 2021). Using a panel of 39 countries in Europe over the period 1980–2019, the empirical analysis presented in this paper finds that increasing the share of nuclear, renewables, and other non-hydrocarbon energy and improving energy efficiency could contribute to a significant reduction in CO_2 emissions and imported sources of energy. The results show that the share of non-hydrocarbon sources of energy and energy efficiency are associated with lower CO_2 emissions and energy imports in the long run, after controlling for economic, demographic, and institutional factors. These statistically significant effects are particularly more pronounced in emerging European economies, indicating potentially substantial gains in both environmental outcomes and energy security.

This paper takes stock of policies and reforms countries are implementing to mitigate and adapt to climate change. Within Europe, the Baltic Sea basin is particularly vulnerable to global warming caused by climate change. The annual warming trend for the Baltics has been about 0.10°C per decade, which is twice as much as the global average of 0.05°C per decade (Ahola and others, 2021). Over the next century, the projected increase in annual mean surface temperature will remain significantly above the global average under all different scenarios and reach as high as 4.3°C (Meier and others, 2022). Although global warming may initially provide a boost to economic activity in the northern hemisphere, greater volatility in climatic conditions and a projected increase of as much as 75 percent in precipitation during winter in the Baltics will bring significant downside risks. These adverse developments will affect biodiversity, food production,

Figure 2. International Energy Prices



Source: IMF.

infrastructure and weather-sensitive other economic activity such as transportation and tourism. Accordingly, policies and reforms aimed at shifting away from hydrocarbons to alternative sources of energy and increasing energy efficiency in distribution and consumption are key to mitigating climate change, reducing energy dependence, and minimizing exposure to energy price volatility. To this end, environmental taxation, including a carbon tax and "feebates" on fossil fuels, could promote the transition to low-carbon sources of energy and raise additional fiscal revenues, which can provide appropriate funding to compensate the most vulnerable households and invest in structural resilience.

The remainder of this paper is structured as follows. Section II provides an overview of potential macroeconomic effects of climate change. Section III presents the data used in the analysis and stylized facts on CO_2 emissions, energy security, and energy efficiency in Europe. Section IV presents the empirical analysis and discusses climate change mitigation strategies. Section V provides an overview of climate change adaptation strategies. Finally, Section VI offers concluding remarks with policy recommendations.

II. Climate Change and the Economy

Climate risks fall into two categories—physical risks and transition risks—that could also have cross-border spillovers. Climate refers to a distribution of weather outcomes for a given location, and climate change describes environmental shifts in the distribution of weather outcomes towards extremes. Accordingly, climate risks reflect the probability or likelihood of occurrence of weather-related hazardous events in the foreseeable future or trends multiplied by the impacts of these events or trends occurring over a long period of generations. Risks associated with climate change fall into two categories: (i) physical risks; and (ii) transition risks.

- **Physical risks of climate change** relate to damages caused by current weather-related events, such as hurricanes, heat waves, droughts or flooding, which are projected to increase in frequency and intensity, and long-term changes in climate such as global warming and sea-level rise. Extreme changes in climatic conditions could significantly reduce the productivity of coastal areas and agricultural land due to an increase in sea level and changes in precipitation patterns, respectively. Hence, physical risks associated with climate change may lead to significant economic and financial losses due to potentially severe damages to the income flow and asset portfolio of households, nonfinancial firms, banks, and insurers (Batten, Sowerbutts, and Tanaka, 2016; Battiston and others, 2017; Campiglio and others, 2018; IMF, 2020a, 2021; Monasterolo, 2020; Ramírez, Thomä, and Cebreros, 2020). Physical risks of climate change may also have significant impact on the fiscal position and debt sustainability, with negative repercussions throughout the economy (Cevik and Jalles, 2020; 2021; 2022).

- **Transition risks of climate change** emanate from efforts to build a green economy. Transition risks materialize when changes in technology, standards, taxation, and other policies turn carbon-intensive assets into stranded assets and amplify losses through financial interconnectedness (Batten, Sowerbutts, and Tanaka, 2016; Battiston and others, 2017; Caldecott, 2018; Campiglio and others, 2018; Pointner and Ritzberger-Grünwald 2019; IMF, 2020a, 2021). There is an additional liability risk, which refers to the legal risks from parties adversely affected by climate change and climate change policy (Kunreuther and Michel-Kerjan, 2007; Ackerman, 2017). Therefore, transition risks capture the uncertainties related to the timing and speed of the adjustment to a low-carbon economy. While moving towards a greener economy is the beneficial objective, it generates significant financing needs and results in structural changes.

