THE INTERACTION BETWEEN POLICY UNCERTAINTIES AND CLIMATE CHANGE: EVIDENCE FROM EMERGING AND DEVELOPED COUNTRIES

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Evidence from Emerging and Developed Countries

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ABSTRACT

The Interaction between Policy Uncertainties and Climate Change:

Evidence from Emerging and Developed Countries

Since the turn of the twenty-first century, the world has experienced many episodes of high economic policy uncertainty (EPU). Recent repercussions of climate change also raised concerns about climate policy uncertainties (CPU). The thesis aims to investigate the interactions of EPU and CPU with climate change for emerging (EME) and developed countries. It also tests Environmental Kuznets Curve (EKC) hypothesis that proposes an inverted U-shaped curve between affluence and environmental degradation. Two models were created and tested, Model 1 with EPU and Model 2 with CPU. Pooled Mean Group (PMG) estimations with Model 1 reveal that population escalates climate change in both country groups in the long-term. Consistent with consumption effect, EPU decreases consumption of energy and pollution-intensive commodities and mitigates climate change in EMEs in the long-term. Renewable energy consumption also alleviates climate change in both country groups in the short-term. Thus, energy transition holds the key to tackling climate change. The EKC hypothesis is verified only with Model 1 and for EMEs, implying that they are expected to benefit from increased adoption of clean technologies. In Model 2, EKC hypothesis cannot be verified in any country groups but CPU alleviates climate change in EMEs in the short-term. This might be because of the reliance of economic agents` decisions on current and future policy expectations. In the additional analysis, we find evidence in OECD countries for the interrelation of energy-related indicators with current account deficit. We conclude that energy policies are related to the well-being of countries’ economies.

ÖZET

Politika Belirsizlikleri ve İklim Değişikliği Arasındaki Etkileşim:

Gelişmekte Olan ve Gelişmiş Ülkeler Örneği

Yirmi birinci yüzyılın başlangıcından bu yana, dünyada birçok kez yüksek ekonomi politika belirsizliği (EPB) dönemi yaşanmıştır. İklim değişikliğinin son zamanlardaki yansımaları, iklim politika belirsizliklerine (İPB) ilişkin endişeleri de artırmıştır. Bu tez, gelişmekte olan ülkeler (GOÜ) ve gelişmiş ülkelerde EPB ve İPB'nin iklim değişikliği ile etkileşimini incelemektedir. Aynı zamanda refah ile çevresel bozulma arasında ters U şeklinde bir eğri öneren Çevresel Kuznets Eğrisi (ÇKE) hipotezini de test etmektedir. Bu amaçla, EPB'li Model 1 ve İPB'li Model 2 olmak üzere iki model oluşturulmuştur. Havuzlanmış Ortalama Grup (PMG) tahmincisi Model 1 sonuçlarına göre, nüfus iki ülke grubunda da uzun dönemde iklim değişikliği problemini artırmaktadır. EPB, tüketim etkisiyle tutarlı şekilde, enerji ve kirlilik yoğun emtiaların tüketimini azaltarak, GOÜ'lerde uzun dönemde iklim değişikliğini hafifletmektedir. Yenilenebilir enerji tüketimi ise, iki ülke grubunda da kısa dönemde iklim değişikliğini hafifletmekte olup, enerji dönüşümünün iklim değişikliğiyle mücadelede anahtar rol oynadığı ortaya konmaktadır. ÇKE hipotezi ise yalnızca Model 1'de, GOÜ'ler için doğrulanmaktadır. Bu sonuç, GOÜ'lerin temiz teknolojileri daha fazla benimsemesinin olumlu olduğunu ima etmektedir. Model 2'de hiçbir ülke grubu için ÇKE hipotezi doğrulanamazken, İPB'nin kısa dönemde gelişmekte olan ülkelerde iklim değişikliğini hafiflettiği görülmektedir. Tezin ilave analizinde, EİKT ülkelerinde enerjiye ilişkin göstergelerin cari açıkla ilişkisine dair kanıtlar bulunurken, enerji politikalarının ülke ekonomilerinin refahıyla bağlantılı olduğu sonucuna varılmaktadır.

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To my Dad whom I miss so much…

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ABBREVIATIONS

AMG	Augmented Mean Group
ARDL	Autoregressive Distributed Lag
CD	Cross-sectional Dependence
CIPS	Cross-sectional Im, Peseran, Shin
CO_2	Carbon dioxide
COP	Conference of the Parties
CPU	Climate Policy Uncertainty
EF	Ecological Footprint
EME	Emerging Market Economies
EKC	Environmental Kuznets Curve
EPU	Economic Policy Uncertainty
EU	European Union
FDI	Foreign Direct Investment
GEPU	Global Economic Policy Uncertainty
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GPR	Geopolitical Risk
IEA	International Energy Agency
IMF	International Monetary Fund
IRENA	International Renewable Energy Agency
LM	Lagrange Multiplier
MDBs	Multilateral Development Banks
NARDL	Non-linear Autoregressive Distributed Lag

NDC	Nationally Determined Contribution
OECD	Organization for Economic Co-operation and Development
PMG	Pooled Mean Group
PPP	Purchasing Power Parity
PV	Photovoltaic
R&D	Research and Development
SDGs	Sustainable Development Goals
UK	United Kingdom
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
USD	United States Dollar
VAR	Vector Autoregressive
WB	World Bank

CHAPTER 1

INTRODUCTION

The concept of sustainability was first formulated at the first United Nations (UN) conference on the environment in 1972. However, it has only really taken shape since 1987, when Brundtland Report ("Our Common Future") clarified the goals of sustainable development. The report highlights that humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own (UNEP, 1987).

Although sustainable development encompasses the connections between the environmental, social, economic and technological aspects of development, environmental sustainability has recently taken center stage. Environmental sustainability refers to the ability to preserve and protect the natural environment over time through appropriate practices and policies. Recently increased attention of the public and many other stakeholders to the concept of environmental sustainability is mainly due to the repurcussions of climate change on the environment, economies and societies.

Burning of fossil fuels like coal, oil and gas generates greenhouse gas (GHG) emissions and causes temperatures to rise. Climate change refers to the long-term shifts in temperatures and weather patterns. Although such shifts can be natural, due to changes in the sun's activity or large volcanic eruptions, human activities have been considered the main driver of climate change since the 1800s. (UN, 2023a). To tackle climate change, climate action is proposed as the 13th goal of the seventeen

Sustainable Development Goals (SDGs) specified in the “2030 Agenda for Sustainable Development” that was adopted by all UN members in 2015.

Despite the updated national pledges by jurisdictions in the 2023 United Nations Climate Change Conference (Conference of the Parties—COP), the international community is far from achieving the Paris Agreement goal of limiting global warming to well below 2 °C, preferably to 1.5 °C. Crippa et al. (2023) highlights that global greenhouse gas emissions started to grow again just after the peak of the pandemic, reaching the level of 53.8 gigatons CO_2 equivalent in 2022, which is 2.3% and 1.4% higher than the levels in 2019 and in 2021, respectively. Based on the same source, China, the United States (US), India, the EU27, Russia and Brazil were the six largest greenhouse gas emitters in 2022. Together they account for 50.1% of the global population, 61.2% of global GDP, 63.4% of global fossil fuel consumption and 61.6% of global GHG emissions. As supported by the above figures, the 2023 Emission Gap Report also reveals that fully implementing unconditional Nationally Determined Contributions (NDCs) made under the Paris Agreement points to limiting the rise in global temperature to 2.9 °C above pre-industrial levels by the end of the century (UN, 2023b).

To ensure full and effective implementation of the United Nations Framework Convention on Climate Change (UNFCCC) and to comply with the climate mitigation goals of the Paris Agreement, vast amounts of investment in low-carbon infrastructure and clean technologies will be needed over the next decades. The Sharm el-Sheikh Implementation Plan highlights that almost 4 trillion United States dollar (USD) per year needs to be invested in renewable energy up until 2030 to be able to reach the global net zero emission target by 2050 (UN, 2022). Energy accounts for more than two-thirds of global emissions and thus energy transition holds the key to tackling climate change and the global energy crisis. Furthermore, a global transformation to a low-carbon economy is expected to require investment of at least USD 4–6 trillion per year, including energy investments. However, there exists a huge financing gap that needs to be addressed.

Due to the limited fiscal policy space in the aftermath of COVID-19 and the still prevailing global energy crisis, public investment alone is insufficient for achieving the transition. Thus, private sector resources should play a complementary role. However, many barriers exist against the private sector’s climate investments. Large uncertainties about the development of climate-related technologies, lower and potentially delayed financial returns of climate projects, and unclear future climate policies are among these barriers (Berestycki et al., 2022). Since private sector investments in climate-friendly, low-carbon or green technologies are significantly reliant on current and future policies (both economic and climate policies), there is great concern among private sector actors about policy uncertainties.

This thesis aims to find evidence for the interrelation of policy uncertainties with climate change. While starting with an investigation of the interaction between economic policy uncertainty (EPU) and climate change in a group of countries, the study expands the discussion to the interaction of climate policy uncertainty (CPU) with climate change in a subset of countries. Investigating the interrelation between carbon dioxide (CO_2) emissions and selected variables; namely, the real Gross Domestic Product (GDP) per capita, squared real GDP per capita, renewable share in consumption, the EPU, the CPU and population, the research highlights the differences between emerging and developed countries.

The thesis also tests the Environmental Kuznets Curve (EKC) hypothesis that proposes an inverted U-shaped curve between affluence and environmental degradation. High levels of economic activity are argued to cause significant environmental problems or damages that negatively impact sustainable development. However, the reversed argument might also be valid as there is a need for combating environmental problems without compromising economic prosperity. Specifically, for emerging countries, there is a need to be mindful of the particular trade-offs between supporting overall economic growth and sustainable growth. Thus, an investigation of the relationship between economic growth and the environment will be helpful in devising appropriate policies to support the sustainable development.

Furthermore, the thesis acknowledges that energy has been the main contributor to climate change since the 2000s but it is also a key to the solution. Renewable energy sources, which are replenished by nature and abundantly available, emit little to no greenhouse gases or pollutants into the air. Thus, these sources undoubtedly support decarbonization efforts, while also improving energy independence of jurisdictions. The recent energy crisis also stressed the importance of diversifying the energy mix in favor of renewable energy. On a positive note, the renewable energy capacity around the world more than doubled in the 10 years between 2013 and 2022. While global renewable capacity was 1567 gigawatts in 2013, it reached to 3381 gigawatts in 2022 (IRENA, 2023). Arguing for the crucial role of renewable energy in decarbonization efforts, we test the EKC hypothesis by incorporating the renewable energy indicator into the model.

The second chapter focuses on the interaction of policy uncertainties as well as renewable energy indicator with climate change, while also testing the EKC hypothesis for emerging and developed countries. This part of the research contributes to the existing body of literature in two dimensions. First, to the best of our knowledge, this is the first study to investigate the interrelation of CPU with climate change, differentiating between emerging and developed countries. The EPU index introduced by Baker et al. (2016) has been frequently used by prior studies, but the CPU index introduced by Berestycki et al. (2022) is a new indicator used to assess the level of domestic climate policy uncertainty over time and is the first of its kind. Both indexes use the same methodology and reflect the frequency of articles in leading newspapers, which contain specific terms either related to economic policy uncertainty or climate policy uncertainty. The second contribution of this part of thesis is that it proposes new evidence related to the EKC hypothesis, differentiating between emerging and developed countries.

The thesis continues with the third chapter that empirically investigates the role of energy policies on the well-being of selected Organization for Economic Co-operation and Development (OECD) economies. The main aim of this section is to find empirical evidence for the interaction of energy-related indicators with the current account deficit, an important macroeconomic indicator that policymakers gauge in devising policies. This part of the thesis contributes to the existing body of literature in two dimensions. First, it differs from other studies as it investigates the relationship among selected variables, specifically for OECD economies, and by additionally grouping sample countries based on per capita GDP levels. Contrary to earlier literature that investigates the relationship of renewable energy-related indicators with selected macroeconomic indicators, this part of the research also tests the twin deficit hypothesis, utilizing country-based annual data from 1990 to 2021.

The literature, data, model and methodology and estimation results of the each of upcoming two chapters of the thesis are presented separately.

The fourth and the last part chapter of the thesis concludes the study. This section summarizes key findings and proposes valuable policy recommendations based on the estimation results of the earlier two chapters. Finally, the limitations and further improvement areas are also discussed in this section.

CHAPTER 2

THE INTERACTION OF EPU AND CPU WITH CLIMATE CHANGE AND THE TEST OF EKC HYPOTHESIS: EVIDENCE FROM EMERGING AND DEVELOPED COUNTRIES

This section aims to investigate the role that policy uncertainties might play on climate change, both in emerging and developed economies, while also testing the EKC hypothesis that proposes an inverted U-shaped curve between affluence and environmental degradation. More specifically, this section explores the interrelation between carbon dioxide emissions and selected variables; namely, the real GDP per capita, squared real GDP per capita, renewable share in consumption, the EPU, the CPU and population.

The remainder of the section is ordered as follows. Section 2.1 reviews the literature in three channels: first focusing on the drivers of climate change, second focusing on the EPU and the impact of EPU on climate change, and third, the impact of CPU on climate change and how climate policies affect innovation and investments in low-carbon technologies. Research questions and hypotheses are discussed in Section 2.2, while Section 2.3 describes the data. Section 2.4 presents the theoretical and empirical model as well as the methodology. Section 2.5 discusses empirical estimation results based on the ex-ante hypotheses put forward.

2.1 Literature review

2.1.1 Literature on determinants of climate change

Since CO_2 emissions constitute 76% of the total global greenhouse gas emissions, many studies use CO_2 emissions as a proxy for “climate change” or “environmental degradation”. While environmental degradation covers an extensive range of issues related to the pollution of air, water and soil, greenhouse gas emissions, climate change, biodiversity and waste management; climate change focuses on air pollution and carbon emissions. Thus, climate change might be considered as a subset of environmental degradation. However, many studies as well as ours use these two terms interchangeably.

