

# **EXPORT DIVERSIFICATION AND ENERGY SECURITY RISK IN PAKISTAN**



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**PAKISTAN INSTITUTE  
OF DEVELOPMENT  
ECONOMICS**

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## *Dedication*

To my mother, who still light the clay stove with hope, and my father who breaks stones, so I could build dreams.

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## **LIST OF ABBREVIATION**

<b>CBAM</b>	Carbon Boarder Adjustment Mechanism
<b>CAREC</b>	Central Asia Regional Economic Cooperation
<b>CDPR</b>	Consortium for Development Policy Research
<b>DE</b>	Disaggregated Energy
<b>DOLS</b>	Dynamic Ordinary Least Square
<b>ED</b>	Export Diversification
<b>ECM</b>	Error Correction Model
<b>ESR</b>	Energy Security Risk
<b>FMOLS</b>	Fully Modified Ordinary Least Squares
<b>GOP</b>	Government of Pakistan
<b>HC</b>	Human Capital
<b>IQ</b>	Institutional Quality
<b>NRE</b>	Non Renewable Energy
<b>OSCE</b>	Organization of Security and Co-operation in Europe
<b>OFDI</b>	Outward Foreign Direct Investment
<b>PCSE</b>	Panel Corrected Standard Error
<b>RE</b>	Renewable Energy
<b>UNCTAD</b>	United Nation Trade and Development
<b>VECM</b>	Vector Error Correction Model

## ABSTRACT

This study aim to analyze the nexus between export diversification and energy security risk in Pakistan and other selected CAREC countries including (Azerbaijan, China, Kazakhstan, Pakistan, Turkmenistan and Uzbekistan).The study employs the panel data methodology including both FGLS and PCSE and for time series analysis Engle Granger Co-integration method is opted for the time period of 1990-2023 to understand the influence of increased in export diversification on other energy related factors including energy security risk, renewable consumption and fossil fuel consumption. As shown through the research conducted through panel data analysis and time series estimation, low export diversification possesses high risk to energy security and raises the burden by depending more on fossil fuel. Export diversification on the contrary can be linked with less dependence on fossil fuel and increase integration of renewable energy. The moderating effect of CO<sub>2</sub> emission demonstrate the impact of environmental pressure that greatly affect the relationship between export and energy outcomes. The result underscore that Pakistan should focus more on export diversification that will be facilitated by institutional adjustment and investment in clean energy. In case of CAREC countries trade and climate policy coordinated with international systems such as Carbon Border Adjustment Mechanism (CBAM) can help to switch to sustainable energy regimes and great climate vulnerability.

**Keywords:** Export diversification, Energy security risk, Feasible Generalized Least Square, Panel Corrected Standard Error, Engle Granger co-integration

# CHAPTER 1

## INTRODUCTION

### 1.1 Background

Energy security has received significant global attention due to its crucial role in economic growth and social development. It is broadly defined as the stable, sustainable and affordable access to energy resources (OSCE, 2013), ensuring long term economic resilience and environmental sustainability. In addition, energy security has become increasingly critical because population growth and rapid industrialization have significantly enhanced energy consumption around the world. For example, historical estimates indicate that global energy consumption has increased from 112842 terawatt hours in 1995 to 183230 terawatt hours in 2023 (WDI, 2024a). This increasing demand has escalated energy security risks across the region particularly to the developing economies that are deeply dependent on energy imports.

Based on this issue, previous literature has documented various antecedents that can play a significant role in energy security risk. These factors include environmental regulation (Aslam et al., 2024), Financial development (Lee & Wang, 2022), geopolitical risk (Lee et al., 2024) and climate change (Iyke, 2024). The literature is not conclusive especially regarding variables related to trade. The proposed study will also help in advancing the debate by examining the ways in which export diversification effects energy security risk in the CAREC (Central Asia Regional Economic Cooperation), which are characterized by their structural weaknesses, reliance on fossil fuels and trade openness. The CAREC countries form a unique setting in which the twin goals of diversifying the economies and the constant energy security face each other that's why it would be worthwhile to investigate the relationship between export diversification and energy security risk.

Export diversification can be defined as the widening the range of export product serve as the organizational foundation for reducing economic risk and driving ongoing economic development (Hesse, 2009). A broad portfolio of exports stabilizes foreign exchange earnings at the same time it improves macroeconomic resilience and decrease market shocks that are effecting the

affordability of imported energy (Can et al., 2023). In the CAREC regions, where a large number of countries are not energy importers or are dependent on a few commodities, export diversification may be a lifeline in terms of reducing the exposure to energy security vulnerabilities. The higher dependency on oil imports to fulfil energy needs creates a major problem for Pakistan energy security because the country faces persistent problems of supply chain disruptions and price shocks along with geopolitical risk (Jamil & Ahmad, 2010).

The study of export diversification influence on energy consumption needs detailed separation of renewable and non-renewable energy sources. Disaggregated energy consumption try to capture the response of different economic sectors towards change in the trade patterns. The existing literature demonstrate that industrial development caused by export diversification determine the evaluation of energy demand by driving advanced industries towards sustainable energy sources (Kahia et al., 2016). Countries that have a higher export diversification will invest in the renewable energy sector and would probably reduce its investment in the non-renewable energy to ensure environmental sustainability (U. Shahzad et al., 2021).