Cross-border spillovers stemming from the occurrence of physical and transition risks in other countries should also be taken into account. Cross-border spillover of climate risks occur through international trade and supply chain linkages as well as changes in standards, taxation and other policies in trading partners (Benzie and others, 2019; Carter and others, 2021; Feng, Li, Prasad, 2021). Overall, although identifying the macroeconomic impact of annual variation in climatic conditions remains a challenging empirical task, Gallup, Sachs, and Mellinger (1999), Nordhaus (2006), and Dell, Jones, and Olken (2012) find that higher temperatures result in a significant reduction in economic growth in developing countries. Burke, Hsiang, and Miguel (2015) confirm this finding and conclude that an increase in temperature would have a greater damage in countries that are concentrated in geographic areas with hotter climates. Using expanded datasets, Acevedo and others (2018), Burke and Tanutama (2019) and Kahn and others (2019) show that the long-term macroeconomic impact of weather anomalies is uneven across countries and that economic growth responds nonlinearly to temperature.

Box 1. Effects of Climate Change

Sea level increase. Sea level is rising at an increasing rate, worsening the extent of high-tide flooding and storm surge around the world. Even if global warming stays below 2°C, sea levels are projected to surge 2-3 meters by 2300 and by 5-7 meters with faster global warming. By 2100, once-in-a-century coastal flood events will occur at least once per year at more than half of coastlines across the globe.

Widespread flooding. Climate change is intensifying the risk of floods as well as droughts. While more intense evaporation will lead to more droughts, warmer air can produce extreme rainfall. On average, the frequency of heavy downpours has already increased by about 30 percent and they contain about 7 percent more water.

Extreme heat waves. Extreme heat waves, such as the deadly one that occurred in many parts of North America in summer 2021, are already about five times more likely to occur with existing warming of 1.2°C. With global warming of 2°C, this frequency increases to 14 times as likely to occur. Heat waves are getting hotter, and with 2°C of global warming, the hottest temperatures would reach nearly 3°C higher than previous heat waves.

Severe droughts. Climate change is increasing the frequency and severity of droughts. Severe droughts that used to happen at an average of once per decade are now occurring about 70 percent more frequently. If global warming reaches 2°C above the preindustrial average, severe droughts will occur between two and three times as often.

Weather whiplash. Climate change is not just increasing the severity of extreme weather events, but it is also interrupting the natural patterns and creating a “weather whiplash”—wild swings between dry and wet extremes—destructive floods in one year and extreme droughts in the next.

Source: IPCC (2021).

III. Data Overview and Stylized Facts

This paper uses an unbalanced panel dataset of annual observations covering 39 countries in Europe during the period 1980–2019. The series are drawn from the IMF's International Financial Statistics and World Economic Outlook databases, the World Bank's World Development Indicators database, the U.S. Energy Information Administration, and the International Country Risk Guide. Summary statistics, presented in Table 1, indicate large variations in environmental outcomes in terms of CO_2 emissions in metric tons per capita[2] and energy security as measured by the ratio of net energy imports to GDP. The main explanatory variables of interest are energy efficiency (or intensity) as measured by energy consumption per unit of real GDP[3] and the share of nuclear, renewable and other non-hydrocarbon sources of energy, which show considerable heterogeneity across countries and over time. Following the literature, I introduce a set of control variables, including real GDP per capita, trade openness as measured by the share of international trade in GDP, population, the share of urban population in total, and a measure of institutional quality. It is necessary to analyze the time-series properties of the data to avoid spurious results by conducting panel unit root tests. The stationarity of all variables are checked by applying the Im-Pesaran-Shin (2003) and the Karavias-Tzavalis (2014) tests, which are widely used in the empirical literature to conduct a panel unit root test (with structural breaks in the case of the Karavias-Tzavalis (2014) procedure). The results, available upon request, indicate that the variables used in the analysis are stationary after logarithmic transformation or upon first differencing.

Table 1. Summary Statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
CO2 emissions per capita	1,471	7.6	4.1	0.6	34.5
Net energy imports	1,366	34.9	106.5	-843.5	100.0
Energy efficiency	1,361	5.8	6.6	1.6	166.9
Non-hydrocarbon energy	1,417	52.9	37.5	0.0	100.0
Real GDP per capita	1,544	25,204	21,154	619	112,373
Trade openness	1,492	96.0	52.7	13.4	380.1
Population	1,845	17,700,000	28,200,000	21,453	149,000,000
Urbanization	1,804	69.7	14.7	33.8	98.1
Bureaucratic quality	1,275	3.1	1.0	0.0	4.0

Source: EIA; IMF; World Bank; author's calculations.