Earlier literature frequently investigated the drivers of CO_2 emissions. The investigated factors include economic growth, energy consumption, foreign direct investment (FDI), foreign trade, and renewable energy for different country groups. For instance, Al-Mulali & Özturk (2019) reported that energy consumption, urbanization, trade and industrialization are key determinants of environmental degradation in the Middle East and North Africa region. Similarly, Baloch et al. (2019) focused on fifty-nine Belt and Road countries and found that economic growth, energy consumption, urbanization, foreign direct investment (FDI) and financial development surge environmental degradation. The results are quite similar in Alola et al. (2019) study that named economic growth and energy consumption as the key determinants of environmental degradation in sixteen European Union (EU) countries. Nathaniel et al. (2020) also found that economic growth, energy consumption, financial development, urbanization and non-renewable energy consumption escalate environmental degradation, whereas renewable energy consumption impedes environmental degradation.

However, all these studies stated above are built on Kuznets (1955) which conceptualizes the Environmental Kuznets Curve (EKC). Later, Grossman and Krueger (1991) proposed a non-linear relationship between economic growth and environmental degradation, illustrated by the inverted U-shaped curve (Figure 1).

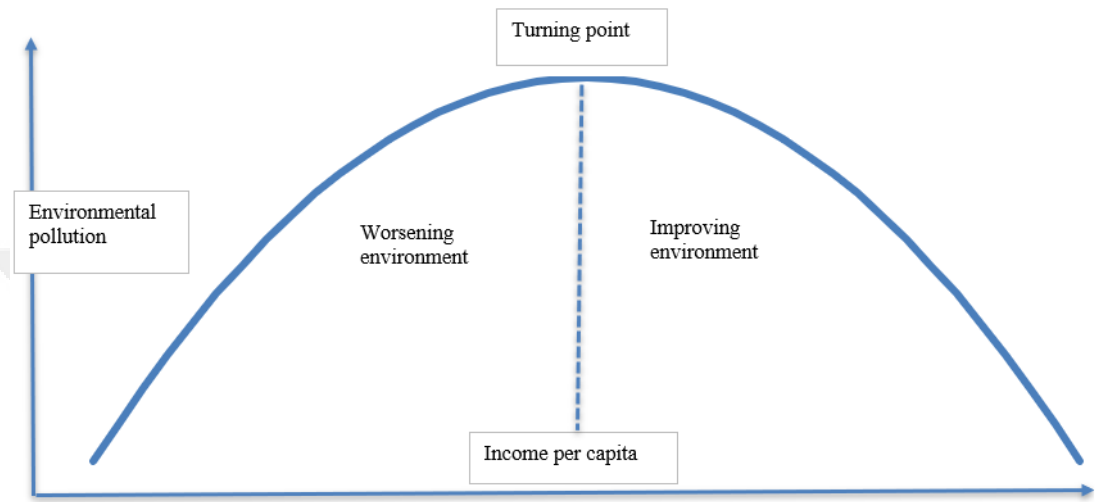


Figure 1. Environmental Kuznets Curve (EKC)

EKC hypothesizes that a rise in real GDP per capita initially leads to an increase in CO_2 emissions in the first stages of economic growth due to fossil-based energy consumption. However, after reaching a certain turning point, economic growth leads to a decrease in CO_2 emissions due to the adoption of clean technologies and policies.

As one of the most recent studies, Işık et al. (2023) tested the EKC hypothesis in BRIC and G7 countries. They confirmed the EKC hypothesis for G7 countries and argued that a turning point takes place earlier if the renewable consumption indicator is added to the model. However, the study found no evidence supporting the EKC hypothesis for the BRIC countries.

Contrary to the studies that confirm the EKC hypothesis and argue for the efficiencies gained from the adoption of clean technologies and policies, there are some studies that have found evidence in the opposite direction and reaffirm the Jevons paradox of Jevons (1865). The Jevons paradox is first expressed in relation to the use of coal and argues that an increase in the efficiency of using a resource leads to increased usage of that resource rather than to a reduction in its usage. Later, Polimeni and Polimeni (2006) used energy data from the Energy Information Administration and developed models that provide empirical support for the Jevons paradox on a macro level. They found that high efficiency is associated with high levels of resource consumption. Polimeni et al. (2008) also provide evidence for the existence of the Jevons paradox and apply it to complex systems.

More recent literature investigates the impact of other specific factors on climate change. For instance, Mongo et al. (2021) investigates the association of environmental innovations, namely the effect of green technologies on CO_2 emissions, in fifteen EU countries. In the model, they try to find the interrelation of environmental innovations, renewable energy consumption, GDP per capita and the degree of economic openness with CO_2 emissions. Their results reveal that environmental innovations would reduce CO_2 emissions in the long run, while the effect of environmental innovations is reversed in the short run, indicating a possible rebound effect.

In summary, an examination of this line of literature reveals that most of the literature uses CO_2 emissions as a proxy for climate change or environmental degradation and tries to find the determinants. The studies discussed above either employ Panel Autoregressive Distributed Lag (ARDL) or Panel Augmented Mean Group (AMG) estimators to investigate their specific research question.

2.1.2 Literature on the impact of EPU on climate change

The uncertainty in the economic environment, caused by unpredictable government and macroeconomic policies, political instability and market volatility is known as Economic Policy Uncertainty (EPU). Figure 2 depicts the level of monthly global economic policy uncertainty index (GEPU) from 1997 to 2023. The GEPU Index is a GDP-weighted average of national EPU indices for twenty-one countries: Australia, Brazil, Canada, Chile, China, Colombia, France, Germany, Greece, India, Ireland, Italy, Japan, Mexico, the Netherlands, Russia, South Korea, Spain, Sweden, the United Kingdom (UK), and the US. It is witnessed from the data that recent events, such as the financial crisis, oil price shocks or fluctuations, Brexit, the US–China trade war, the COVID-19 pandemic, the Russia–Ukraine conflict and the subsequent energy crisis, have surged the global economic policy uncertainty (EPU, 2022).

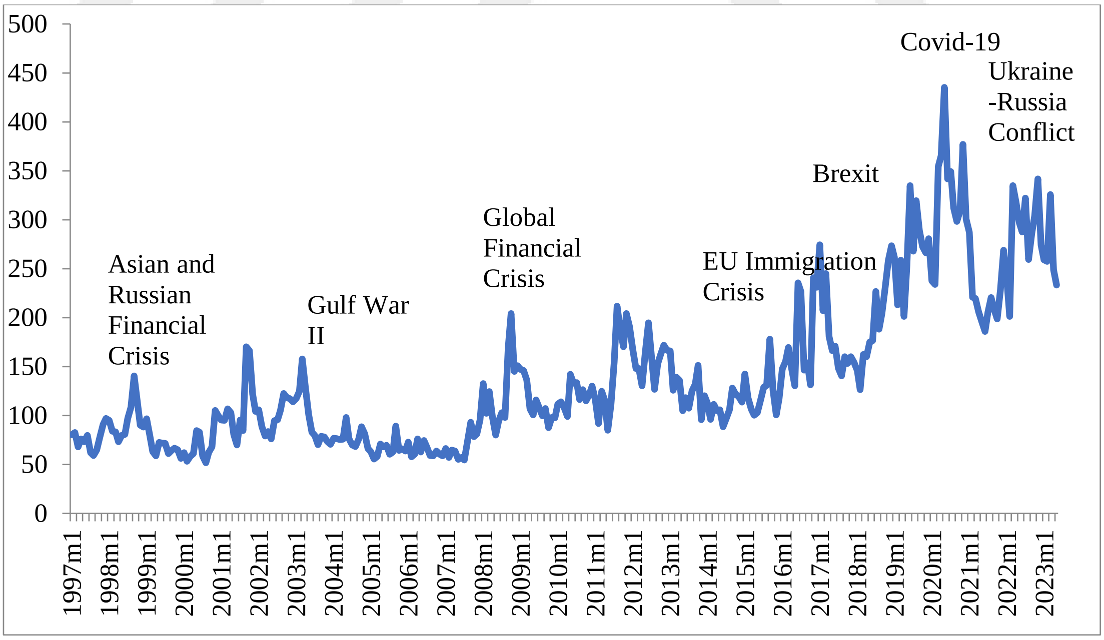


Figure 2. Monthly global economic policy uncertainty index

Empirical studies related to the impact of policy uncertainty on various other economic indicators rely on the extent to which policy uncertainty may be effectively captured. Baker et al. (2016) developed a now widely used indicator of global and country-based economic policy uncertainty. They achieved a major step in constructing a breakthrough index that defines policy uncertainty from an economic perspective. They constructed their index based on newspaper article counts. Each national EPU index reflects the relative frequency of own-country newspaper articles that contain a trio of terms related to the economy (E), policy (P) and uncertainty (U) in that month. Going one step further and merging the index with firm-level data, they also empirically show that economic policy uncertainty is associated with greater stock price volatility, reduced investment and employment in policy-sensitive sectors like defense and healthcare.

Following this phenomenal research, their index was applied to other empirical settings. The existings literature shows that EPU can impact various macroeconomic and financial indicators, such as oil prices (Cheng et al., 2019; Elder and Serletis, 2010; Kang and Ratti, 2013; Van Robays, 2016) and firms' investment choices (Bernanke, 1983; Bloom et al., 2007; Handley and Limão, 2015; Kellogg, 2014). For instance, Şahinoz and Erdoğan (2018) report that EPU affects economic growth; Kang and Ratti (2013) report that EPU has an impact on energy prices; while Rehman and Apergis (2019) and Kang et al. (2014) focuses on the impact of EPU on stock markets and firm-level investments, respectively.

The EPU literature related to our study is the one that deals with the environmental impacts of EPU. The evidence for the direction (positive or negative) of interaction between EPU and the environment is mixed and does not have a real consensus. While some studies (Wang et al., 2020, Anser et al., 2021) report that

EPU surges environmental degradation, other studies (Syed and Bouri, 2021, Chen et al., 2021) find that EPU plunges environmental degradation. In addition, Anser et al. (2021) explore the impact of EPU and geopolitical risk (GPR) on environmental degradation in selected emerging countries. Their findings reveal that EPU and non-renewable energy consumption escalate environmental degradation proxied by ecological footprint (EF), whereas GPR and renewable energy decrease EF.

We base our discussion on the ex-ante hypotheses of Wang et al. (2020) that propose two channels that relate EPU with environmental degradation: i. consumption (mitigating) effect, and ii. investment (escalating) effect. According to the consumption effect, EPU decreases use of energy and pollution-intensive commodities, negatively affects economic activity, and as a result mitigates environmental degradation. However, the investment effect asserts that EPU impedes the investment in renewable energy, environmentally related research and development (R&D) and innovation, which ultimately escalates the environmental degradation.

2.1.3 Literature on climate policy uncertainty

In the earlier literature, there exist no country-based studies that particularly investigate the impact of climate policy uncertainties on climate change. This might be attributed to the fact that there was no indicator to measure the policy uncertainty from a climate perspective until the Berestycki et al. (2022) constructed the CPU index. They filled the gap with their phenomenal research and constructed a Climate Policy Uncertainty (CPU) index. Similar to the study of Baker et al. (2016), Berestycki et al. (2022) created a lexicon of words for each of the three components (climate, policy and uncertainty). The first category includes terms such as “CO_2”, or "climate change" which refer to a specific environmental or climate change concern. It also includes terms referring to technologies addressing these concerns such as "solar PV" or "renewable energy". The second category includes terms related to policy-making such as "regulation", "legislation", or "tax", but also terms more specific to climate mitigation policies such as "emissions trading system" or "cap and trade". The third category includes the words "uncertain", "uncertainty", "vague" and "unclear". They select articles that include at least one term from each category. In addition, merging their CPU index with a global firm-level dataset, they empirically reveal that CPU is associated with economically and statistically significant decreases in investment, particularly in pollution-intensive sectors that are most exposed to climate policies and among capital-intensive companies.

Although cross-country analyses are rare in this field, Lüthi (2010) analyze the role of renewable energy policies across countries (Germany, Spain and Greece) and find political instability to be a critical determinant of investments in solar energy.

We also reviewed another line of literature that investigates the impact of climate policies on innovation and investments in low-carbon technologies. Reviewing this line of literature, we recognized that the logic associated with climate policy in driving innovation might be traced back to Hicks (1932), which argues that a change in relative prices for factors of production is itself a driver toward the invention of a particular kind of technology. This shift to a particular type of technology aims to economize the use of a factor of production that has become more expensive. Hicks (1932) in his Theory of Wages, postulates the idea that relative factor prices influence the type of technological progress, in particular that high wages induce labor-saving innovations. However, later studies such as Aghion et al. (2019) argued that market failures, technology path dependencies and behavioral factors justify the need for coordinated climate policy action to switch innovation systems from a dirty to clean pathway to deliver emission reductions at the pace required for global net zero. Acemoglu et al. (2012) highlighted the same idea, asserting that there is path dependence in the direction of technical change. Firms in economies with significant innovation in dirty technologies will find it more profitable to innovate in dirty technologies in the future, given existing information and skills are present. Similarly, firms more exposed to clean innovation are more likely to direct their research energies to clean innovation in the future due to a directed knowledge spillover effect. Such path dependency coupled with the environmental externality (where the loss in aggregate productivity or consumer utility induced by environmental degradation is not factored in) will induce the economy to innovate in dirty technologies more than what is deemed as socially optimum. Thus, this situation will require government intervention (policy) to "redirect" technical change. Additionally, they claim that the cost will increase in the case of any delay in intervention (policy) and the economy will face environmental disaster if there is no intervention.

Along with these theoretical arguments, there are some empirical findings regarding the impact of climate policy uncertainties and innovation. Ciccarelli and Marotta (2024) find that a change in the stringency index of climate policies induces an increase in new patents, driving innovation in low-carbon technologies. Similarly, Bhattacharya et al. (2017) shows that policy uncertainties negatively impact innovation, particularly in innovation-intensive industries. Based on our inquiries of this line of literature on climate policies and innovation, we understand that various studies argue for government interventions, namely for climate policies in our setting, to redirect technical change from dirty to clean technologies. According to these studies, the lack of proper climate policies or the existence of climate policy uncertainties is expected to discourage innovation in clean technologies.