$CO_2$  emission as a moderating variable makes the link between export diversification and energy use little complicated. Economic development first causes  $CO_2$  emission to rise According to the environmental Kuznet Curve hypothesis yet leads economies towards cleaner source of energy for environmental sustainability (Grossman & Krueger, 1995). A countries that promote export diversification ends up selecting less energy intensive production sectors for their export and resultantly the  $CO_2$  emission declines (Nguyen et al., 2024). Countries having less export diversification tend to depend on energy intensive manufacturing which increases the  $CO_2$  emission and further damage the environment (Cole, 2004). The analysis of this moderating effect become vital for Pakistan and other CAREC countries to develop successful energy policies because the countries suffer from ongoing energy inefficiency along with environmental pollution.

To cater a better socioeconomic context of the CAREC region, this research paper incorporates a new set of control variables specifically remittances, growth of GDP per capita and unemployment rate is added to improve the main analysis. These variables have been chosen because they have large impact on energy consumption patterns as well as macroeconomic stability that are very close aspects to energy security.

In most developing and transition economies, the value of the remittances may equal or surpass foreign direct investment or aid, since it is a significant source of financial inflow. They are also crucial in influencing the behavior of energy consumption because household with remittances are most likely to spend more on electricity, heating and modern devices (Abdih et al., 2012; World Bank, 2023). Remittances have in others instances, been found to facilitate the shift to cleaner and more efficient energy system, especially within the underserved and rural areas (Yoggeswari Subramaniam, 2022).

An increase in GDP per capita is an indicator of how economically developed a country is, and the rate is highly correlated with an increased in energy demand (Narayan et al., 2007; Sadorsky, 2010). Energy consumption by household and industry usually arises with the expansion of economies, and higher earnings. Nonetheless it is possible that this relationship will change at a higher level of development, richer economies tend to invest in renewable energy installation, energy efficient technologies. and environmental protection facilities, hence resultantly shifting the energy mix and improving energy security (Lin & Moubarak, 2014).

Unemployment, however is a measure of economic pressure that can have an adverse impact on the energy profile of a given nation. Unemployment negatively affects the income of a large number of people means disposable income are likely to be low, which could result in reduction of the short term household energy demand (Azam et al., 2015). Yet, on the long run, this can also undermine investment in renewable energy infrastructure and discourage any possibility of a public policy to advance energy efficiency (Al-Mulali & Sab, 2012). Again unemployment may be associated with the mismatch of labor resources in the clean energy industries that worsen the shift towards sustainable energy sources.

Additionally, global climate policies are becoming more severe posing a serious challenge to countries like Pakistan. Eurpion Union created the Carbon Boarder Adjustment Mechanism (CBAM) which is the first carbon border tax which will minimize the total carbon emissions. It is mainly aimed at trying to solve a problem known as carbon leakage and offshoring emissions. This occur in cases where the firm outsource the manufacturing of products to nation with less stringent emission requirements, which in most of the cases increase the total emissions(Carbon Trust, 2023). The Textile industry in Pakistan is in a quagmire since the climate policies in the world become strict. CBAM by EU will affect exports negatively by increasing the cost. There is the

necessity to introduce urgent reforms, green technologies and policy changes to remain competitive.

Thus through changing the study area to the CAREC region, this paper will strike a new topic on how export diversifications effects energy security risk and disaggregated energy consumption including consideration of socioeconomic dynamic with control variables like remittances, GDP per capita growth and unemployment. By doing so, the study doesn't only increase the geographical extent of past research but also points to key policy issues that needs to be addressed when it comes to energy transitions in emerging economies. Finally, the study is a part of the more holistic approach to the study of the interaction of trade structures and economic aspects with the energy sustainability concept, especially when applied to regional development and climate stability areas in CAREC countries.

## **1.2 Problem Statement**

The energy sector of Pakistan need to tackle a fundamental problem to achieve sustainable economic development through energy security. External price shocks together with supply chain breakdowns endanger Pakistan because it depends on imported fossil fuel (Saeed, 2022) can be seen in the graph below. The growing gap between Pakistan energy production and consumption together with poor resource efficiency and obsolete system has created additional security threats to the nation's energy supply (WDI, 2024a). The country's fossil fuel dominated energy consumption result in environmental damages in the form of higher  $CO_2$  emission that further creates problem like climate change (Iyke, 2024).