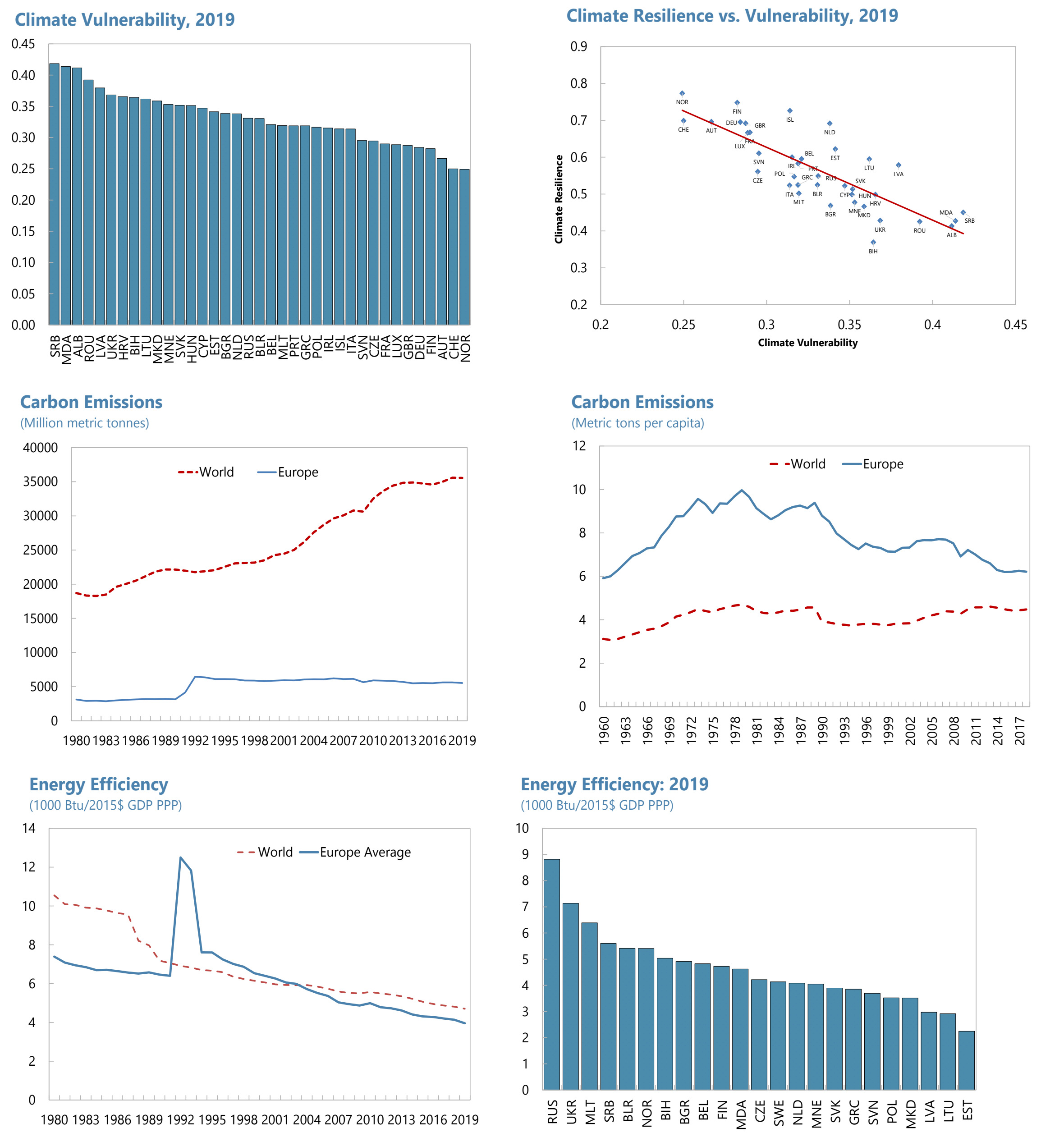
There is considerable heterogeneity in the vulnerability to climate change among European countries. As presented in Figure 3, some countries in Europe are almost twice as

[2] CO_2 emissions represent more than 80 percent of greenhouse gas emissions in Europe.

[3] While energy intensity measures the quantity of energy required per unit output at the aggregate level, energy efficiency measures the amount of energy used at the disaggregated level in individual activities. In this paper, I use these terms interchangeably to capture the amount of energy used to produce a unit of real GDP in a panel of countries. As presented in the charts in Figure 3, a lower reading of energy consumption per unit of real GDP implies a higher level of energy efficiency (or intensity).

vulnerable to threats associated with climate change than others. Furthermore, there is a significant relationship between climate change vulnerability and resilience. Countries with greater vulnerability also tend to be less resilient to climate change, according to the ND-GAIN indices. In the meantime, the evolution of CO_2 emissions shows Europe's greater progress relative to the rest of the world. There is a clear downward trend since 1980 both in advanced and developing European counties. However, the prevailing trend in CO_2 emissions, especially on a per capita basis, is still not consistent with the pathway to net zero emissions by 2050. This is largely due to Europe's dependence on hydrocarbons as a major source of energy source, even