To sum up, a review of these three lines of literature reveals that climate change is still untapped territory. Our research will be a contribution to the climate literature, which is still evolving. Specifically, it contributes to prior versions of the literature with a comparison of emerging and developed countries and an investigation of an additional variable, the CPU.

2.2 Research questions and hypotheses

Our research aims to explore the interrelation between policy uncertainties (EPU and CPU) and climate change. We also test the EKC hypothesis for emerging and developed economies. The research will focus on answering the three questions below:

Is there an interaction between policy uncertainties and climate change?

Is there a difference between emerging and developed countries in terms of the interaction between policy uncertainties and climate change?

Is the EKC hypothesis valid for emerging or developed countries?

In more detail, the first research question aims to explore the interrelation between climate change and policy uncertainties. Policy uncertainty is proxied by a country-specific Economic Policy Uncertainty (EPU) Index in one set of panel regressions, and a Climate Policy Uncertainty (CPU) Index in another set of regressions, for a subset of countries. Climate change (environmental degradation) is proxied by CO_2 emission levels. Based on the second research question, the study differentiates between emerging and developed countries.

The research bases its discussion on the ex-ante hypotheses of Wang et al. (2020) that propose two channels that relate EPU with environmental degradation: consumption (mitigating) effect and investment (escalating) effect. These effects are summarized as follows:

Consumption (Mitigating) Effect: EPU/CPU mitigates the use of energy and pollution-intensive commodities, meaning that the economic activity will be negatively affected. As a result, environmental degradation will be mitigated.

Investment (Escalating) Effect: EPU/CPU impedes the investment in renewable energy, diminishes environmentally related R&D and discourages innovation in clean (climate-friendly) technologies, which ultimately escalates environmental degradation.

Additionally, with the third research question, the study tests the EKC hypothesis for two different country groups to explore whether or not an inverted-U shape relationship between real GDP per capita and climate change exists.

2.3 Data

This section of the study utilizes data from various open and closed sources. To ensure the reliability of the emissions data, we cross-checked indicators from different data sources such as OECD, United Nations and World Bank. The procedure for selecting the variables and the data sources for Chapter 2 is detailed in Appendix A. The data were used in annual frequency from 1990 to 2018. This was because of the fact that the dependent variable was available only in annual frequency. Similarly, the countries included in each group (emerging or developed) are selected on the basis of data availability of country-based EPU and CPU indices.

In the first set of regressions that utilizes EPU, Brazil, Chile, China, Colombia, India, Mexico, Russia were included in emerging countries, while Australia, Canada, France, Germany, Japan, Republic of Korea (Korea), Italy, Netherlands, Singapore, Spain, Sweden, the UK, and the US were included in developed countries. In the second set of regressions that utilizes CPU, Chile and Mexico are included in emerging country groups, whereas Australia, Canada, France, Germany, Italy, Spain, the UK, and the US were included in developed countries. To be compatible with the countries whose EPU were used in the first set of regressions, we used similar countries but a small subset due to the data availability issue. CPU is only available for 12 countries, 10 of which were included in our analysis. The sample of the model with CPU includes countries whose EPU and CPU are simultaneously available. Furthermore, in an attempt to understand whether or not CPU includes additional information that the EPU does not propose, we plotted the two as depicted in Appendix B, Figure B1. The charts visually depict that changes in CPU over time are weakly associated with changes in EPU. The correlation coefficient between CPU and EPU is quite low in the emerging countries included in our model (Chile and Mexico), being 0.05 and 0.28, respectively. As for the developed countries, the correlation coefficient between EPU and CPU is positive and very high in the UK, Spain, and Canada, whereas it is low in Germany, Italy and moderate in the US and Australia. However, visualizing the charts, we see that Brexit in 2016 had a much larger impact on the EPU of the UK than on its CPU. The EPU index is largely dominated by economic crisis, wars, and oil shocks, while the CPU index is specific to uncertainties related to climate policy. Thus, we infer that CPU has a distinct component and gives additional information regarding policy uncertainty.

As an additional information, we use variables in logarithmic form. Table 1 summarizes the data utilized in the study.

Table 1. Data Description

Indicator	Definition	Unit	Data Source	Mean	Std. Dev.	Min	Max
Carbon Dioxide Emissions	CO_2_Level	Million metric tons, annual	WB (2024a)	1004.19	1729.37	28.97	10,567.26
Per Capita Gross Domestic Product	GDP	Real 2021 international dollars	WB (2024b)	37,344.53	20,149.33	1645.58	117,426.8
Renewable Share in Consumption	REN	% of total final energy consumption	IEA (2022)	12.56	12.20	0.19	51.91
Economic Policy Uncertainty Index	EPU	# of newspaper articles having economic policy uncertainty-related words	EPU (2022)	116.06	57.90	27.00	542.77
Climate Policy Uncertainty Index	CPU	# of newspaper articles having climate policy uncertainty-related words	Berestycki (2022)	100.00	48.97	18.30	325.30
Population	POP	# of residents (in millions) in a country regardless of legal status or citizenship	WB (2024c)	187.96	349.86	3.05	1402.76

Note: Descriptive statistics of common variables of two distinct models are reported based on the full sample.

2.4 Model and methodology

2.4.1 Theoretical background

The theoretical background of our study is based on the IPAT approach (Commoner, 1972, Ehrlich & Holdren, 1971, Ehrlich & Holdren, 1972) in which the impact (I) of the population (P), affluence (A), and technology (T) on the environment is examined. Subscript "*i*" in the below equations emphasizes that these quantities might vary across cross-sectional observation units. The letter "*a*" denotes the constant term, while "*b*", "c", and "*d*" are the elasticities that determine the net impact of population, affluence and technological changes on the environment, respectively. Finally, the "*e*" represents the error term.

$$I_i = aP_i^{\,b} A^c{}_i T_i^{\,d} e_i \tag{1}$$

Although we base our logic on the IPAT framework, we include policy uncertainty (U) in the model and finally a time dimension (t). Then, we obtain Equation (2), with policy uncertainty added.

$$I_i = a\, P_i^{\,b}\, A^c{}_i\, T_{\mathrm{i}}^{\,d}\, U_i^{\,f}\, e_i \tag{2}$$

If we take logarithms, we obtain Equation (3), where "*a*" is the intercept, "*b*", "*c*", "*d*" and "*f*" are coefficients, with "*i*" and "*t*" representing cross-sections and time, respectively, whereas "e_{it}" is the error term.

$$\log I_{it} = a + b(\log P_{it}) + c(\log A_{it}) + d(\log T_{it}) + f(\log U_{it}) + e_{it} \tag{3}$$

We used population itself for the (P) and real GDP per capita as a proxy for affluence (A), renewable energy share in final consumption as a proxy for technology (T) and finally, EPU or CPU as a proxy for policy uncertainty (U).

The last but not least, the IPAT framework was merged with the EKC hypothesis to test if the real GDP per capita, namely the affluence variable, has an inverted U-shaped impact on the environment, as specified in Figure 1. Thus, the squared real GDP per capita was also added to the model to test this non-linear relationship, as detailed in Section 2.4.2.

2.4.2 Empirical model

This study's empirical approach is based on the following models (Model 1 and Model 2) with EPU and CPU, respectively. Model variables are used in logarithmic forms to reduce heteroscedasticity and scale variables that have different sizes.

Model 1. $\log\_CO_2\_Level_{it} = a_0 + a_1 \log GDP_{it} + a_2 \log^2 GDP_{it} + a_3 \log REN_{it} + a_4 \log EPU_{it} + a_5 \log POP_{it} + e_{it}$

Model 2. $\log\_CO_2\_Level_{it} = \beta_0 + \beta_1 \log GDP_{it} + \beta_2 \log^2 GDP_{it} + \beta_3 \log REN_{it} + \beta_4 \log CPU_{it} + \beta_5 \log POP_{it} + e_{it}$

where a2 < 0, maximum (optimal) real GDP per capita for Model 1 is calculated by GDPmodel1 = exp(−a1/2a2), while maximum (optimal) real GDP per capita for Model 2 is calculated by GDPmodel2 = exp($-\beta 1/2\beta 2$), where $\beta 2 < 0$. Based on the EKC hypothesis, the expected sign for a1 in Model 1 and $\beta 1$ in Model 2 is positive, while the signs of a2 in Model 1 and $\beta 2$ in Model 2 are expected as negative. More specifically, the rise in real GDP per capita will lead to an increase in CO_2 emissions initially but after a certain point, will lead to a decrease in CO_2 emissions, as suggested by the EKC hypothesis. The expected signs for a3 and $\beta 3$ are negative, as renewable energy consumption will decrease energy-related carbon emissions and alleviate the climate change problem. Our ex-ante expectations for a4 and $\beta 4$ will be tested based on investment or consumption effects specified in Section 2.2. The sign of the coefficient of EPU or CPU is expected to be positive if an investment effect is at play. If the consumption effect is valid, the signs are expected to be negative.

Finally, the coefficients of population variables (a5 and $\beta 5$) are expected to be positive ex-ante. This expectation is in line with the UN`s definition that addresses human activities as the main driver of the climate change.

Due to the cross-sectional dependence and slope heterogeneity in the dataset as well as the existence of different non-stationarity levels for included variables, a Panel Autoregressive Distributed Lag (ARDL) model, namely the Pooled Mean Group (PMG) estimator of Peseran et al. (1999) is employed.

The PMG model is particularly suited for dynamic panels with non-stationary variables, allowing to model both short-term and long-term relationships, while accounting for heterogeneity across countries in the short-run. PMG estimator allows for the short-run dynamics and error variances to differ among countries while assuming homogeneity in long-term relationships. Differences among countries explain the heterogeneous short-run behavior.

The PMG model finds short-run coefficients $\lambda, \lambda`, \lambda``, \lambda```, \lambda````, \lambda`````$ that are associated with lagged dependent variable and the explanatory variables. The model reveals long-run coefficients (θ type coefficients) for explanatory variables. The speed of adjustment, namely the error correction terms ϕ_{1i} and ϕ_{2i}, are proposed by the model to show the pace of adjustment between short-term and long-term behavior. Panel ARDL Model 1 with EPU and Model 2 with CPU is represented as:

$$\text{Model 1. } CO2it = a_{1i} + \sum_{l=1}^{p} a_{10} CO2_{it-l} + \sum_{l=0}^{q} a_{11} GDP_{it-l} + \sum_{l=0}^{q} a_{12} GDP_{it-l}^{2} + \sum_{l=0}^{q} a_{13}\, REN_{it-l} + \sum_{l=0}^{q} a_{14}\, EPU_{it-l} + \sum_{l=0}^{q} a_{15}\, POP_{it-l} + e1_{it}$$

$$\text{Model 2. } CO2it = \beta_{1i} + \sum_{l=1}^{p} \beta_{10} CO2_{it-l} + \sum_{l=0}^{q} \beta_{11} GDP_{it-l} + \sum_{l=0}^{q} \beta_{12} GDP_{it-l}^{2} + \sum_{l=0}^{q} \beta_{13}\, REN_{it-l} + \sum_{l=0}^{q} \beta_{14}\, CPU_{it-l} + \sum_{l=0}^{q} \beta_{15}\, POP_{it-l} + e2_{it}$$

After parameterization, for Model 1 and Model 2, respectively, the previous equations are represented as follows:

$$\text{Model 1.}\ \Delta \mathrm{logCO2}_{it} = a_{1i} + \phi_{1i}(\mathrm{logCO2}_{it-l} + \theta_{11}\log \mathrm{GDP}_{it-l} + \theta_{12}\log^2 \mathrm{GDP}_{it-l} + \theta_{13}\log \mathrm{REN}_{it-l} + \theta_{14}\log \mathrm{EPU}_{it-l} + \theta_{15}\log \mathrm{POP}_{it-l}) + \sum_{l=1}^{p-1}\lambda_{1il}\Delta \mathrm{logCO2}_{it-l} + \sum_{l=0}^{q-1}\lambda`_{1il}\Delta \mathrm{logGDP}_{it-l} + \sum_{l=0}^{q-1}\lambda``_{1il}\Delta \log^2 \mathrm{GDP}_{it-l} + \sum_{l=0}^{q-1}\lambda```_{1il}\Delta \mathrm{logREN}_{it-l} + \sum_{l=0}^{q-1}\lambda````_{1il}\Delta \mathrm{logEPU}_{it-l} + \sum_{l=0}^{q-1}\lambda`````_{1il}\Delta \mathrm{logPOP}_{it-l} + e1_{it}$$

$$\text{Model 2.}\ \Delta \mathrm{logCO2}_{it} = \beta_{1i} + \phi_{2i}(\mathrm{logCO2}_{it-l} + \theta_{21}\log \mathrm{GDP}_{it-l} + \theta_{22}\log^2 \mathrm{GDP}_{it-l} + \theta_{23}\log \mathrm{REN}_{it-l} + \theta_{24}\log \mathrm{CPU}_{it-l} + \theta_{25}\log \mathrm{POP}_{it-l}) + \sum_{l=1}^{p-1}\lambda_{2il}\Delta \mathrm{logCO2}_{it-l} + \sum_{l=0}^{q-1}\lambda`_{2il}\Delta \mathrm{logGDP}_{it-l} + \sum_{l=0}^{q-1}\lambda``_{2il}\Delta \log^2 \mathrm{GDP}_{it-l} + \sum_{l=0}^{q-1}\lambda```_{2il}\Delta \mathrm{logREN}_{it-l} + \sum_{l=0}^{q-1}\lambda````_{2il}\Delta \mathrm{logCPU}_{it-l} + \sum_{l=0}^{q-1}\lambda`````_{2il}\Delta \mathrm{logPOP}_{it-l} + e2_{it}$$

2.5 Estimation results

2.5.1 Cross-sectional dependence test

In order to determine the appropriate estimator, some assumption checks are employed. Cross-sectional dependence in the data was tested with Breusch–Pagan Lagrange Multiplier (LM), Peseran Scaled LM and Peseran Cross-sectional Dependence (CD) tests. (Table 2)

Table 2. (a) Cross-sectional Dependence Test w/EPU Model; (b) Cross-sectional Dependence Test w/CPU Model

(a)	Breusch-Pagan LM	Peseran Scaled LM	Peseran CD
log_CO_2_Level	(2445.18) [0.00]*	(115.69) [0.00]*	(8.84) [0.00]*
log_GDP	(4428.41) [0.00]*	(217.43) [0.00]*	(65.77) [0.00]*
log_sqrd_GDP	(4421.24) [0.00]*	(217.06) [0.00]*	(65.71) [0.00]*
log_REN	(2459.35) [0.00]*	(116.41) [0.00]*	(20.34) [0.00]*
log_EPU	(1300.21 [0.00]*	(56.95) [0.00] *	(27.57) [0.00]*
log_POP	(4447.92) [0.00]*	(218.43) [0.00]*	(52.97) [0.00 *
Residuals (w/ EPU)	(1498.06) [0.00]*	(67.10) [0.00]*	(23.92) [0.00]*
(b)	**Breusch-Pagan LM**	**Peseran Scaled LM**	**Peseran CD**
log_CO_2_Level	(570.25) [0.00]*	(55.36) [0.00] *	(5.87) [0.00] *
log_GDP	(1083.69) [0.00]*	(109.49) [0.00]*	(32.64) [0.00]*
log_sqrd_GDP	(1081.73) [0.00]*	(109.28) [0.00]*	(32.60) [0.00]*
log_REN	(578.32) [0.00]*	(56.22) [0.00]*	(6.72) [0.00]*
log_CPU	(262.06) [0.00]*	(22.88) [0.00]*	(8.04) [0.00]*
log_POP	(1008.08) [0.00]*	(101.52) [0.00]*	(30.03) [0.00]*
Residuals (w/ CPU)	(213.67) [0.00]*	(17.78) [0.00] *	(9.09) [0.00]*

Note: H0: No cross-sectional dependence (correlation). (.) and [.] indicate test statistics and probability values, respectively. * represents the level of significance at 5%.