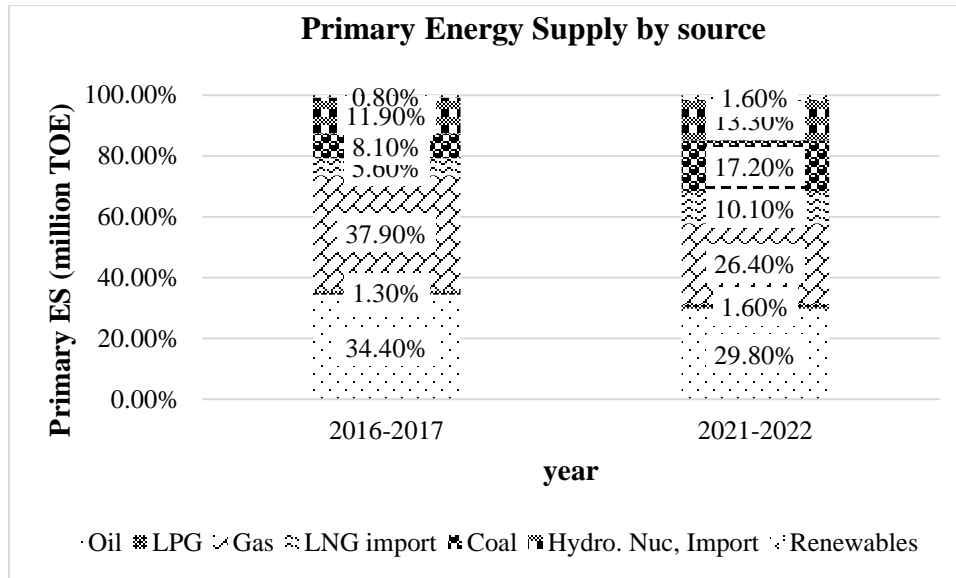


Figure 1. 1: Primary Energy Supply by Source

Source: Pakistan Energy Yearbook 2021

Export diversification became an essential policy measure because of these circumstances. The development of export diversification in the market enables countries to boost their economic resilience along with improving energy security (Hesse, 2009). Countries achieve economic stability through their diversified exports because it reduces their reliance on imported sources of energy. Pakistan is continuously facing external vulnerabilities because of its reliance on the concentrated export sector that is textile. The lack of economic diversification reduces Pakistan's potential for overall growth and its ability to build a renewable energy system, thereby increasing the country's energy security risk (Gul & Yasin, 2011).

The weaknesses are further compounded by the international trade mechanisms that have started to change, including the Carbon Border Adjustment Mechanism (CBAM) introduced by the European Union to levy tariffs on carbon-intensive imports. Heavy-emitting industries in the textile and basic production sectors, including countries like Pakistan, are likely to endure the increased trade threats as this could result in decreased trade revenues and increased economic uncertainty (European Commission, 2025). Herein it is all the more critical to promote the export diversification not only to enhance energy security but also to ensure competitiveness in trade, as well as investment and desperately needed economic sustainability beyond the 2030 and 2050 horizons (Taghizadeh-Hesary & Yoshino, 2020). Though these are pointed issues in Pakistan, they

are not the only scenario in Pakistan. A lots of nations of the Central Asian Regional Economic Corporations (CAREC) have a similar kind of structural vulnerabilities, the absence of diversified export base and the escalating risk of energy security (ADB, 2022). Against this backdrop of restrictions, the integration of export diversifications along with energy security is crucial for improving trade competitiveness, attract investment in green industries, and also help to ensure the long term economic sustainability.

### **1.3 Research Gap**

Although there have been many studies that have explored the relationships between export diversification and economic growth (Can et al., 2023; Young, 2024) but none of the study have yet empirically examined the nexus between export diversification and energy security risk in case of CAREC countries and Pakistan in general. The existing literature on energy consumption patterns through trade diversification (KILIÇARSLAN, 2022; Lee & Ho, 2022) lacks differentiation between renewable and non-renewable energy use.  $CO_2$  emission moderation plays an essential part in the energy environment connections yet the studies about its moderating effect remain scarce (Mania, 2020; U. Shahzad et al., 2021). Existing studies ((Apergis & Payne, 2011) Adams Jr & Cuecuecha, 2013 Akarca & Long II, 1979) have examined the impact of GDP, remittances and unemployment on energy security but fail to address their collective influence on the framework. While this study would try to fill the gap by empirically examining the impact of export diversification on ESR and DE (RE & N RE) and will take control variables including GDP per capita growth, Remittances and unemployment. As according to our limited knowledge none of the study have yet empirically examined these linkages in case of CAREC countries including Pakistan.

### **1.4 Research Objective**

- To analyze the relationship between export diversification and energy security risk.
- To examine the nexus between export diversification and disaggregated energy consumption.
- To investigate the moderating role of  $CO_2$  emission in the relationship between export diversification and disaggregating energy consumption.

## **1.5 Research Questions**

- What is the relationship between export diversification and energy security risk?
- How does export diversification impact disaggregated energy consumption (Renewable and nonrenewable energy)?
- Does  $CO_2$  emission moderate the relationship between export diversification and disaggregated energy consumption?

## **1.6 Policy Context**

The research outcomes can have significant policy implication in Pakistan energy and trade sector. Pakistan rely on the concentrated structure of export the reason of facing higher energy security risk making it more vulnerable to the external shocks and the trade restrictions under the CBAM. There has been a need of the strategic energy and the trade policies to ensure the energy sustainability by maintaining the international competitiveness.

### **1.6.1 Promoting Export Diversification**

Pakistan needs to establish policies to increase export variety so the country can reduce dependency on energy intensive industries that are highly susceptible to CBAM tariffs. Foreign exchange stability along with minimum external shocks can be achieved by Pakistan if it expands into less energy intensive industries that uses minimal energy for the production process (Hesse, 2009). The decision to develop new manufacturing and service oriented export markets will cut dependence on energy intensive commodities and foster economic stability and energy security (Sadorsky, 2014). By aligning the trade policies with the CBAM Pakistan can reduce the risk along with avoiding costly carbon tariffs in the European markets.

### **1.6.2 Investment in Renewable Energy**

Policy makers ought to give top priorities to create financial incentive to increase renewable energy investment while improving the regulatory framework to enable shift from fossil fuel energy to renewable energy (U. Shahzad et al., 2021). The implementation of renewable energy subsidies together with better grid infrastructure development and structured public private partnerships will enhance sustainable energy project investment (Olasehinde-Williams et al., 2023). Additionally, by integrating the renewable energy in the industrial zone and the export oriented sectors will ensure the compliance with CBAM and enhance the long term energy security.