Figure 3. Climate Vulnerability, CO_2 Emissions, Energy Efficiency



Source: ND-GAIN; EIA; World Bank; author's calculations.

as the share of non-hydrocarbon energy continues to increase across the continent. An important consideration with the energy mix is heavy reliance on imports, which account for over 60 percent of all forms of energy and as much as 90 percent in the case of natural gas. In this context, energy efficiency is a critical factor for reducing CO2 emissions and energy imports. Europe has made a significant progress—even more than the rest of the world—in energy efficiency and managed to reduce the amount of energy used to produce a unit of GDP by 46.4 percent over the past four decades. There is, however, still considerable cross-country variation, with the Baltics leading the rest in energy efficiency.

IV. Climate Change Mitigation

European countries still have ample opportunities to reduce CO_2 emissions through broad-based policies and reforms. In particular, there are three key areas where more ambitious and comprehensive initiatives could make a significant contribution towards net-zero emissions throughout Europe: (i) eliminating distortionary energy subsidies; (ii) introducing a carbon tax and fees on high-emission products combined with rebates on low-emission products; and (iii) improving energy efficiency and decarbonizing the energy sector.

Energy subsidies in Europe continue to distort economic incentives and contribute to environmental degradation. Subsidies on fossil fuels and electricity amount to significant amounts in some countries in Europe, but there is considerable variation in the size and types of energy subsidies. Fossil fuel subsidies are larger in commodity-rich countries, such as Russia, while electricity subsidies are more prevalent in the rest of the continent.[4] The widespread use of energy subsidies undermines fiscal sustainability, divert resources away from more productive areas (such as education and healthcare), benefits the rich more than the poor, and discourages efficiency improvements in the energy sector. Consequently, energy subsidies have become a distortionary burden on long-term economic growth and the environment due to overconsumption. More efficient pricing of energy, on the other hand, would reduce CO_2 emissions by more than a third relative to the baseline level, keep global warming below 1.5°C, raise additional revenues, and improve environmental quality (Parry, Black, and Vernon, 2021).

Fiscal policy measures, including a carbon tax on fossil fuels, are the most efficient tool for climate change mitigation. Even a modest carbon price can help mobilize investment in non-hydrocarbon sources of energy, encourage greater energy efficiency, and thereby induce significant abatement in CO_2 emissions (IMF, 2020b; Black and others, 2021; Gugler, Haxhimusa, and Liebensteiner, 2021; Parry, Black, and Roaf, 2021). As long as CO_2 emissions remain free, there is no effective incentive to alter behavior. In contrast, imposing a tax on CO_2 emissions relays a powerful signal throughout the economy. Carbon-intensive goods and services would become more expensive and rebalance consumption patterns toward low-carbon options. Black and others (2021) proposes a range of carbon taxes for advanced, high-income emerging markets and low-income emerging markets—$75, $50 and $25 per metric ton of CO_2 emissions,

[4] Even EU governments provided €112 billion in subsidies to the production and consumption of fossil fuels in 2021 (Nowag, Mundaca, and Åhman, 2021).

respectively.[5] It is also necessary to consider other measures such as "feebates"—fees on products with high emissions combined with rebates on products with low emissions—in carbon-intensive sectors.

Simulation exercises confirm the effectiveness of a carbon tax in reducing CO_2 emissions in line with the Paris Agreement. The simulation analysis, based on the Climate Policy Assessment Tool (CPAT) framework (IMF, 2019; Parry, Black, and Vernon, 2021), shows that fossil fuels are underpriced in European countries relative to negative externalities.[6] A comprehensive carbon tax would therefore help attain the optimal price that takes into account negative externalities and leads to convergence towards the emissions reduction target.[7] Table 2 presents the impact of an economy-wide carbon tax set to gradually increase to US$50 per metric ton of CO_2 emissions by 2030. Assuming that a carbon tax of US$50 per metric ton of CO_2 emissions is the only policy instrument used, the simulation results suggest that all Baltic countries would achieve reducing GHG emissions by 40 percent by 2030. There is, however, considerable variation across countries. While Estonia and Latvia would need higher carbon taxes to cut emissions in line with the targets, Lithuania would reduce emissions more than targeted with a carbon tax of US$50 per metric ton. This variation in the impact of a carbon tax reflects cross-country differences in emission-reduction targets and the existing energy mix, which lead to differences in the

Table 2. Impact of Carbon Tax in the Baltics and Beyond

	Carbon Tax of US$50 by 2030			
	Proportion of Emissions Gap Narrowed by Policy (percent)	Additional Fiscal Revenue (percent of GDP)	Real GDP Growth Impact (percentage points)	
Country			Full recycling of carbon tax	No recycling of carbon tax
Estonia	29.8	1.03	-0.19	-0.57
Latvia	77.4	0.64	-0.11	-0.35
Lithuania	119.8	0.75	-0.13	-0.41
Czech Republic	35.5	1.07	-0.20	-0.60
Germany	40.0	0.42	-0.08	-0.23
Hungary	94.4	0.95	-0.16	-0.52
Poland	54.6	1.38	-0.25	-0.77

Note: The impact of a carbon taxes per ton of CO2 is determined according to the CPAT framework as outlined in IMF (2019) and Parry, Black, and Vernon (2021).