Since the probability value shows a 5% level of significance in all individual variables, confirmed by all three tests, the null hypothesis of no cross-sectional dependence is rejected. Thus, we report that there is cross-sectional dependence in all series. Furthermore, after estimating a simple ordinary panel regression with EPU and with CPU separately, we also confirm that residuals are cross-sectionally correlated. We mostly rely on Peseran's CD test as it is known as more robust to small samples.

2.5.2 Slope homogeneity test

The slope homogeneity test of Peseran and Yamagata (2008) called the Delta test, and its adjusted version reveals that the slope coefficients of all individual variables as well as the overall model are heterogeneous. We report results utilizing the Stata 16 software package (Table 3).

Table 3. (a) Slope Homogeneity Test for the Model w/ EPU; (b) Slope Homogeneity Test for the Model w/ CPU

(a)						
Delta	Overall Model	log_GDP	log_sqrd_GDP	log_REN	log_EPU	log_POP
$\hat{\Delta}$	(17.12) [0.00] *	(5.42)[0.00]*	(5.38) [0.00]*	(12.82)[0.00]*	(2.28)[0.02]*	(6.11)[0.00]*
$\hat{\Delta}$ adj.	(20.22) [0.00] *	(5.86)[0.00]*	(5.82) [0.00]*	(13.87)[0.00]*	(2.46)[0.01]*	(6.61) [0.00]*
(b)						
Delta	Overall Model	log_GDP	log_sqrd_GDP	log_REN	log_CPU	log_POP
$\hat{\Delta}$	(11.55) [0.00]*	(4.64) [0.00]*	(4.52) [0.00]*	(6.19)[0.00]*	(1.98) [0.04]*	(4.36)[0.00]*
$\hat{\Delta}$ adj.	(13.61)[0.00]*	(5.01) [0.00]*	(4.88) [0.00]*	(6.69) [0.00]*	(2.14) [0.03]*	(4.71)[0.00]*

Note: H0: slope coefficients are homogenous. (.) and [.] indicate test statistics and probability values, respectively. * represents the level of significance at 5%.

2.5.3 Unit root test

We apply Peseran (2007) unit root test to test for stationarity in panels in the existence of cross-sectional dependence. Cross-sectionally augmented Im, Pesaran and Shin (CIPS) test statistics are the sample averages of the individual cross-sectionally augmented Dickey Fuller statistics. The results of the CIPS tests for the panel are presented in Table 4a,b, utilizing E-views 12 software. The CIPS test results indicate that the only variable that is stationary in the level is the log_REN in Model 1, while other variables are integrated order 1, except the population variable, which is integrated order 2 in both models. While running the model, we used adequately differenced versions of variables, based on the results of the unit root test.

Table 4. (a) CIPS Unit Root Test Statistic (Constant and Trend) for Model 1 w/EPU; (b) CIPS Unit Root Test Statistic (Constant and Trend) for the Model 2 w/CPU

(a)

	Level	First Difference	Second Difference
log_CO_2_Level	(−2.22)	(−4.85)*	
log_GDP	(−1.87)	(−3.48)*	
log_sqrd_GDP	(−1.81)	(−3.48)*	
log_REN	(−3.22)*		
log_EPU	(−1.83)	(−3.11)*	
log_POP	(−1.68)	(−1.95)	(−3.44) *

Note: If the test statistics are more positive or more negative than the critical values, we reject the hypothesis. H_0: there is a unit root. * indicates the level of significance at 5%. Critical value at 5% significance is −2.72.

(b)

	Level	First Difference	Second Difference
log_CO_2_Level	(−2.78)	(−5.42)*	
log_GDP	(−1.99)	(−4.22)*	
log_sqrd_GDP	(−1.99)	(−4.17)*	
log_REN	(−1.60)	(−5.62)*	
log_CPU	(−1.87)	(−2.99)*	
log_POP	(−1.33)	(−1.19)	(−3.66) *

Note: If the test statistics are more positive or more negative than the critical values, we reject the hypothesis. H0: there is a unit root. * indicate the level of significance at 5%. To be on the safer side, we base our decision on CIPS statistics, constant option for log_GDP, log_sqrd_GDP and log_REN variables and cannot reject the unit root level. The critical value at 5% significance is −2.87 constant and trend option, and −2.33 for constant option.

2.5.4 Cointegration tests

Although all three tests, namely the Kao (1999) test and Pedroni (1995, 1997, 1999) and Westerlund (2007) reveal cointegration in Model 1, the evidence for cointegration is mixed for Model 2. While Kao (1999) finds no cointegration in Model 2, the tests of Pedroni (1995, 1997, 1999) conclude the existence of cointegration. The Westerlund (2007) test also finds that some panels are cointegrated in Model 2. The panel ARDL model can also be applied in the case of no clear cointegration; thus, we also applied panel ARDL to Model 2 (Table 5a,b).

Table 5. (a) Cointegration Tests for the model w/EPU; (b) Cointegration Tests for the Model w/CPU

(a)		
H_0: No Cointegration	Statistic	*p*-Value
Kao Test–Ha: All panels are cointegrated		
Modified Dickey–Fuller t	1.94	0.03*
Dickey–Fuller t	1.81	0.04*
Augmented Dickey–Fuller t	2.08	0.02*
Unadjusted modified Dickey Fuller t	1.84	0.03*
Unadjusted Dickey–Fuller t	1.70	0.04*
Pedroni Test–Ha: All panels are cointegrated		
Modified Phillips–Perron t	1.00	0.15
Phillips–Perron t	−3.86	0.00*
Augmented Dickey–Fuller t	−4.28	0.00*
Westerlund Test		
Variance Ratio:		
Ha:Some panels are cointegrated	−2.98	0.001*
Ha:All panel are cointegrated	−1.63	0.051
(b)		
H_0: No Cointegration	Statistic	*p*-Value
Kao Test–Ha: All panels are cointegrated		
Modified Dickey–Fuller t	−0.85	0.20
Dickey–Fuller t	−1.13	0.13
Augmented Dickey–Fuller t	−0.22	0.41
Unadjusted modified Dickey–Fuller t	−1.49	0.07
Unadjusted Dickey–Fuller t	−1.49	0.07
Pedroni Test–Ha: All panels are cointegrated		
Modified Phillips–Perron t	0.30	0.38
Phillips–Perron t	−5.34	0.00*
Augmented Dickey–Fuller t	−4.36	0.00*
Westerlund Test		
Variance Ratio:		
Ha: Some panels are cointegrated	−2.20	0.01*
Ha: All panels are cointegrated	−1.07	0.14

Note: * indicate level of significance at 5%.

2.5.5 PMG estimation results

Based on the assumption checks, there is cross-sectional dependence and cointegration between variables and slope coefficients are heterogeneous. Thus, we applied the Pooled Mean Group (PMG) estimator of Peseran et al. (1999) to estimate the coefficients in Model 1 with EPU and in Model 2 with CPU. The PMG estimation results are reported in Table 6a,b for emerging and developed countries.

Table 6. (a) PMG Estimation Results w/EPU (Model 1); (b) PMG Estimation Results w/CPU (Model 2)

		(a)	
log_CO_2_Level		EMEs	Developed
	log_GDP	(5.943) [0.000]*	(4.767) [0.127]
	log_sqrd_GDP	(−0.280) [0.000]*	(−0.228) [0.117]
Long-run relationship	log_REN	(0.149) [0.246]	(0.134) [0.034]*
	log_EPU	(−0.063) [0.024]*	(−0.00002) [0.99]
	log_POP	(1.953) [0.000]*	(1.297) [0.000]*
EC term		(−0.296) [0.001]*	(−0.358) [0.000]*
	d_log_GDP	(2.418) [0.658]	(−26.23) [0.187]
	d_log_sqrd_GDP	(−0.115) [0.688]	(1.236) [0.181]
Short-run relationship	log_REN	(−0.362) [0.002]*	(−0.203) [0.001]*
	d_log_EPU	(−0.0004) [0.967]	(0.012) [0.161]
	d2_log_POP	(5.657) [0.681]	(−1.568) [0.464]
Residuals		I(0)	I(0)

		(b)	
log_CO_2_Level		EMEs	Developed
	log_GDP	(9.865) [0.644]	(12.670) [0.075]
	log_sqrd_GDP	(−0.465) [0.664]	(−0.553) [0.097]
Long-run relationship	log_REN	(−0.362) [0.324]	(−0.383) [0.000]*
	log_CPU	(−0.040) [0.553]	(0.013) [0.344]
	log_POP	(2.054) [0.216]	(−0.082) [0.597]
EC term		(−0.311) [0.493]	(−0.29) [0.005]*
	d_log_GDP	(−24.04) [0.280]	(1.008) [0.953]
	d_log_sqrd_GDP	(1.242) [0.265]	(−0.010) [0.990]
Short-run relationship	d_log_REN	(0.029) [0.705]	(−0.143) [0.004]*
	d_log_CPU	(−0.031) [0.001]*	(−0.0007) [0.888]
	d2_log_POP	(−0.869) [0.974]	(−2.701) [0.384]
Residuals		I(0)	I(0)

Note: H_0: Coefficient is equal to 0, (.) and [.] indicate coefficient and probability values, respectively.
* represents the level of significance at 5%.

In Model 1 with EPU, population escalates climate change in both country groups in the long term, which is in line with the UN definition of climate change that addresses human activities as the main driver of the climate change since the 1800s. Furthermore, EPU is negatively related to climate change in emerging countries in the long term, confirming the consumption effect theorized earlier in the literature. Based on the consumption effect, the EPU decreases the use of energy and pollution-intensive commodities, ultimately mitigating climate change. The negative relationship between EPU and CO_2 emissions might be attributed to the potential impact of economic policy uncertainties on the level of economic activity. It means that when uncertainties increase, economic agents might subsequently decrease overall economic activity. Thus, lower levels of production leads to a decline in CO_2 emissions. It might also be attributed to the future expectations on the economic policy uncertainties in these countries and the impact of those on the current economic activity. On the other hand, in developed countries, EPU is not significantly associated with climate change. This might be attributed to the possibility that developed countries are mature or economically developed enough to avoid implications of economic policy uncertainties on determining their economic activities. This shows that uncertainty is not affecting these countries' development policies or decisions on economic activities, ultimately having no effect on climate change. Additionally, consistent with our ex-ante expectations, renewable energy consumption reduces CO_2 emissions and alleviates climate change to a large extent in both country groups in the short term. This implies that global energy transition is crucial in addressing climate change.

PMG estimation results also indicate that the EKC hypothesis is verified only with Model 1 and for emerging countries. However, it should be kept in mind that Model 1 is superior to Model 2, as it has more cross-sectional items than Model 2, due to the limited availability of country-based data for the CPU variable in Model 2. This means that for emerging countries, CO_2 emissions increase at the first stages of economic growth due to fossil-based consumption. In other words, a rise in the level of economic activity is associated with an upsurge in the climate change problem. However, after a certain point, CO_2 emissions decrease due to the adoption of clean technologies and policies, thanks to the improvements in the affluence of countries.

In Model 2, with CPU, we find no evidence supporting the EKC hypothesis for any country groups. The signs of the coefficients of real GDP per capita and squared real GDP per capita variables are positive and negative, respectively, as expected by the EKC hypothesis. However, they are insignificant based on a 5% significance level. Thus, we are not able to confirm the EKC hypothesis for Model 2.

In addition, similar to Model 1, the sign of the coefficient of renewable energy consumption variable in Model 2 appears as significantly negative for developed countries both in the short term and long term. This finding points out the importance of energy policies to reduce energy-related emissions. Developed countries are better than emerging ones, in terms of utilization of clean energy sources.

Finally, the most striking finding is that CPU alleviates climate change problem in EMEs in the short-term, suggesting that the consumption hypothesis is at play again. CPU is negatively related to CO_2 emissions only in the short term, contrarily to EPU, which is negatively related to climate change in the long term. This might be attributed to the possibility that economic policy uncertainties mostly stem from economic shocks and are considered a primary concern for the longer-term economic activity in emerging countries, while the topic of climate policy uncertainties might be considered a fairly new subject area and a secondary concern for decisions. However, at this point, the limitations regarding the availability of CPU data for EMEs should be borne in mind. Our CPU data include only two emerging countries.