### **1.6.3 Enhancing Environmental Policy Reinforcement**

Export diversification have also been aligned with the proper environmental sustainability to ensure the compliance with the CBAM and the other emerging regulations of the climate change. The combination of effective carbon taxation and tightening emission regulations and energy efficient technology incentive will enable Pakistan to reduce environmental degradation in Pakistan without harming economic growth (Mania, 2020). The investment into green technology and industrial innovations help Pakistan to lower its emission while giving its export better market competitiveness by meeting rising global environmental standards (Nguyen et al., 2024). By tightening the standards of the emissions and integrating carbon accounting mechanism, Pakistan can achieve the sustainability in the energy security while also can mitigate risk in the trade under CBAM.

### **1.7 Significance of the Study**

The research add value to the current literature by delivering three important contributions. First the research will empirically investigate the impact of export diversification on energy security risk. Previous studies have examined various factors that can effect energy security but none of the study have yet empirically investigate this nexus (Iyke, 2024; Kartal et al., 2024; Lee et al., 2024). This research will address an essential knowledge gap which delivers vital information's to policymakers seeking to control foreign exchange reserves and reduce global energy market vulnerability (Apergis & Payne, 2009).

Second this research investigation extends knowledge by examining the export diversification impact on disaggregated energy use that includes both renewable and non-renewable. Most previous studies have analyzed total energy consumption with differentiating between energy sectors which effects energy demand patterns (Nguyen et al., 2024). This study presents disaggregated energy data for creating concrete insight about energy transformation patterns in emerging export system while demonstrating how industrial development cut down fossil fuel usage (KILIÇARSLAN, 2022).

Third the study enriches the existing literature by empirically investigating the moderating role of  $CO_2$  emission between export diversification and disaggregate energy in case of Pakistan. This

study combine  $CO_2$  emission with other variables to understand how green trade policies support sustainable energy practices by using econometric techniques (U. Shahzad et al., 2021).

## CHAPTER 2

### ENERGY AND EXPORT SECTOR IN PAKISTAN

#### 2.1 Energy Sector

Pakistan energy requirements has grown rapidly through the course of its economic development. However, if we look at the Pakistan energy sector it has been facing significant challenges due to its heavily reliance on import, inefficient resource utilization, and increasing financial burdens. Pakistan energy mix is heavily reliant on fossil fuels including coal, natural gas accounting for almost 59% of the total energy supply (Cheema et al., 2022).

Nearly half of the country primary energy supply that is almost 49% comes from the imports, placing immense strain on it's already limited foreign exchange reserve. As of April 2023, Pakistan total net reserves stood at US\$ 11.5 billion with the state bank of Pakistan holding US \$ 4.6 billion. The country trade deficit has widened reaching US\$ 1.99 billion while external debt and liabilities have soared to US\$ 125.7 billion. Of this amount approximately 77% (US\$ 96.3 billion) is owed directly by the government to various multilateral and bilateral creditors. Looking ahead Pakistan is facing a daunting challenge of repaying over US\$ 77 billion in the next three years, making it crucial to manage energy imports efficiently to ensure economic stability (A. Malik, 2023). Figure 1.1 clearly demonstrate the largest share of fossil fuel.

## 2.2 Energy Consumption by Sector

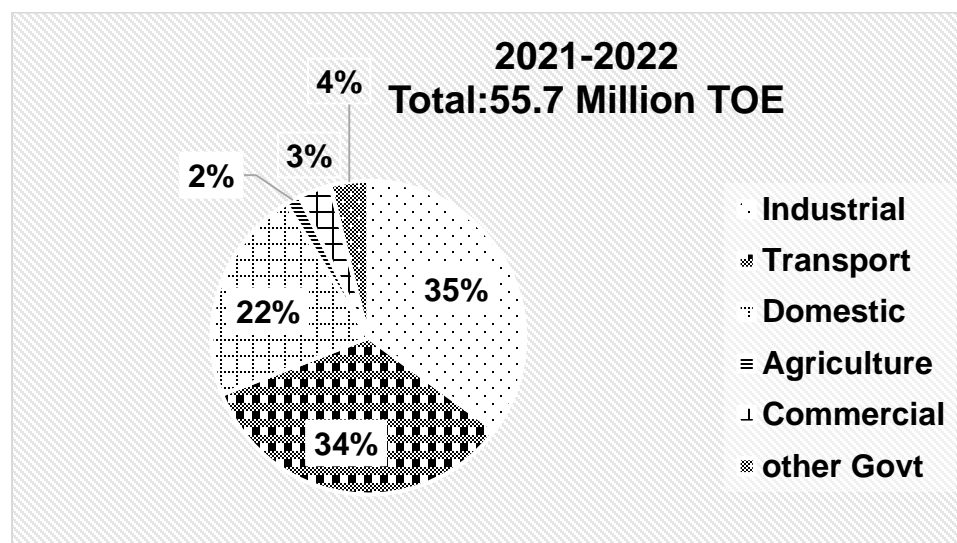


Figure 2. 1: Energy consumption by sector

**Source:** Energy yearbook 2022

The consumption of different sources of energy that were depicted in **Figure 1.1** is used by different sectors of the economy that is depicted in **Figure 2.1**. It can be seen clearly that industrial sector consumes most of the energy account for almost 35.05% of total consumption. Around 34% is consumed by the transport sector. 22% is consumed by the domestic sector while other approximately 1.52%, 3.33% and 3.89% is consumed by the agriculture, commercial and other sectors. While if we look at the overall scenario Almost half of the population haven't access to the clean cooking sources while there are more than 40 million people who haven't even access to electricity.