Source: Author's calculations

[5] Only 17 percent of emissions are covered by a carbon price, which remains at an average of US$3 per metric ton of CO_2 emissions.

[6] The CPAT provides country-specific projections of fuel use and CO_2 emissions by the energy, industrial, transportation, and residential sectors. The model is parameterized using data compiled from the IEA on recent fuel use by country and sector. Real GDP projections are from the latest IMF forecasts. Data on energy taxes, subsidies, and prices by energy product and country is compiled from publicly available and IMF sources, with inputs from proprietary and third-party sources. International energy prices are projected forward using an average of IEA and IMF projections for coal, oil, and natural gas prices. Assumptions for fuel price responsiveness are chosen to be broadly consistent with empirical evidence and results from energy models.

[7] The Baltics participate in the EU Emissions Trading System (ETS), which covers only about 30 percent of national CO_2 emissions.

responsiveness of emissions to changes in fossil-fuel prices. Furthermore, since the CPAT uses price elasticity assumptions to determine changes to the energy mix, if a country initially has an exceptionally low level of renewable energy, changes in fossil-fuel prices will not elicit a large increase in renewables. Thus, non-tax policies are necessary to stimulate investment in alternative sources of energy, and these policies are not covered in the CPAT framework.

The economic impact of a carbon tax varies from country to country according to the initial energy matrix and upstream linkages in the energy sector. Simulations based on the CPAT model also show that there would be substantial revenue gains from the introduction of a carbon tax, with a moderate negative impact on economic growth. These macro-fiscal effects will vary from country to country according to the initial energy matrix and upstream linkages in the energy sector. For example, at US$50 per metric ton of CO_2 emissions, a carbon tax would yield additional revenue of 0.64 percent of GDP in Latvia and 0.75 percent of GDP in Lithuania and as much as 1.03 percent of GDP in the case of Estonia. The impact on economic growth, on the other hand, appears to be moderate (-0.4 percentage points for Lithuania, -0.35 for Latvia and -0.6 for Estonia) and small assuming that additional revenues are recycled back into the economy through lower taxes or higher investment spending (-0.1 percentage points in Lithuania and Latvia and -0.2 percentage points in Estonia). Furthermore, compensatory policies designed to recycle additional revenue through lowering other taxes and increasing targeted cash transfers and public investment can alleviate adverse effects on disposable household income.

Decarbonization must start in the energy sector, which is responsible for about 80 percent of CO_2 emissions in Europe. CO_2 emissions are a result of (i) population, (ii) GDP per capita, (iii) carbon content of energy resources, and (iv) energy consumption per unit of GDP. Reducing CO_2 emissions requires the reduction of one or more of these four factors, which implies that policies should focus on decarbonizing the energy matrix (lower CO_2 emissions per unit of energy) and enhancing energy efficiency (lower energy consumption per unit of GDP). While the amount of energy used to produce a unit of GDP declined by 55.4 percent across the world over the past four decades thanks to more energy-efficient production processes and greater energy efficiency of consumer goods and services, improving energy efficiency remains one of the most important factors to reduce CO_2 emissions and strengthen energy security.

A. Changing the Energy Matrix

Increasing the share of renewable, nuclear and other non-hydrocarbon energy should lower CO_2 emissions and strengthen energy security. This paper uses a conceptual framework that relates to CO_2 emissions and energy security to technological and regulatory improvements and policy choices as manifested in energy efficiency and the share of non-hydrocarbon energy, along with macroeconomic and institutional determinants. Moving away from fossil fuels can make a big contribution to efforts throughout Europe toward meeting the climate commitments by reducing CO_2 emissions. Hence, I empirically investigate the impact of nuclear, renewable and other non-hydrocarbon energy on CO_2 emissions in a panel of 39 countries in Europe over the period 1980–2019 according to the following specification:

$$y_{i,t} = \beta_1 + \beta_2 AE_{i,t} + \beta_3 X_{i,t} + \eta_i + \mu_t + \varepsilon_{i,t}$$