CHAPTER 3

THE INTERACTION BETWEEN ENERGY-RELATED INDICATORS AND CURRENT ACCOUNT DEFICIT AND THE TEST OF TWIN DEFICIT HYPOTHESIS: EVIDENCE FROM OECD COUNTRIES

In the post-COVID global outlook, while the predictability in commodity markets has decreased, global geopolitical uncertainties have substantially increased. Then, with the Ukraine-Russia war, energy import dependency has become an important concern around the globe. IMF (2023) points out that the combined cost of the energy crisis and reaching the NDCs is higher than the cost of reaching the NDCs alone in many countries, except in oil exporter ones. This increase in costs is mainly resulting from the loss of access to relatively cheap natural gas and its substitution by more expensive imports. Thus, energy trade balance has been the main factor behind current account imbalances of many countries. In this regard, recent energy crisis stressed the importance of diversifying the energy mix, in favor of renewable energy resources such as wind, solar, hydraulic, geothermal, biomass and biogas. Renewable energy produced domestically and being inexhaustible, will undoubtedly improve energy independence by reducing the share of imported energy.

Since energy policies might also be related to the well-being of a country's economy, studies are carried out to investigate this relationship. This section aims to support the earlier section of the research, trying to find evidence for the interaction between energy-related indicators and the current account deficit, one of the most important macroeconomic indicators that policy makers and economic agents gauge in making their decisions. More specifically, the section investigates if renewable energy conveys information to the current account deficit of selected Organization for Economic Co-operation and Development (OECD) countries. The remainder of the section is ordered as follows. While Section 3.1 establishes the link between energy trade balance and current account balance, Section 3.2 examines selected indicators of sample countries in detail. Section 3.3 reviews the literature. The data are presented in Section 3.4, while Section 3.5 discusses the model and methodology. Finally, Section 3.6 details estimation results.

3.1 The link between energy trade balance and current account balance

Before reviewing the literature, it is helpful to establish the link between energy trade balance and current account balance. The balance of payments of a country is comprised of 4 account types: current account, capital account, financial account, and the net errors and emissions account. These accounts reveal detailed information about countries' foreign economic activities and financial relations. While the current account shows the difference between imports and exports of a country's goods and services, the capital account tracks capital flows between countries. The financial account keeps track of foreign investments, loans, and other financial transactions. Net errors and omissions accounts are used when the accounts do not match and adjust the balance of payments to achieve accounting balance.

Current account imbalances have been an important concern for developing economies since the global financial liberalization of the 1980s. However, specifically after the Global Financial Crisis of 2008, current account deficits also became a problem for advanced economies. If the level of current account deficit exceeds the critical threshold of 5%–6% of GDP for recurring years, it might signal a potential future crisis, specifically an exchange rate crisis. Furthermore, as the current account deficit needs to be financed by foreign direct investments, portfolio investments, and other investments, this might lead countries to be dependent on foreign resources. Current account imbalances of many countries often result from the large deficits in goods trade balance, which is categorized under 3 parts; energy, unprocessed gold and core goods. A deficit occurs in goods trade balance if imports of goods are higher than exports of goods, namely if the country is a net importer. Moreover, as energy expenditures constitute a big portion of goods trade balance; countries with high current account deficits are the ones whose energy trade balances are sizably negative.

Considering this link between energy trade balance and current account balance, it might be noted that energy policies have significant implications for the well-being of economies. Countries whose energy import dependencies have historically been high, are quite sensitive to global energy prices as well as to the changes in exchange rates. These effects are elevated for more vulnerable countries that have unstable macroeconomic indicators.

3.2 The comparison of sample countries based on selected indicators

Checking the data of selected OECD countries in our sample, it is seen that when net energy imports increase, current account imbalances deteriorate. As an example from Türkiye, historical monthly figures depict that Türkiye would have given current account surplus in most months if energy imports were not existent (Figure 3).

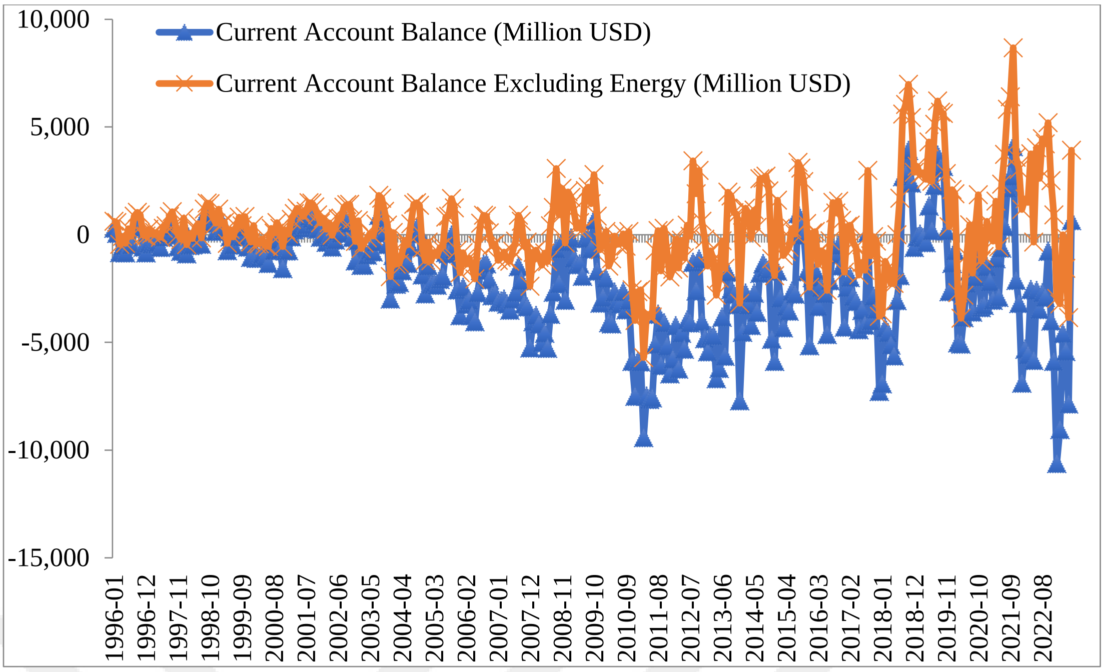


Figure 3. An example from Türkiye: Current account balance including and excluding energy trade balance. CBRT (2023)

Digging the data of selected OECD economies in our sample, it is seen that net energy import of Chile, Türkiye and Greece is in the range of 55%-64% of their total final energy consumption and surpasses the rest of the sample. US and New Zealand is in the lowest range in terms of average net energy import as a percentage of total final energy consumption throughout the sample period. While, New Zealand is utilizing renewable energy sources to a higher extent with an 81% share in its total electricity output, US generates 61% of its total electricity using fossil-based sources, 19% and 18% of its total electricity output, utilizing nuclear power and renewable sources, respectively. We understand from these figures that exchange rates also play a major role in net energy import levels.

Furthermore, it is seen that Greece, Türkiye and Chile are not adequately utilizing their renewable sources in the electricity generation, while New Zealand and Costa Rica`s share of renewable sources in total electricity output is 99% and 81%, respectively. We might argue that US, Türkiye, Poland, Greece and Estonia might improve their utilization of renewable sources, as fossil-based electricity production in these countries are above the world average of 61.9%. Although some countries (Czechia, US) also started to utilize nuclear energy to cut their energy imports and expenses, fossil-based electricity production still dominates picture.

Checking the fiscal deficits data of the sample, it is seen that fiscal deficit as a percentage of GDP of almost all countries is well above the average level of the country groups that they belong to; advanced or emerging and middle-income. In 2022, average fiscal deficit as a percentage of GDP of advanced and emerging and middle-income countries are 3.15% and 4.89% respectively. In the post-COVID period and specifically after global energy crisis, additional expenses led to narrow fiscal spaces in both advanced and emerging and middle-income economies.

3.3 Literature review

In the literature, studies on current account balance are divided into 2 groups. While one group focuses on testing the twin deficit hypothesis, the other group tries to find the drivers of current account balance.

The ones in the first group of the literature suggest that current account deficit and budget deficit move together. These studies test twin deficit hypothesis and try to capture the relationship between current account deficit and budget deficit. There are 3 theoretical arguments for the twin deficit hypothesis. While Traditional Keynesian View argues for a causality running from the budget deficit to current account deficit, Ricardian Equivalence Hypothesis claims that there is no relationship between the two. Finally, the Current Account Targeting by Summers (1988) posits the idea that causality is from current account deficit to budget deficit, contrary to Keynesian view.

On the other hand, the second group of studies in the literature try to find the drivers of current account balances, using different variables and applying various methodologies. In these studies, lagged current account deficit, economic growth, budget deficit, real interest rate, real exchange rate, investments, savings, and financial openness are among the indicators investigated. As an example of these studies, Kesikoğlu et al. (2013) focuses on OECD economies and try to find the determinants of current account deficit. Applying a Panel Vector Autoregressive (VAR) approach to 28 OECD economies in the period of 1999-2009, they find that growth, interest rate and budget deficit have a small and medium-term effect on the current account deficit while the exchange rate does not have any effect for these economies.

Our main investigation point in this section of the study is to understand the relationship between energy and current account balance. Thus, rather than determining the drivers of current account deficit, we focused more on the line of literature that discusses the link between current account deficit and various energy-related indicators.

Domestic and international literature that we searched through, include but not limited to 5 main headings; i. renewable energy consumption- economic growth ii. renewable energy consumption-economic growth- current account balance iii. renewable energy consumption-energy import-current account balance iv. renewable energy consumption- economic growth- environmental degradation and v. renewable energy consumption- current account balance-environmental degradation.

A summary of the literature reveals that most of the studies use annual data and apply Autoregressive Distributed Lag (ARDL) bounds test to capture the interrelation between variables. However, country-based studies utilizing Panel ARDL or AMG estimators also exist in the literature.

Many studies in the domestic literature analyze the relationship between economic growth and renewable energy consumption. For instance, one of the most recent studies that analyze the relationship between economic growth and renewable energy consumption in Türkiye is Pehlivan (2022). Utilizing annual data covering 1960-2017 periods, the study investigates the relationship between renewable energy consumption, financial development and economic growth. Based on the Non-linear Autoregressive Distributed Lag (NARDL) long-term estimation results, both the increases in renewable energy consumption and in financial development are associated with an increase in economic growth.

Çandarlı & Unakıtan (2021) also focus on Türkiye and use vector error correction model to analyze the interrelation between renewable energy consumption and economic growth in the period of 1990-2019. They find a positive Granger causality running from renewable energy to economic growth. They argue that increasing the share of renewable energy investments would support Türkiye`s sustainable development.

For our specific research interest, we mostly focused on the literature that investigates the interrelation of current account deficit with some other variables. In this regard, Yanar & Kerimoğlu (2011) adds current account deficit to the analysis, using the data spanning from 1975 to 2009. Based on Johansen co-integration test, they find long-term relationship between economic growth and energy consumption, as well as between economic growth and the current account deficit.

Other studies in the literature also consider the fact that energy imports are important in understanding the dynamics of current account balance. Thus, they add energy imports to the econometric analysis. For instance, Topçu (2022), Yalçın & Yalçın (2021), İnançli & Akı (2020), Ürkmez & Okyar (2022) studies focus on the interrelation between energy imports and current account balance.

In more detail, Topçu (2022) investigates the impact of renewable energy consumption and energy import on current account balance. The study selects eleven countries, which are the highest energy importers in the period of 1995-2015. Based on the cross-sectional dependence and slope homogeneity tests, Panel AMG estimator is employed to find the long-term slope coefficients. According to the estimation results, the effect of renewable energy consumption on the current account balance is positive. It has also been found that energy imports deteriorate the current account imbalances. Dumitrescu-Hurlin causality tests show that there is a bidirectional relationship between renewable energy consumption and current account balance. Similarly, there is bidirectional causality between energy import and current account balance.

Ürkmez & Okyar (2022) also analyze the impact of renewable energy on energy import dependency in Türkiye. Utilizing 1990-2018 annual data and applying ARDL bounds test, they find that while renewable energy-based electricity production, GDP per capita, urban population growth, and world natural gas prices have strong interrelation with energy import dependency, world oil prices do not. They infer that renewable energy production reduces energy import dependency, while the most important determinant of this indicator is the GDP per capita.

İnançlı & Akı (2020) rather focus on investments, and investigate the impact of renewable energy investments on energy import dependency in Türkiye. They find that a 1% increase in renewable energy investments will be leading to 0.0041% decrease in energy imports.

Vaona (2016) investigates the relationship between renewable energy production and import demand, utilizing panel data. The study concludes that renewable energy production helps decrease import dependency and supports debt and economic sustainability.

Fedoseeva & Zeidan (2018) study focuses on understanding the factors that affect the energy import demand in European countries. Utilizing an annual dataset of 1990-2015, they apply a NARDL methodology and find that GDP growth variable has the most important implication on energy imports. They also infer that a reduction in fossil fuel consumption is associated with a decrease in energy imports. Thus, they argue for the positive role of renewable energy for the sustainable development of European countries.

Hosseinabad and Moraga (2020) is an interesting study that utilizes a scenario approach and finds that till 2025, almost USD 17 billion energy-related savings will be achieved in Illinois, US, in the case that 100% renewable energy was used. They are in favor of renewable energy, as it reduces energy import dependency.

Yalçın & Yalçın (2021) utilize country-based data covering 1990-2018 period and employ panel fixed effects model. They find that an increase in the renewable energy share in more urbanized countries will cause a higher level of decrease in energy import dependency, compared to less-urbanized ones. They also make a scenario analysis, specifically for Türkiye. They argue that positive developments in the renewable energy share and energy efficiency, will lead a USD 21 billion improvement in Türkiye`s current account balance in 2030.