## 2.3 Import Dependence

Domestic energy production of Pakistan in 2022 has been obtained from the waste and the biofuels accounting for almost 44.2% while natural gas is of 29.4%, nuclear fuel is of 10.4% while crude oil is 5.9% this reflects an overdependence on the conventional natural gas and there have been very minimal reliance on the crude oil resulting of the over reliance on the imports.

While with regards of the electricity production Pakistan energy mix is led by natural gas accounting for almost 27.7% that is further followed by hydropower coal, oil, nuclear and wind (IEA, 2022). While according to the most recent report of the international renewable energy

agency Pakistan total solar installed capacity was almost 1244 megawatt that has been increased almost 17% if we compare it with 2021.

Pakistan is heavily relied on the imported fossil fuel that is why it's more vulnerable to external shocks the reason Pakistan is facing high energy security risk if we compare it with other countries majorly China, and India. The study will definitely explore the facts of the issue remain persistent and how to get rid of it by introducing and examining export diversification as a potential solution.

## **2.4 Export Diversification of Pakistan**

Traditionally the export basket of Pakistan is highly concentrated, having less diversification in the export sector as compare to the other regional countries(World Bank Group, 2018). Although there have been some small-scale efforts at the diversification during the 1990s and the early 2000s but the export basket still comprised of the few traditional products. Textile, leather and rice comprised of the 70% export in 2021. The last few years have low export value of USD 36.7 billion in 2021 ranking Pakistan in 63<sup>rd</sup> position globally in term of export performance in improving its industry and product base. According to (CDPR, 2025) there have been many constraints that is the main cause of Pakistan lower export diversification including

- Low productivity in the manufacturing sector
- Inadequate value addition
- Shortage of skilled Labor
- Energy inefficiencies and shortages
- Lack of research and development

## **2.5 Linking Export Diversification to Energy Security**

Export diversification stabilizes the earnings of a foreign exchange, thus increasing the capacity of a country to finance the imported energy, against global energy price shocks. The article by (Hesse, 2009) empirically demonstrates that concentrated export structures raise macroeconomic vulnerability because of a perilous inflow of revenue, restricting the capability of a country to handle outside shocks. The situation is supported concerning energy security as (R. M. Khan & Farooq, 2024) report that the coalitions of variable trade revenues and exposure to energy import vulnerability further increase the risk of exposure to energy supplies in Pakistan.

Also, in the framework of the South Asian Trade Dependency, the less diversified countries in the export market demonstrate the lesser shock absorption capacity, and thus, they are more prone to the disruption of energy supply chains and the occurrence of price volatility (Can et al., 2023). Thus, diversification is not only associated with growth, but also serves as a strategic instrument of risk management purpose by raising fiscal space and foreign reserve power so that governments can stay sure and steady in energy acquisition even in the external crisis situations like oil price spikes or currency devaluations.

## **2.6 Electricity Production by Source**

To determine the energy security situation within a country, it is significant to understand how its electricity generation mix has developed and how it is structured. Dependence upon local versus imported fuels, and the extent of energy source diversification, directly influence the national susceptibility to supply shocks, price volatility, and geo-political disturbances, all of which export diversification can help alleviate, because of stabilizing foreign exchange earnings and decreasing exposure to energy-based risks.

In 2000-2024, electricity generation in China increased considerably and coal production, as the leading power source, grew by approximately 1,060 TWh to 5,860 TWh. Hydropower increased continuously, making it the second-largest energy source, whereas renewable energy (particularly wind and solar) have been rapidly expanding almost since zero to 992 TWh and 834 TWh, respectively. There was also a significant rise in bioenergy and nuclear power but they constitute smaller proportions. Oil and gas played a secondary role, with the consumption of gas stepping up following 2010. This is an overall trend of China remaining dependent on coal and having a strong shift on renewable and low-carbon generation.