where $y_{i,t}$ denotes the logarithm of CO_2 emissions in metric tons per capita or energy security measured by net energy imports as a share of GDP in country i and time t; $AE_{i,t}$ is the share of alternative sources of energy including nuclear, renewable and other non-hydrocarbons; $X_{i,t}$ is a vector of control variables including the logarithm of real GDP per capita, trade openness, the logarithm of population, the share of urban population and a measure of institutional quality, which are commonly used in the literature (Narayan and Narayan, 2010; Piaggio and Padilla, 2012; Özbuğday and Erbaş, 2015; Gökgöz and Güvercin, 2018; Tajudeen, Wossink, and Banerjee, 2018; Xia and others, 2020; Cevik, 2022a; 2022b). The η_i and μ_t coefficients denote the time-invariant country-specific effects and the time effects controlling for common shocks that may affect CO_2 emissions and energy security across all countries in a given year, respectively. $\varepsilon_{i,t}$ is the error term. To account for possible heteroskedasticity, robust standard errors are clustered at the country level.

Estimation results, presented in Table 3, confirm that the shift away from hydrocarbon sources of energy helps reduce CO_2 emissions and bolsters energy security. The estimated coefficient on non-hydrocarbon energy is highly significant. In the case of all European countries, a 10 percentage point increase in the share of non-hydrocarbon energy is associated with lower CO_2 emissions of 3 percentage points in the long run, after controlling for economic, demographic, and institutional

Table 3. Non-Hydrocarbon Energy, CO_2 Emissions and Energy Security

	CO_2 Emissions			Energy Imports		
	All	AEs	EMs	All	AEs	EMs
Non-hydrocarbon energy	**-0.003*** **	**-0.001*** **	**-0.012*** **	**-0.006*** **	**-0.003*** **	**-0.022*** **
	[0.002]	**[0.001]**	**[0.002]**	**[0.005]**	**[0.002]**	**[0.012]**
Real GDP per capita	0.618***	0.419***	0.689***	0.447***	0.229***	1.733***
	[0.117]	[0.105]	[0.169]	[0.310]	[0.344]	[0.731]
Trade openness	-0.001*	-0.001*	-0.001*	0.001*	0.001*	0.005*
	[0.001]	[0.001]	[0.001]	[0.001]	[0.002]	[0.004]
Population	0.663*	0.376*	2.007***	-0.125*	-0.129*	2.176*
	[0.348]	[0.167]	[0.298]	[0.620]	[0.712]	[1.483]
Urbanization	0.005	0.008	0.003	0.046*	0.057*	0.052*
	[0.008]	[0.006]	[0.008]	[0.024]	[0.031]	[0.073]
Bureaucratic quality	0.048	0.143	0.020	0.062	0.017	0.272
	[0.056]	[0.048]	[0.066]	[0.078]	[0.098]	[0.193]
Number of observations	1,145	823	322	874	640	234
Number of countries	39	27	12	37	26	11
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj R^2	0.41	0.56	0.78	0.45	0.46	0.44

Note: The dependent variable is carbon emissions in metric tons per capita and energy security as measured by the share of net energy imports in total energy use. Robust standard errors, clustered at the country level, are reported in brackets. A constant is included in each regression, but not shown in the table. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Source: Author's estimations.

factors.[8] The magnitude of this effect is even greater among emerging European countries, with a coefficient of -0.012 compared to -0.001 in advanced European economies. The analysis also shows that reducing reliance on hydrocarbon-based energy has a highly significant effect on energy security. For the full sample of countries, a 10 percentage point increase in the share of non-hydrocarbon energy is associated with a reduction of 6 percentage points in energy imports, after controlling for conventional factors. The magnitude of this effect is significantly greater with a coefficient of -0.022 among emerging European countries compared to -0.003 in advanced economies. All in all, these empirical findings confirm that decarbonization not only has a central role in mitigating CO_2 emissions, but also in bolstering energy security throughout Europe.

B. Improving Energy Efficiency

Greater energy efficiency brings a significant reduction in CO_2 emissions and strengthens energy security. Improving energy efficiency—measured as energy intensity of economic activity—can make a big contribution to efforts throughout Europe toward meeting the climate commitments by reducing CO_2 emissions per capita. There is anecdotal evidence indicating that countries with greater energy efficiency tend to have lower energy imports and CO_2 emissions, as well as lower energy cost for consumers. Accordingly, this paper also investigates the impact of energy efficiency on CO_2 emissions and energy security, as defined above, in a panel of 39 countries in Europe over the period 1980–2019, employing the following specification:

$$y_{i,t} = \beta_1 + \beta_2 EE_{i,t} + \beta_3 X_{i,t} + \eta_i + \mu_t + \varepsilon_{i,t}$$

where $y_{i,t}$ denotes the logarithm of CO_2 emissions per capita or net energy imports as a share of GDP in country i and time t; $EE_{i,t}$ is energy efficiency as measured by the logarithm of energy consumption per unit of real GDP; $X_{i,t}$ is a vector of control variables including the logarithm of real GDP per capita, trade openness, the logarithm of population, the share of urban population, and a measure of institutional quality. As above, the η_i and μ_t coefficients denote the time-invariant country-specific effects and the time effects controlling for common shocks that may affect CO_2 emissions and energy security across all countries, respectively. $\varepsilon_{i,t}$ is the error term. To account for possible heteroskedasticity, robust standard errors are clustered at the country level.