Ateş et al. (2023) study is also a unique one as it utilizes monthly data spanning from 2016 to 2022. They investigate the interrelation among renewable energy production, installed power, current account balance and net energy imports.

In the model that defines current account balance as the dependent variable, they find co-integration among the variables. They employ a Toda-Yamamoto causality test and find that there is one-way causality between renewable energy production and current account balance. There is also one-way causality between installed power and current account balance. The long-term interrelation between current account balance and net energy imports is found as negative. They infer that energy policies that favor renewable energy would support Türkiye to decrease its current account deficit and improve its economic sustainability.

Uysal et al. (2015) also argues that renewable energy would improve Türkiye`s current account balance. They employ a VAR methodology to investigate the relationship between renewable energy consumption and current account deficit in Türkiye, for the period of 1980-2012.

Gökçe & Demirtaş (2018) study investigates the interrelation of renewable energy consumption and current account deficit in some European countries, in the period of 1995-2018. They utilize panel data and find that and increase in renewable energy consumption is associated with a decrease in current account deficit and energy import dependency in many countries. Similarly, Karadaş and Işık (2018) find that renewable energy usage improves current account deficit in OECD countries in the long-term.

Bildirici & Kayıkçı (2022) is another study that examines the relationship between renewable energy consumption and current account balance in G20 countries in the period of 1976-2019. They investigate dynamic and causal relationship among renewable energy production, current account balance, energy imports, renewable energy consumption, and economic growth through panel fourier bootstrapping ARDL model. They find that there is a unidirectional causality from energy imports, renewable energy consumption, and current account deficit to renewable energy production. They argue that if countries decrease their dependence in energy imports, they might increase the quality of environment through production of more renewable energy. They also find that countries also reduce their current account imbalances, by decreasing their dependence on energy imports.

Uçak (2019) examines the so-called vulnerable 5 countries (Brazil, India, Türkiye, South Africa and Indonesia) in the period of 2000-2017, utilizing panel data. The study investigates the interrelation between renewable energy consumption and current account deficit. While they find a positive long-term relationship between two indicators; economic growth, external trade deficit, oil prices, and reel exchange rate also have impact on current account deficit.

Going forward, as climate change has emerged as an important global problem, many studies started to integrate variables into their models to proxy environmental degradation. Kahia and Jebli (2021) is one of these studies. The study focuses on industrialized countries and investigates short-term causality among renewable energy production, economic growth and CO_2 emissions. Based on Granger causality tests, an increase in clean energy production will lead to a reduction in CO_2 emissions of Chili, Australia and Austria. However, an increase in Denmark and Holland`s CO_2 emissions in the long-term.

Çetintaş and Aydın (2022) is another study that tries to understand the interrelation among renewable energy, environmental degradation and economic growth in OECD member countries. They find that renewable energy has a positive impact on economic growth and environmental degradation up to a certain threshold, but after that threshold, the impact is negative.

Rehman et al. (2023) is also an interesting study that utilizes dynamic ARDL to investigate the relationship between current account balance, renewable energy consumption and CO_2 emissions in the period of 1981-2020. The study is a country-based one, using US, China and India data. They find that increased use of renewable energy and improvements in current account balance help decrease CO_2 emissions.

To summarize, a review of literature reveals that studies find varying evidences for the investigated topics, using different variables in their models.

3.4 Data

In an attempt to make a robust analysis, the countries included in our sample are selected based on a predetermined logic. Out of thirty eight OECD member countries, fifteen were selected based on satisfaction of three criteria. Countries that have i. positive net energy import, ii. negative current account balance, and iii. negative fiscal balance were included in our whole sample. Chile, Costa Rica, Czechia, Estonia, Greece, Hungary, Latvia, Lithuania, New Zealand, Poland, Portugal, Slovak Republic, Türkiye, UK, and US are the countries that satisfy the above three criteria simultaneously and are included in our sample.

In our second set of panel regressions, we classified these fifteen countries into three groups, based on their per capita GDP levels. The first group includes countries whose GDP per capita is lower than or equal to USD 25,000. The second group includes countries with a per capita income level between USD 25,000 and USD 50,000. Finally, the third group includes countries that have equal to or more than USD 50,000 per capita income. Since the national energy balances are only available in annual frequency, our sample includes country-based annual data of 15 OECD countries in the period of 1990–2021. The time series data of each country’s net energy import, total final energy consumption, as well as electricity generation by source (fossil-based, renewable-based, and nuclear-based) indicators are available in International Energy Agency (IEA). Fossil-based sources include coal, oil, and natural gas, while renewable sources consist of hydro, geothermal, solar photovoltaic (PV), solar thermal, wind, tide, and biofuels. Table 7 summarizes the description and sources of the data utilized in the study. The detailed procedure for selecting the variables and data sources is available in Appendix C.

Table 7. Data Description and Sources

Indicator	Definition	Unit	Data Source
Current Account Balance	CAB	% of GDP	(WB, 2024d)
Net Energy Import	NEI	% of total final energy consumption	(IEA, 2024a)
Share of Renewable Sources	REN_TEO	% of total electricity output	(IEA, 2024b)
Fiscal Balance	FAB	% of GDP	(IMF, 2024)

Descriptive statistics of the variables are presented in Table 8, as follows:

Table 8. Descriptive Statistics

	CAB	NEI	REN_TEO	FAB
Mean	−0.03	0.39	0.30	−0.03
Min	−0.21	−0.18	0	−0.15
Max	0.08	0.69	0.99	0.08
Std. Dev.	0.04	0.20	0.29	0.04
Skewness	−0.78	−0.51	0.87	−0.27
Kurtosis	4.86	2.49	2.51	3.54
Observations	447	480	480	421

In our study, we try to find the interrelation between energy-related indicators and the current account deficit in both short-term and long-term, rather than focusing on a cause and effect relationship.

Although our study does not focus on cause and effect relationship between the variables, the correlation among the variables is also checked. As it is seen in Table 9, variables included in the model have quite low levels of correlation.

Table 9. Correlation Matrix

	CAB	NEI	REN_TEO	FAB
CAB	1			
NEI	−0.18	1		
REN_TEO	0.09	0.14	1	
FAB	0.06	−0.15	0.22	1

3.5 Model and methodology

This study's empirical approach is based on the following model and applied to a panel of fifteen OECD countries. Model variables are used in differenced forms based on the results of unit root tests.

$$CAB_{it} = a_0 + a_1 NEI_{it} + a_2 REN\_TEO_{it} + a_3 FAB_{it} + e_{it}$$

The expected sign for a_1 is negative, since a percentage increase in net energy imports is expected to deteriorate the current account deficit problem. Our main inquiry in this study is to investigate the interrelation of renewable energy with current account balance. Our ex-ante expectation is that if the share of renewable-based sources in total electricity production (REN_TEO) increases, the current account deficit will improve. Since the sign of our dependent variable is in negative terms, we expect coefficient a_2 to be positive. Additionally, we would like to test the Keynesian view on the twin deficit hypothesis, thus our ex-ante expectation for a_3, the coefficient of fiscal deficit is negative.

Due to the existence of cross-sectional dependence, slope heterogeneity, and non-stationarity in the dataset, a Panel ARDL model, namely the Pooled Mean Group (PMG) estimator, is employed. The estimator was proposed by Peseran et al.

(1999) and supposes homogeneous long-run equilibrium across countries and heterogeneous short-run relationships. Differences among countries explain the heterogeneous short-run behavior. PMG estimator allows for the short-run dynamics and error variances to differ among countries while assuming homogeneity in long-term relationships. Since the study covers OECD countries, which might have diverse economic conditions and energy policies, PMG not only allows us to explore long-term trends but also helps recognize short-term country-specific adjustments.

The PMG model finds short-run coefficients $\lambda, \lambda', \lambda'', \lambda'''$ that are associated with lagged dependent variable and explanatory variables. The model also reveals long-run coefficients (θ type coefficients) for explanatory variables. The speed of adjustment, namely the error correction term ϕ_{1i} is also proposed by the model to show the pace of adjustment between short-term and long-term behavior. Peseran et al. (1999) state that the pace of adjustment, namely the error correction term, should be negative to indicate that a disequilibrium is adjusted in the long-run. According to Peseran and Shin (1999), PMG approach is more consistent in generating long-run coefficients regardless of whether the order of integration is I (0) or I (1). In this study, the Panel ARDL Model is represented as:

$$CABit = a_{1i} + \sum_{l=1}^{p} a_{10} CAB_{it-l} + \sum_{l=0}^{q} a_{11} NEI_{it-l} + \sum_{l=0}^{q} a_{12} REN\_TEO_{it-l} + \sum_{l=0}^{q} a_{13}\, FAB_{it-l} + e1_{it}$$

After parameterization, the previous equations are represented as follows:

$$\Delta CAB_{it} = a_{1i} + \phi_{1i}(CAB_{it-l} + \theta_{11} NEI_{it-l} + \theta_{12} REN\_TEO_{it-l} + \theta_{13} FAB_{it-l}) + \sum_{l=1}^{p-1} \lambda_{1il} \Delta CAB_{it-l} + \sum_{l=0}^{q-1} \lambda'_{1il} \Delta NEI_{it-l} + \sum_{l=0}^{q-1} \lambda''_{1il} \Delta REN\_TEO_{it-l} + \sum_{l=0}^{q-1} \lambda'''_{1il}\, \Delta FAB_{it-l} + e1_{it}$$

3.6 Estimation results

3.6.1 Cross-sectional dependence test

Before estimating the model, various assumption checks were employed. Cross-sectional dependence in the data was tested with Breusch-Pagan Lagrange Multiplier (LM), Peseran Scaled LM, and Peseran Cross-sectional Dependence (CD) tests. The test results are shown in Table 10. Since the probability value shows a 5% level of significance in all individual variables, the null hypothesis of no cross-sectional dependence is rejected based on at least 2 tests. Thus, we report that there is cross-sectional dependence in all series. Furthermore, after estimating a simple ordinary panel regression, we also confirm that residuals are also cross-sectionally correlated.

Table 10. Cross-sectional Dependence Test

	Breusch-Pagan LM	Peseran Scaled LM	Peseran CD
CAB	(672.54) [0.00]*	(39.16) [0.00]*	(15.03)[0.00]*
NEI	(975.00) [0.00]*	60.03 [0.00]*	(−0.25) [0.79]
REN_TEO	(1365.00) [0.00]*	(86.95) [0.00]*	(22.13) [0.00]*
FAB	(505.88) [0.00]*	(27.66) [0.00]*	(16.60)[0.00]*
Residuals	(649.98) [0.00]*	(37.61) [0.00]*	(14.89)[0.00]*

Note: H0: No cross-sectional dependence (correlation) (.) and [.] indicate test statistics and probability values, respectively. * represents the level of significance at 5%.

3.6.2 Slope homogeneity test

The slope homogeneity test of Peseran and Yamagata (2008), called the Delta Test, and its adjusted version reveal that slope coefficients of all individual variables as well as the overall model are heterogeneous. Slope homogeneity test results are depicted in Table 11.

Table 11. Slope Homogeneity Test

Delta	**Overall Model**	**NEI**	**REN_TEO**	**FAB**
$\hat{\Delta}$	(10.89) [0.00] *	(4.74) [0.00]*	(8.97) [0.00]*	(7.47) [0.02]*
$\hat{\Delta}$ adj.	(12.04) [0.00] *	(5.05) [0.00]*	(9.55) [0.00]*	(7.96) [0.01]*

Note: H0: slope coefficients are homogenous. (.) and [.] indicate test statistics and probability values, respectively. * represents the level of significance at 5%.

3.6.3 Unit root test

Under the existence of cross-sectional dependence, we apply Peseran (2007) to test for the stationarity in panel models. Both constant as well as constant and trend options of the CIPS test results indicate that CAB and FAB variables are stationary in the first difference. However, it appears that two options of the CIPS test propose different stationarity levels for REN_TEO and NEI variables. Visualizing the charts of these 2 variables as well as testing whether or not trend exists, we find that there was not a clear sign of trend for these variables. To be on the safe side, while running the model, we used the first differenced versions of all variables. The results of the CIPS tests for the panel are presented in Table 12.

Table 12. CIPS Unit Root Test

	Level	First Difference
Constant Option		
CAB	(−2.10)	(−3.94)*
NEI	(−2.06)	(−5.03) *
REN_TEO	(−1.76)	(−4.89) *
FAB	(−1.96)	(−3.56) *
Constant and Trend Option		
CAB	(−2.29)	(−3.83) *
NEI	(−2.94) *	
REN_TEO	(−3.25) *	
FAB	(−2.47)	(−3.71) *

Note: If the test statistics are more positive or more negative than the critical values, we reject the hypothesis. Ho: There is a unit root. * indicate level of significance at 5%. The critical value at 5% significance is −2.26 for the constant option and −2.78 for the constant and trend option.

3.6.4 Cointegration tests

While the Kao (1999) and Pedroni (1995, 1997, and 1999) cointegration tests reveal cointegration in all panels, Westerlund (2007) test finds that at least some panels are cointegrated. Thus, based on the results of cointegration tests that are shown in Table 13, the hypothesis of no cointegration is rejected.

Table 13. Cointegration Tests

H_0: No Cointegration	Statistic	*p*-Value
Kao Test–Ha: All panels are cointegrated		
Modified Dickey–Fuller t	-3.20	0.0007*
Dickey–Fuller t	-3.27	0.0005*
Augmented Dickey–Fuller t	-3.70	0.0001*
Unadjusted modified Dickey Fuller t	-6.74	0.0000*
Unadjusted Dickey–Fuller t	-4.63	0.0000*
Pedroni Test–Ha: All panels are cointegrated		
Modified Phillips–Perron t	-3.18	0.0007*
Phillips–Perron t	-5.68	0.0000*
Augmented Dickey–Fuller t	-4.39	0.0000*
Westerlund Test		
Variance Ratio:		
Ha:Some panels are cointegrated	-2.32	0.010*
Ha:All panels are cointegrated	-1.21	0.110

Note: * indicate level of significance at 5%.