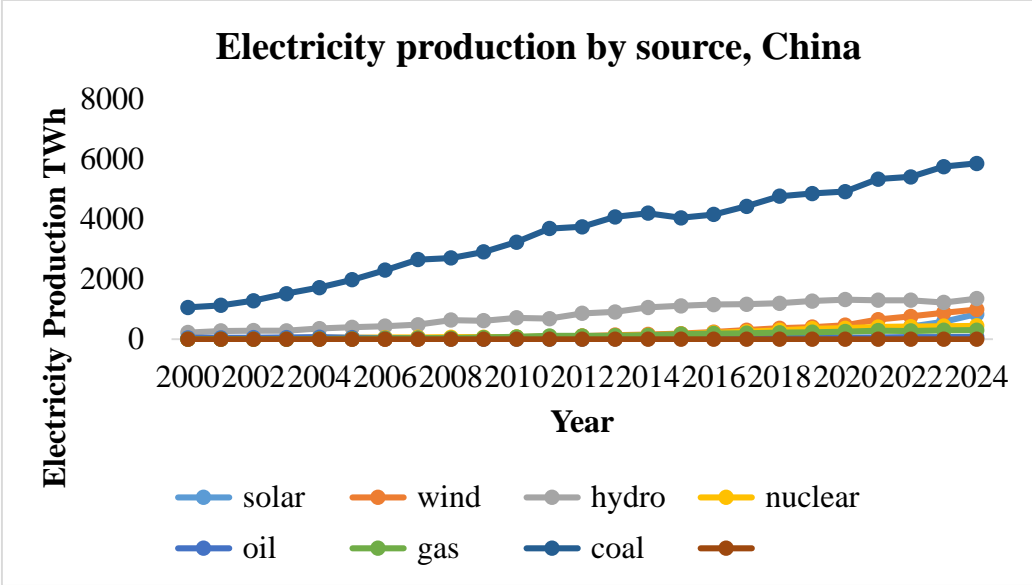


Figure 2. 2: Electricity production by source, China

Source: WDI

The electricity production mix of Azerbaijan between 2000 and 2024 has been mostly dominated with natural gas whose production has risen to 3.71 TWh in 2000 to the peak in 2023 of 27.08 TWh before slightly decreasing in 2024. Before 2005, oil made a notable contribution of more than 13 TWh in the year 2000, but was drastically reduced in its share after the year 2005 and in the 2010s became insignificant. The output of power at hydropower generation varied in a range between 1.07 TWh and 3.41 TWh, although it has shown remarkable rise to 2.9 TWh in 2024. Alternative renewable sources (bioenergy, solar and wind) were virtually absent until 2013, and thereafter were reflected in very low volume with solar and wind remaining well under 0.5 TWh each up to 2024. The general trend indicates that Azerbaijan relies heavily on gas as a source of electricity, and recently it has made some limited diversification into renewable.

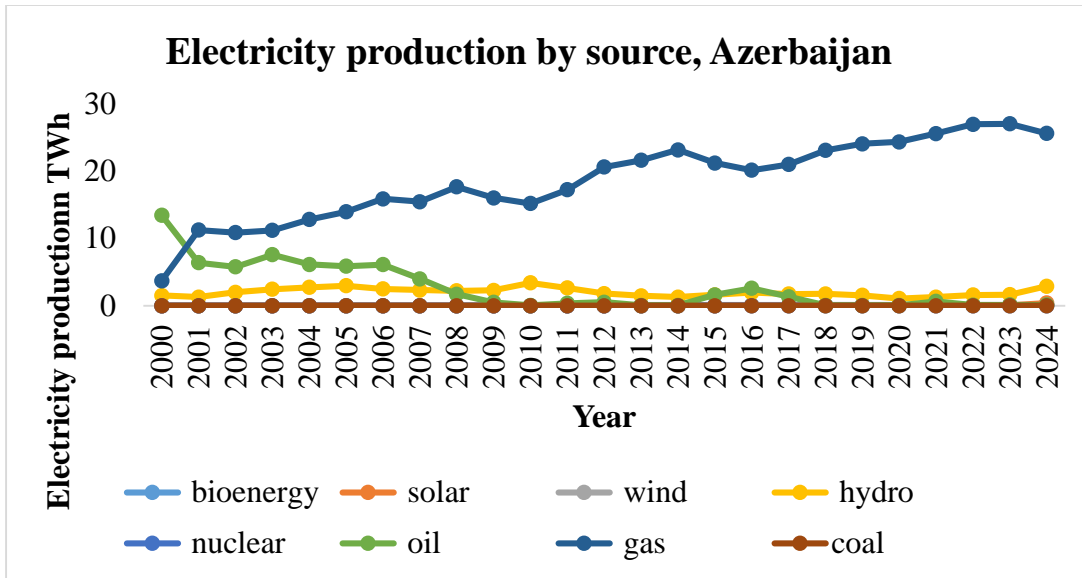


Figure2. 3: Electricity production by source, Azerbaijan

Source: WDI

In Kazakhstan, electricity production at the years 2000 and 2024 was very much dominated by coal with coal contributing the largest portion during the 2000-2024 period with variation between 35.9TWh in the year 2000 increasing to more than 65 TWh in the year 2024. The output of the hydropower remained relatively constant, generally between 7 and 11 TWh and was lately increased to 11.28 TWh in 2024. After 2014, gas-fired generation continued to increase, eventually more than triple between 2000 and 2024 (5.52 TWh to 32.87 TWh). Oil had a minor and a diminishing contribution, to decrease by 2.69 TWh in 2000 to approximately 2.4 TWh by 2024. Wind and solar did not begin contributing until the mid-2010s, and by 2024 they generate solar 2 TWh and wind 4.34 TWh. Bioenergy was insignificant during the time. In general, the power mix of Kazakhstan has been diversified, and the leading source of power in the country is coal which is supplemented by the expansion of gas and the smaller increase of renewable energy.