Estimation results, presented in Table 4, confirm that improving energy efficiency reduces CO_2 emissions and strengthens energy security. The estimated coefficient on energy efficiency is economically and statistically highly significant. Broadly in line with previous studies, a 10 percentage point increase in energy efficiency is associated with lower CO_2 emissions of 8.8 percentage points and energy imports of about 2 percent over the long run, after controlling for economic, demographic, and institutional factors. These effects of energy efficiency are significant across all country groups, but appear to be stronger among advanced economies, which could reflect greater efficiency gains in advanced economies in the past. Nevertheless, these findings indicate that improving energy efficiency can play a fundamental role in mitigating CO_2 emissions and strengthening energy security by reducing dependence on imported sources of energy. Therefore, to

[8] The estimated coefficients on control variables have the expected signs and some are also statistically significant.

decarbonize economic activity, policies and reforms should aim to improve energy efficiency in commercial and residential use as much as shifting the energy matrix away from fossil fuels.

Table 4. Energy Efficiency, CO_2 Emissions and Energy Security

	CO_2 Emissions			Energy Imports		
	All	AEs	EMs	All	AEs	EMs
Energy efficiency	**-0.088*** **	**-0.121*** **	**-0.046*** **	**-0.019*** **	**-0.047*** **	**-0.013*** **
	[0.015]	**[0.013]**	**[0.014]**	**[0.040]**	**[0.038]**	**[0.049]**
Real GDP per capita	0.875***	0.860***	0.678***	0.402***	0.193***	1.663***
	[0.106]	[0.124]	[0.163]	[0.305]	[0.330]	[0.763]
Trade openness	-0.001*	-0.000*	-0.002*	0.001*	0.001*	0.006*
	[0.001]	[0.001]	[0.001]	[0.001]	[0.002]	[0.005]
Population	0.004	0.301	1.065*	0.365	0.500	2.096
	[0.237]	[0.214]	[0.273]	[0.513]	[0.684]	[1.901]
Urbanization	0.006	0.005	0.005	0.044*	0.057*	0.064*
	[0.005]	[0.004]	[0.008]	[0.023]	[0.030]	[0.067]
Bureaucratic quality	0.028	0.076	0.015	0.054	0.028	0.282
	[0.031]	[0.039]	[0.050]	[0.076]	[0.082]	[0.228]
Number of observations	1,143	825	318	880	646	234
Number of countries	38	26	12	36	25	11
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj R^2	0.62	0.67	0.74	0.45	0.46	0.39

Note: The dependent variable is carbon emissions in metric tons per capita and energy security as measured by the share of net energy imports in total energy use. Robust standard errors, clustered at the country level, are reported in brackets. A constant is included in each regression, but not shown in the table. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Source: Author's estimations.

V. CLIMATE CHANGE ADAPTATION

European countries need to mainstream climate change adaptation into development plans to become more resilient. Long-term risks associated with climate change cannot be completely eliminated, which means government must take decisive action to strengthen physical, financial, institutional and social resilience. A variety of adaptation measures have been introduced to enhance resilience to climate change, but there are still significant gaps that keep the region vulnerable to threats associated with climate change. Enhancing structural resilience requires infrastructure and other ex-ante investments to limit the impact of disasters, including "hard" policy measures (e.g., upgrading public infrastructure), and "soft" measures (e.g. developing early warning systems and strengthening zoning and building codes); building financial resilience involves creating fiscal buffers and using prearranged financial instruments to protect fiscal sustainability and manage recovery costs; and post-disaster and social resilience requires contingency planning and related investments ensuring a speedy response to a disaster.

There are upfront fiscal costs of climate change adaptation but investing in structural resilience would yield long-run benefits. Although climate change adaptation has significant upfront costs, the lack of inaction on the climate front would have an even greater cost for generations. Furthermore, investing in climate-resilient infrastructure would reduce damage from natural disasters and increase expected returns to private investment and output. Well-designed policy measures could also have sustained expansionary effects through higher growth in employment and wages and lower migration, which tends to occur in countries that are more vulnerable to climate-related natural disasters.