3.6.5 PMG estimation results

We estimate the coefficients via the Pooled Mean Group (PMG) estimator of Peseran et al. (1999). The PMG estimation results are reported in Table 14 for all fifteen countries in the sample as well as for the 3 classifications of country groups, as specified in Section 3.4.

Table 14. PMG Estimation Results

CAB		All Sample [1]	Group 1 [2]	Group 2 [3]	Group 3 [4]
	NEI	(−0.105) [0.000]*		(−0.313) [0.000]*	(−0.099) [0.000]*
Long-run relationship	REN_TEO	(0.048) [0.001]*		(0.166) [0.000] *	(0.037) [0.013] *
	FAB	(−0.312) [0.000]*		(−0.104) [0.247]	(−0.296) [0.000]*
Error Correction term		(−0.390) [0.000]*		(−0.357) [0.000]*	(−0.439) [0.317]
	d_NEI	(−0.021) [0.667]		(−0.014) [0.795]	(−0.057) [0.417]
Short-Run Relationship	d_REN_TEO	(0.078) [0.215]		(0.113) [0.149]	(−0.017) [0.885]
	d_FAB	(-0.319) [0.007]*		(−0.347) [0.014]*	(−0.060) [0.000]*
	Constant	(-0.0098) [0.015]		(0.016) [0.164]	(−0.014) [0.278]
Residuals		I(0)		I(0)	I(0)

Note: H0: Coefficient is equal to 0, (.) and [.] indicate coefficient and probability values, respectively. * represents the level of significance at 5%. [1] All sample includes 15 OECD countries and is the main estimation in the study. [2] Group 1 includes countries whose GDP per capita is lower than or equal to USD 25,000. Since there is only one country, Costa Rica, in this group, the estimations are not reported. [3] Group 2 includes countries with a per capita income level between USD 25,000 and USD 50,000. [4] Group 3 includes countries that have equal to or more than USD 50,000 per capita income.

In line with our ex-ante expectations, the results of long-term estimations including all fifteen countries in the sample reveal that as net energy import increases, current account deficit deteriorates. As energy trade balance is the main source of current account deficits in many OECD countries, this finding is not surprising.

On the other hand, in the case that countries utilize more of renewable energy in their total electricity output, their current account deficit levels improve in the long-term, as the positive sign of the coefficient of the REN_TEO variable suggests. Renewable energy, as being domestically produced and replenishable, is a critical vehicle to improve the energy independence of countries. Since accumulation of renewable energy in a country takes time, an increase in the share of renewable-based sources in total electricity output is not significantly related to current account deficits in the short-term. The same argument is valid for the relationship between net energy import and current account deficit. As the sources of energy utilized in a country are highly dependent on the energy policies of the country, and it definitely takes time to see the implications of these policies, net energy imports are not associated with the current account deficit in the short-term.

Finally, we also find strong evidence for the twin deficit hypothesis both in the short-run and long-run. In other words, an increase in the level of budget deficit is associated with an upsurge in the current account deficit problem. Furthermore, the Dumitrescu and Hurlin (2012) causality test that considers the cross-sectional dependence among the countries in the sample reveals that there is bidirectional heterogeneous causality between current account deficit and budget deficit.

Group-based estimations also reveal interesting long-term results. Group 2 (the ones whose per capita incomes are between USD 25,000 and USD 50,000) and Group 3 countries (the ones having equal to or more than USD 50,000 per capita income) do not differ in terms of the interaction of the current account deficit with either net energy import or renewable energy share in total electricity output, except the size of the coefficients. More specifically, the coefficients of energy-related indicators for Group 2 countries are higher than those of Group 3 ones, suggesting that energy policy matters more for Group 2 countries' current account imbalances in the long-term. This might be attributed to the fact that Group 2 countries are more vulnerable to energy price shocks as their energy import dependencies are higher. Thus, even small improvements in the renewable energy landscape in these countries would help correct their current account imbalances.

When the results related to the long-term interaction between current account deficit and fiscal deficit are checked, it is seen that two country groups differ from each other. In Group 2 countries we confirm the Ricardian view that postulates no relationship between current account deficit and fiscal deficit. In Group 3 countries, the results are in line with the Keynesian view that proposes a negative interrelation between the two.

Finally, short-run results of group-based panel estimations reveal that the only variable that is significantly associated with the current account deficit is the fiscal deficit. An increase in fiscal deficit worsens the current account deficit in OECD countries, regardless of their income levels.

Overall, the estimation results help us conclude that energy policy matters for the current account balance and subsequently for the well-being of OECD economies.

CHAPTER 4

DISCUSSION AND CONCLUSION

The last but not least, in this section, we summarize main findings and propose policy recommendations based on the estimation results of the earlier two chapters. The section also addresses the limitations and further improvement areas regarding the study.

4.1 The summary of main findings

The world has experienced many episodes of high economic policy uncertainty, since the turn of the twenty-first century. Global economic policy uncertainties have substantially increased due to the recent events such as the financial crisis, oil price shocks or fluctuations, Brexit, the US–China trade war, the COVID-19 pandemic, the Russia–Ukraine conflict and the subsequent energy crisis. As the world gets more interconnected, policy uncertainties related to economic or financial decisions create greater challenges for all economic agents in their planning as well as investment decisions.

While economic policy uncertainty is well known in the literature and tested many times for varying empirical settings, climate policy uncertainty is a fairly new subject area. This is mostly attributable to the fact that jurisdictions around the globe are only just devising their climate policies and there was no indicator that measures climate policy uncertainty until Berestycki et al. (2022) constructed the CPU index.

The main purpose of this thesis is to investigate the interrelation of EPU or CPU with climate change, while also testing the EKC hypothesis for emerging and developed countries. Climate change is proxied by the level of CO_2 emissions in a country. In order to determine the relationship between selected indicators, we employ a PMG estimator. The first set of panel regressions includes EPU (Model 1), whereas the second set includes the CPU indicator (Model 2). The estimations reveal different results for the two country groups.

The estimation results indicate that EPU and CPU are negatively related to climate change in emerging countries, confirming the consumption effect theorized earlier in the literature. Based on the consumption effect, the EPU or CPU is associated with a decrease in the use of energy and pollution-intensive commodities, ultimately mitigating climate change. It might be pointed out that policies should be clear and publicly announced to avoid information asymmetries. Once climate policy uncertainties are alleviated, the ecosystem actors and investors would be more willing to integrate climate-related risks and opportunities into their financial decision-making, rather than moving to an inertia stage.

Consistent with our ex-ante expectations, an increase in the share of renewable energy in consumption leads to a reduction in CO_2 emissions and alleviates climate change to a large extent in both country groups in the short term. Thus, we might argue that energy transition holds the key to tackling climate change on a global scale.

The results also reveal that EKC hypothesis is verified only in Model 1 and for emerging countries. An increase in the level of economic activities will generate more CO_2 emissions due to increased fossil-based energy consumption, at least at the initial stages of economic growth. However, in the later stages of economic growth, the environment will improve due to the increased adoption of clean technologies. Verifying the EKC hypothesis for emerging countries, we might argue that emerging countries might save money and time on environmental costs via the adoption of clean technologies and policies. However, there is a need to be mindful of the particular trade-offs between supporting overall economic growth and green growth, specifically for emerging economies. They have started their economic development process later than developed countries, and will definitely need higher levels of energy to continue their economic development. Therefore, climate policies need to go hand-in-hand with other objectives such as overall economic development and energy security.

Continuing with the conclusions of the second section of the study, the results of long-term estimations reveal that as net energy import increases, current account deficit deteriorates in the selected OECD countries. The results of our study imply that countries that have a lower level of energy import dependency do not confront with current account imbalances. On the other hand, in the case that countries use more of renewable energy in their total electricity output, their current account deficit levels improve in the long-term. However, in the short-term, the share of renewable-based sources in total electricity output is not significantly related to current account deficits. Thus, we acknowledge that it will definitely take time to accumulate adequate low-carbon energy capacity and see its positive implications on the economy. It is highly likely that global and country-based increases in renewable energy capacities in the last decade would support the economic well-being of many countries in the upcoming future. Interestingly, group-based estimations suggest that energy policy matters more for the OECD countries whose income levels are within the mid-range of the sample. Thus, we argue that even small improvements in the renewable energy landscape in these countries would help correct current account imbalances.

In addition, we find strong evidence for the twin deficit hypothesis both in the short-run and long run. In other words, an increase in the level of budget deficit is associated with an upsurge in the current account deficit problem. This finding implies that different economic policies might have close interactions with each other.

4.2 Policy recommendations

Given the elevated energy prices and highly uncertain economic environment, global efforts to decarbonize the economy might not be too ambitious in the short-term. Thus, there is room for improvement in the ambition of targets and in the disclosure of clear transition plans and timelines for meeting those targets. With this said, differentiated responsibilities and conditions of developed and developing countries should be accounted for.

In this regard; finance, capacity building, technology development and transfer might be considered as critical enablers of climate action. Although public finance needs to play a central role in providing the resources to combat climate change, there is an urgent need to scale up privately-sourced climate finance and investment, specifically in emerging countries.

To attract private sector capital to climate investments, the risks and uncertainties borne by private investors should be mitigated. Public sector and ecosystem actors have an important role to play in addressing these concerns and mobilizing private finance. They can create an enabling environment for the design of new innovative financial instruments or for the better utilization of existing resources. Blended finance, structured finance or risk-sharing applications as well as derisking instruments and guarantee mechanisms are just a few to address this need.

Recently, new initiatives like the Private Sector Investment Lab by the World Bank Group or the Global Innovation Lab for Climate Finance by the UN have also been designed to drive more private investment. However, the role of multilateral development banks (MDBs) might be better leveraged in catalyzing private climate finance, particularly in emerging countries. First, MDBs might blend international climate and public development finance with their own resources to scale up climate finance. Second, they can develop pipelines of projects and technologies and increase the supply of bankable projects. Third, they can influence policies in an attempt to reshape policy frameworks those support green private investment. Last but not least, they might play a critical role in strengthening policy guidance and in the capacity building of emerging countries via technical assistance.

Furthermore, the role of innovation and technology in green transition cannot be ignored. Based on OECD Green Growth indicators, an environmentally-related government R&D budget, as a percentage of total government R&D, and a renewable energy public R&D budget, as a percentage of total energy public R&D, do not seem promising in many countries, despite recent improvements. When country groups are compared with each other, there seems a huge gap in the renewable energy public R&D budget, as a percentage of total energy public R&D indicators, in favor of developed countries (OECD, 2023). This is most likely because of the fact that developed countries have more fiscal space to support renewable energy and more inclination to innovations in general. It is undoubted that there is also a need for accelerating broadly accessible technological innovation across the world, through increased international collaboration and support.

Towards the objective of decarbonization, jurisdictions might promote renewable energy utilization, by enhancing vehicles such as subsidies, feed-in-tariffs, tax exemptions, direct tax credits, etc. for renewable energy. They can also allocate part of the public revenues gained through national emission trading systems to investments in renewable energy and energy efficiency. With the help of increased renewable capacities, countries that are highly dependent on energy imports might overcome challenges related to energy security and subsequently avoid negative economic consequences. Renewable energy as being domestically produced and replenishable would greatly support the energy trade balance of many countries. Finally, countries should devise holistic economic and energy policies that target simultaneously decreasing budget and current account deficits, as the two move together.

If we were to comment on Türkiye, we might definitely mention that Türkiye is not an exception. As a country highly dependent on energy imports, the energy trade balance has been the main factor behind the current account deficit of Türkiye. Therefore, energy policies are crucial and have important implications for the Turkish economy as well. Increasing the share of renewables in total energy supply will gradually lead to a decrease in the net energy import of Türkiye and improve energy independence. Subsequently, increasing the share of renewable energy in total energy supply will lead to an increase in the share of renewables in total electricity output.

Fortunately, in line with its “More Domestic, More Renewable” energy strategy, Türkiye’s energy policy has given top priority to utilizing renewable energy sources to the maximum extent, while decreasing energy import dependency and improving supply security. The priority areas set in ETKB (2022), the National Energy Plan (2020–2035), will not only help support decarbonization efforts but also be helpful in decreasing the current account deficit.

Despite the recent positive initiatives, such as diversifying the energy mix and installed capacity to the benefit of renewable sources, there is still room for improvement in Türkiye. Thus, a large amount of climate mitigation finance will need to be channeled to energy investments.

As a final note, Türkiye's "More Domestic, More Renewable" energy policy aspirations will definitely support the development of domestic clean energy technologies, increase the value-added of certain products, and decrease energy import dependency. These developments will not only improve energy trade balance and subsequently the current account balance of Türkiye but also support the country to reach its 2053 net zero emission target.

4.3 Limitations and future directions

The second chapter of the thesis has a few limitations. Due to the unavailability of CPU data for all countries and the need to find the intersection of countries whose EPU and CPU data are simultaneously available, the sample size is small for the second set of panel regressions. The sample size problem is more pronounced with respect to emerging countries. Since our research tries to find the interrelation between the variables rather than finding the drivers of climate change or focusing on cause and effect relationships, we are not subject to the omitted variable bias. Still, there is room for further improvement in the future research. The research might be replicated such that it includes more countries in the analysis, specifically in the application of the CPU model. On the condition that an adequate sample size is attained, the inclusion of additional variables to the model might also enhance the discussions. Furthermore, the test of the EKC hypothesis might be conducted for different country groups, such as high-income OECD, high-income non-OECD, BRICS or G7 countries. Finally, rather than using a panel of countries, the research might be replicated for individual countries, utilizing higher frequency data for specific countries. This type of methodology would allow to make detailed inquiries for the specific countries investigated.

As for the limitations of the third chapter of our study, we utilize annual data due to the fact that energy trade balances are only available in annual frequency. Future research might utilize different energy-related indicators that have monthly frequency. The research could also be replicated such that it includes different country groups in the analysis. On the condition that an adequate sample size is attained, additional variables might be included in the model to enrich the discussions. Finally, future research might employ spatial econometric methods to capture the interdependencies among countries, rather than investigating temporal relationships.