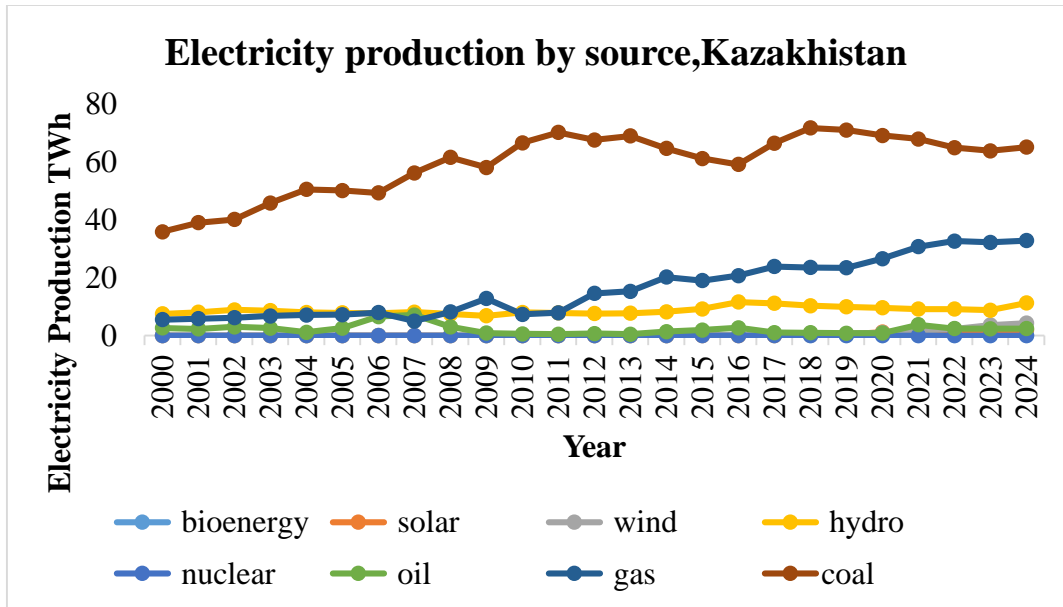


Figure 2. 4: Electricity production by source Kazakhstan

Source: WDI

Between 2000 and 2006, hydro, gas and oil dominated the electricity generation in Pakistan, with slight contribution of bioenergy and next to none of coal. During the late 2000s and early-to-mid-2010s, hydro was constant, gas and oil alternated as the most important and nuclear started to expand, whereas wind and solar emerged, but remained insignificant. As of 2016, the mix changed drastically, with coal growing exponentially to almost 25 TWh in 2019, gases reaching its peak in 2018 and dipping slightly, nuclear output increasing very strongly, and solar rapidly growing, and more rapidly after 2020, to nearly 19 TWh in 2024. By 2024, Pakistan had low power generation with a diverse electricity mix, showing large contributions of hydro, gas, coal, nuclear and solar.

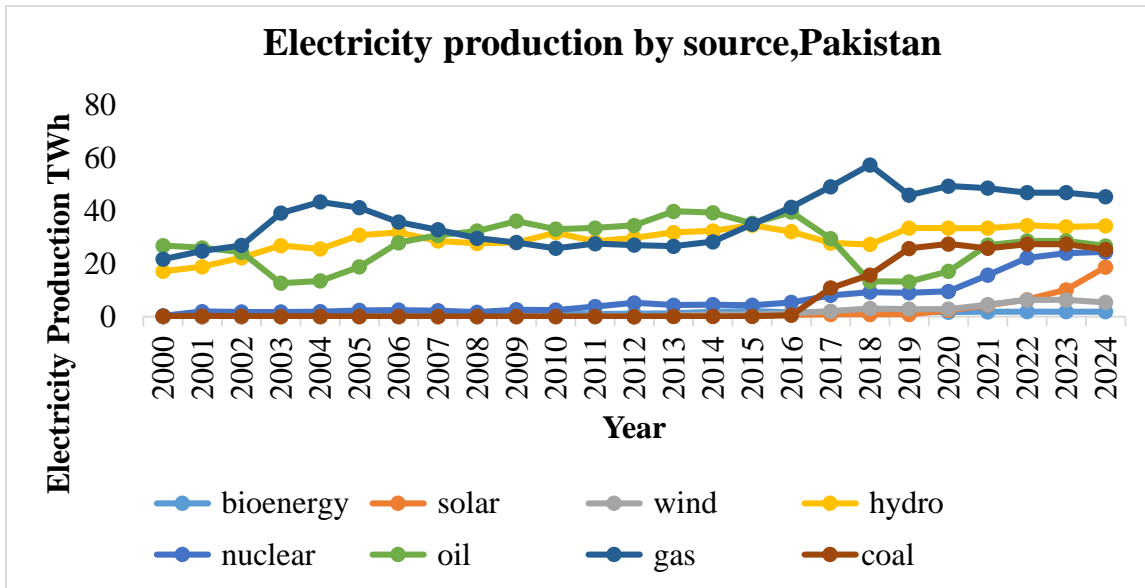


Figure 2. 5: Electricity production by source, Pakistan

Source: WDI

Electricity production in Turkmenistan between 2000 and 2023 was heavily dominated by natural gas and it rose steadily at about 9.85 TWh in 2000, and surpassing 33 TWh in 2023. Other sources, including oil, coal, nuclear, solar, wind, bioenergy, had zero, with a weak appearance of hydro only in the future (2021 onwards) (0.01 TWh), which is insignificant. This trend indicates that Turkmenistan highly depends on its vast stock of domestic gas to generate the power and that there is basically no diversification to renewable and alternative form of energy throughout the period under analysis.