Nature-based solutions are essential in the fight against climate change and could also contribute to the development of new business opportunities. There is growing recognition that climate change is causing biodiversity loss across the world, while nature has a fundamental role in climate change mitigation and adaptation (IPBES, 2019). In view of these interlinkages, nature-based solutions—designed to protect, sustainably manage and restore natural ecosystems—can become highly effective in providing economic well-being as well as greater biodiversity benefits. In particular, nature-based solutions can be applied to address a range of climate risks, including coastal hazards, floods and soil erosion, and rising temperatures and drought (Kapos and others, 2019). Another important advantage of nature-based solutions for adaptation is the cost, which tends to be significantly less than traditional infrastructure for addressing climate hazards (Narayan and others, 2016; Reguero and others, 2020) and generate substantial economic and social benefits (Rizvi, 2014; Menéndez and others, 2020; Seddon and others, 2020).

Financing climate change mitigation and adaptation efforts will require mobilizing additional resources and reforming public financial management. Adapting to climate change is not cheap, and it will require substantial amount of additional upfront resources to invest in physical infrastructure and other key areas to increase resilience and lessen the macro-financial impact of climate change. In this context, green financing could provide valuable resources for sustainable investment projects. The sustainability-linked debt market has reached US$2.5 trillion with net new issuance of US$660 billion in 2020. The most significant component of this market in terms of size and environmental impact is green bonds that are used to finance projects to facilitate climate change adaptation and mitigation. Despite its rapid growth, however, sovereign green bonds remain small—about 1 percent—compared to traditional debt instruments issued by governments. Countries with significant climate-related investment needs must improve the institutional framework, including robust and transparent public financial management systems and processes, to gain full access to the global flow of green financing (Mejía-Escobar, González-Ruiz, and Franco-Sepúlveda, 2021).

VI. Conclusion

Europe is facing the double jeopardy of climate change and energy insecurity, with far-reaching economic and financial repercussions. The global average surface temperature has already increased by about 1.1 degrees °C compared with the preindustrial average, which amplifies the frequency and severity of climate shocks across the world. Within Europe, the Baltic Sea region is particularly vulnerable to global warming caused by climate change, with an annual warming trend twice as much as the global average. At the same, the explosion of geopolitical tensions triggered by Russia's invasion of Ukraine has unsettled global energy markets. While it is still too early to know how events might unfold, the crisis will likely result in long-lasting changes in energy supply networks and energy sources in the generation of electricity. This is why addressing climate change and strengthening energy security are the two faces of the same coin. Policies and structural reforms aimed at reducing dependence on fossil fuels would deliver not only a significant reduction in CO_2 emissions, but also help improve energy security throughout Europe.

Well-designed policies and structural reforms would help reduce CO_2 emissions and strengthen energy security. To guard against threats associated with climate change, countries need to proceed on two fronts: (i) climate mitigation, which refers to policies that help reduce CO_2 emissions and (ii) climate adaptation, which refers to efforts to adapt to the effects of climate change including through minimizing damages from climate-related disasters as well as to adapt to the effects of economic transformations. Using a panel of 39 countries in Europe over the period 1980–2019, the empirical analysis presented in this paper indicates that increasing the share of nuclear, renewables, and other non-hydrocarbon energy and improving energy efficiency could lead to a significant reduction in CO_2 emissions and improve energy security throughout Europe.[9] From a risk-reward perspective, the benefits of reducing the risks of climate change and strengthening energy security clearly outweigh the potential cost of mitigation policies in the short run. Environmental taxes, including a comprehensive, economy-wide carbon tax on fossil fuels, could also raise considerable revenues, which can expand the post-pandemic fiscal space and provide additional funding to compensate the most vulnerable households, build a multilayered safety net, and strengthen structural resilience.

European countries must mainstream adaptation into development plans to strengthen resilience against climate change. Long-term climate risks cannot be completely eliminated, and thus governments must take decisive action to strengthen physical, financial, institutional and social resilience. A variety of adaptation measures have been introduced to enhance resilience to climate change throughout Europe, but there are still significant gaps that keep some countries, such as the Baltics, more vulnerable to threats associated with climate change. Enhancing structural resilience requires infrastructure and other ex-ante investments to limit the impact of disasters, while building financial resilience involves creating fiscal buffers and using prearranged financial instruments to protect fiscal sustainability and manage recovery costs. These measures will have upfront fiscal costs, but the lack of inaction on the climate front would have an even greater cost for generations. Furthermore, strengthening physical and financial resilience would reduce damages from climate change and increase expected returns to private investment and output.

[9] There are also studies showing that increasing the share of renewable sources of energy has a positive effect on economic growth (Narayan and Doytch, 2017; Doytch and Narayan, 2021).

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