APPENDIX A

THE DETAILED PROCEDURE FOR SELECTING THE VARIABLES FOR CHAPTER 2

CO_2 Emissions_Level is sourced from the World Bank, World Development Indicators. The data were available in per capita form. Thus, annual per capita CO_2 emissions in metric tons were multiplied by the corresponding year's population for each country to find the CO_2 emissions in level form. Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.

Real GDP Per Capita is sourced from World Bank, World Development Indicators. The reason for including this variable is that climate change (environmental degradation) is mostly related to human activities, namely the economic activities, based on the UN's climate change definition. GDP per capita used in the model was based on purchasing power parity (PPP) and in constant 2021 international dollars.

Renewable Share in Consumption is sourced from the International Energy Agency (IEA). The variable is defined as SDG-7. This indicator focuses on a concerted global effort to ensure access to affordable, reliable, sustainable and modern energy for all. The IEA database specifies modern renewable sources excluding traditional uses of biomass. Our ex–ante expectation is that if the share of renewables in consumption increases, the climate change problem will be lessened.

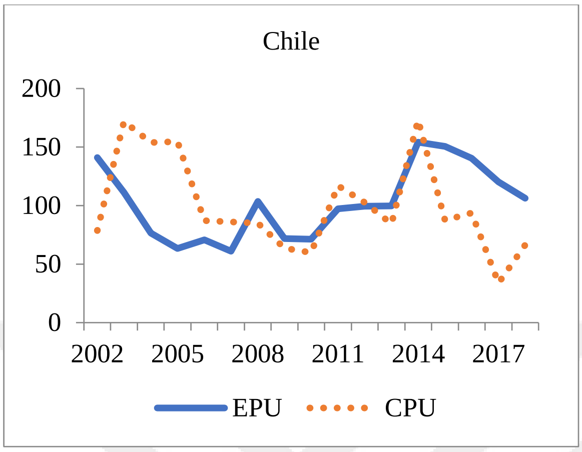
EPU is sourced from the Economic Policy Uncertainty Index monthly country data. The data are available for twenty-two countries. The data of 20 countries have been used in panel regressions, 7 of which are the emerging and 13 of which are the developed countries. Our ex-ante expectation is categorized into two hypotheses. One expectation hypothesizes that when EPU increases, the climate change (environmental degradation) problem will be more pronounced (escalated) as EPU will impede the clean technology investment. The other expectation hypothesizes that when EPU increases, the climate change (environmental degradation) will be mitigated since EPU will cause less economic activity. In utilizing the data, monthly country-based EPU values have been averaged to obtain an annual EPU value for each country. Ireland and Greece were excluded from the model. The reason for the exclusion of Ireland is to avoid any kind of possibility that the emission of northern part of Ireland is accounted in the UK emission data. As for Greece, it has been checked and determined that Greece was under the classification of developed countries in many international institutions' reports such as the World Bank's World Development Report or IMF's World Economic Outlook Report. However, when compared with other developed countries included in our model, the per capita income of this country was much lower than other developed ones and rather tilted towards emerging countries. Thus, Greece has been excluded from the model to avoid any kind of confusion. The countries that were included in emerging country groups are Brazil, Chile, China, Colombia, India, Mexico, Russia. The countries included in developed country groups are Australia, Canada, France, Germany, Japan, Republic of Korea (Korea), Italy, Netherlands, Singapore, Spain, Sweden, the UK, and the US.

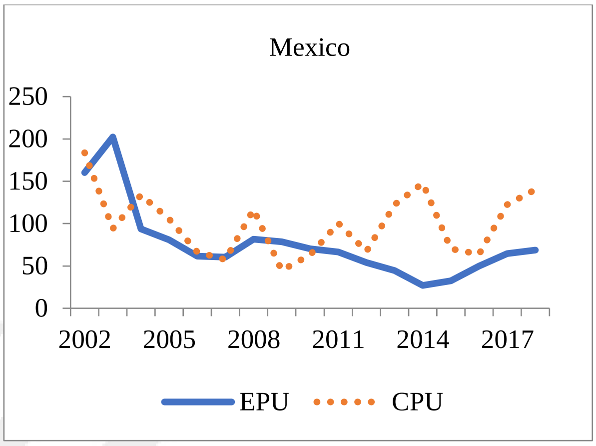
CPU is sourced from the OECD Authors. The data are closed-sourced. CPU is available for 12 countries, 2 of them being emerging and 10 being developed, and runs from 1990 to 2018 in annual frequency. Ireland and New Zealand data were not used. Ireland data are not used for the same specified reason above, while New Zealand data were not used as its EPU is not available. CPU refers to Climate Policy Uncertainty. OECD authors construct it based on newspaper articles. To be compatible with the countries whose EPU were used in the first set of regressions, we used similar countries but a small subset (10 countries) in the second set of regressions. CPU data are only available for 12 countries, 10 of which were included in our analysis. The countries that were included in emerging country groups in the second set of panel regressions are Chile, Mexico. The countries that were included in developed country groups are Australia, Canada, France, Germany, Italy, Spain, the UK, and the US.

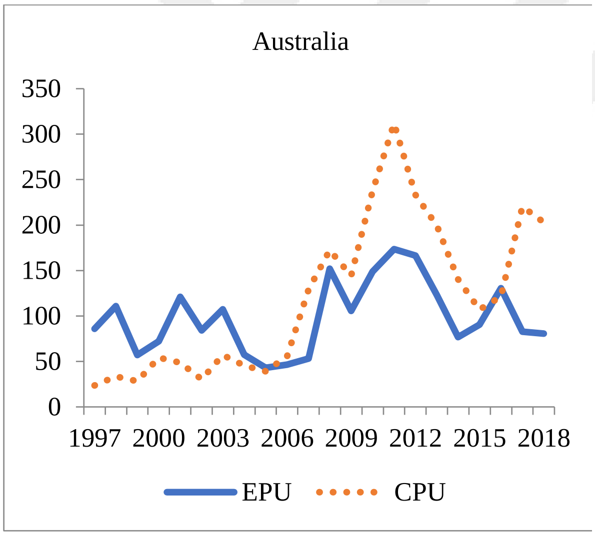
Population is sourced from the World Bank, World Development Indicators. Total population is based on the de facto definition of population, meaning that it counts all residents regardless of legal status or citizenship.

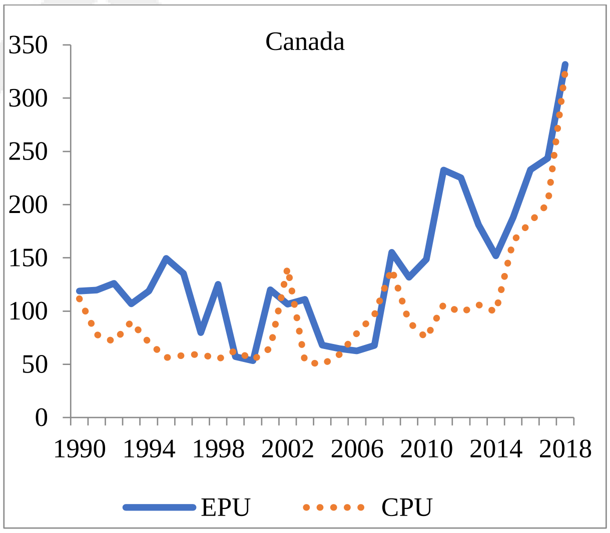
APPENDIX B

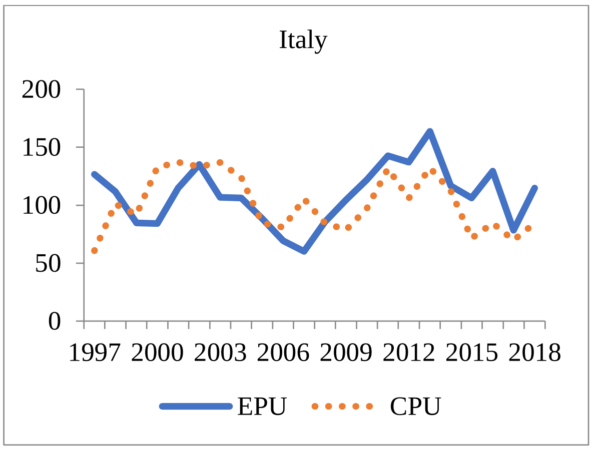
PLOT OF COUNTRY-BASED EPU AND CPU

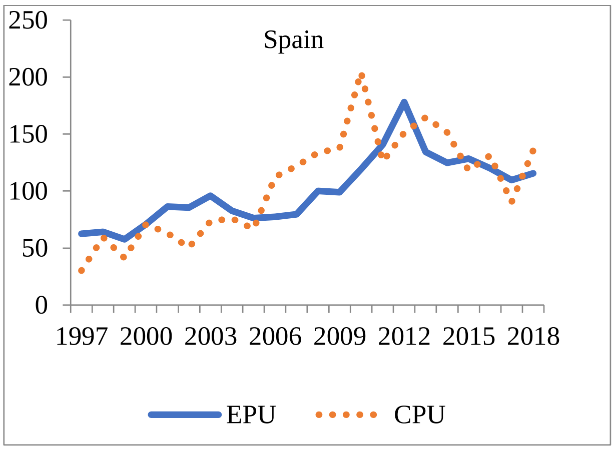












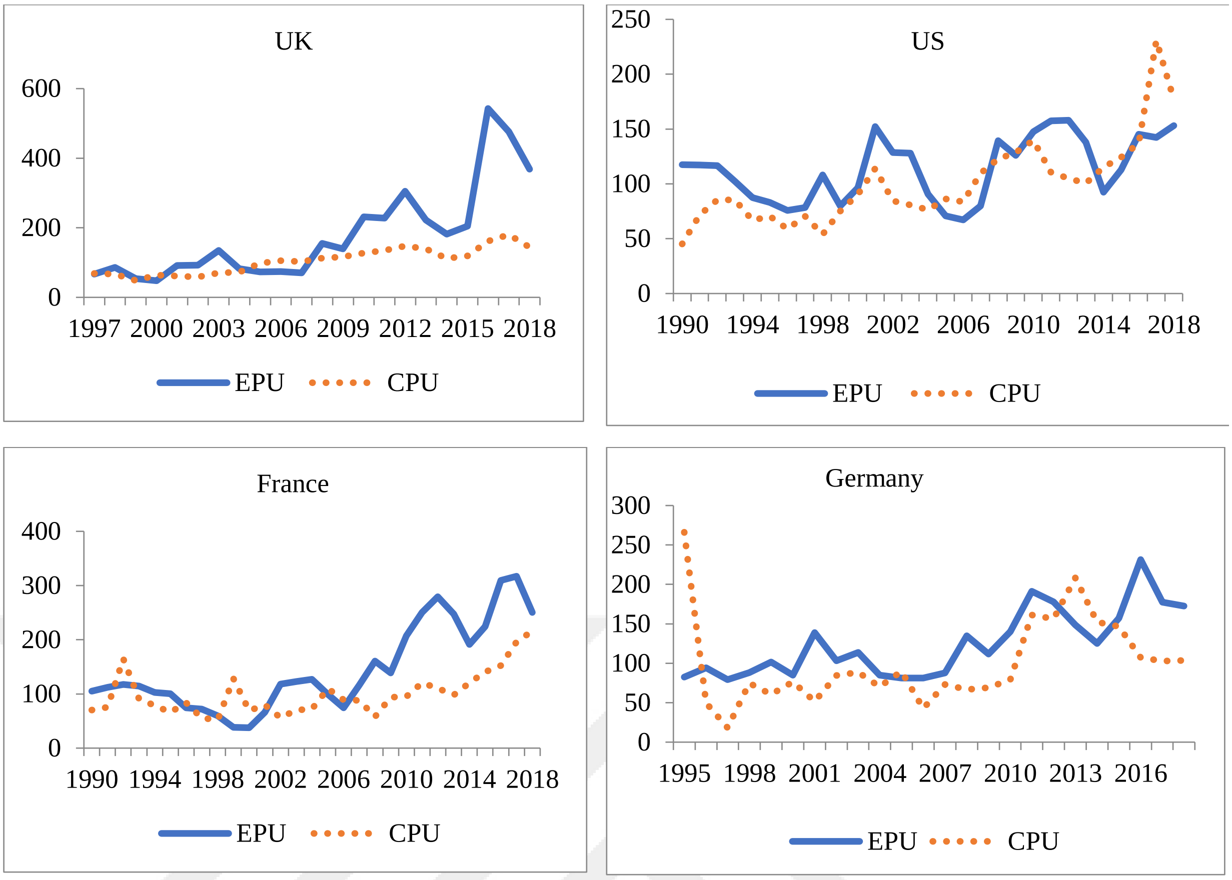


Figure B1. Plot of country-based EPU vs. CPU

APPENDIX C

THE DETAILED PROCEDURE FOR SELECTING THE VARIABLES FOR CHAPTER 3

Current Account Balance, as a % of GDP is the sum of net exports of goods and services, net primary income, and net secondary income, divided by the GDP of the country and multiplied by 100. The data are sourced from the International Monetary Fund, Balance of Payments Statistics Yearbook and data files, and World Bank and OECD GDP estimates. We accessed the data through the World Bank, World Development Indicators dataset.

Net Energy Import, as a % of Total Final Energy Consumption variable is found in two stages. We calculate net energy import as a percentage of total final energy consumption. Net energy import and total final energy consumption figures are both sourced from the IEA Energy Statistics Data Browser. Net energy imports are estimated as energy use less production, both measured in oil equivalents. A negative value indicates that the country is a net energy exporter. Energy use refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport.

Share of Renewable Sources in Total Electricity Output is calculated by dividing the renewable-sourced electricity generation by total electricity generation by all sources. Renewable-based electricity production includes the generation of electricity using hydro, solar PV, solar thermal, geothermal, wind, tide, and biomass energy as the primary sources of energy. The source of data utilized in the study is IEA, World Energy Statistics and Balances, 2023.

Fiscal Balance as a % of GDP is sourced from IMF Fiscal Monitor, 2024. The overall fiscal balance refers to net lending (+)/borrowing (−) of the general government. When the balance is negative, the government has a fiscal deficit. When the balance is positive, the government has a fiscal surplus.

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