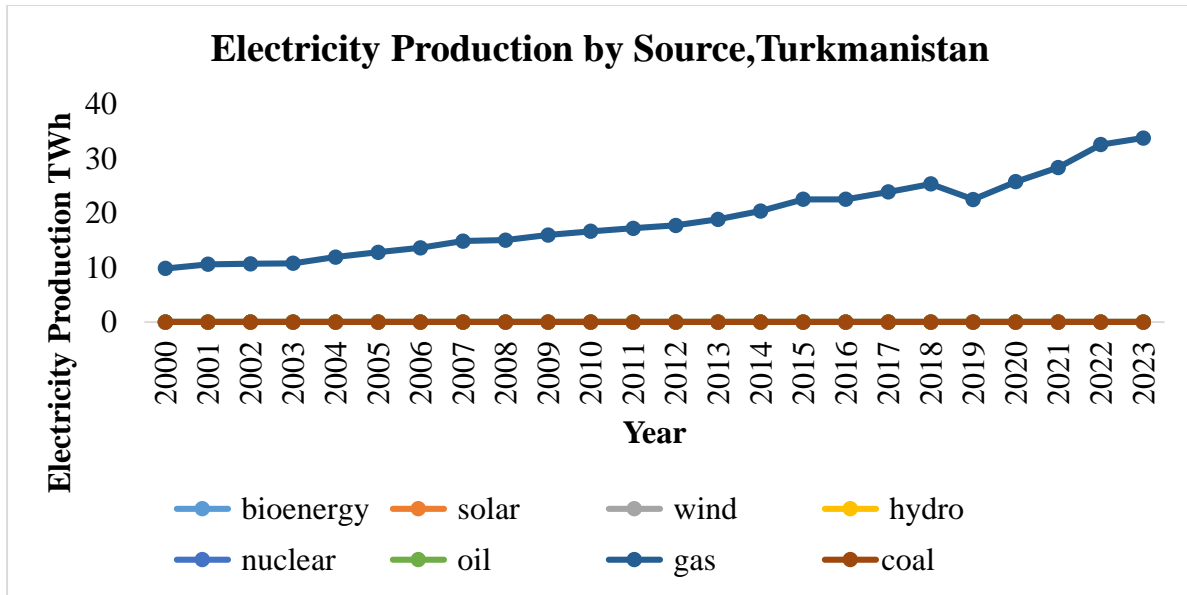


Figure 2. 6: Electricity production by source, Turkmenistan

Source: WDI

During 2000-2023, natural gas took over most of the generation of electricity in Uzbekistan, increasing continuously in the range of approximately 37 TWh to well more than 62 TWh. Hydropower, though a less significant player of 4 to 9 TWh but leveled out each year and had substantial year-to-year variation in production, oil-powered generation decreased significantly after 2000 after which it was minimal. Coal production remained low until the year 2018, and since then, it shot up to about 5.7 TWh by 2023. The use of solar power emerged after 2017 in existence at very low levels but the sluggish rise can be noticed. Bioenergy, wind and nuclear contributed nothing, meaning it was highly dependent on gas (with little diversification towards other sources).

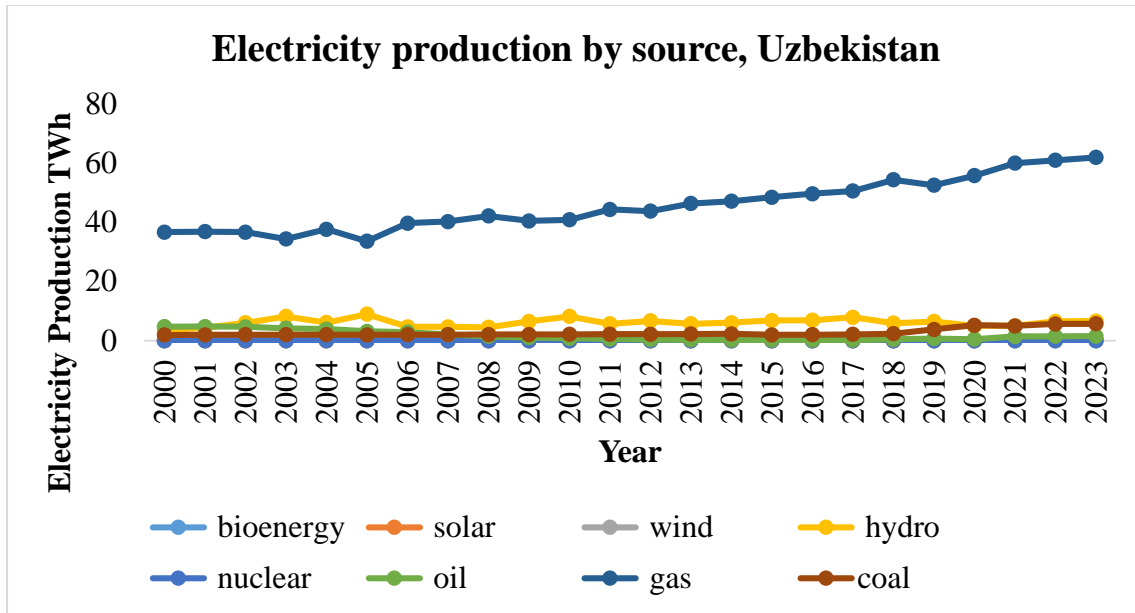


Figure 2. 7: Electricity production by source, Uzbekistan

Source: WDI

## 2.7 Pakistan Export Sector a Narrow Basket

Pakistan has skewed export basket that has its focus on labor intensive industries as well as resource based exports. The textile sector alone contributes to about 50 to 60% of the total export and other 10 to 15% is contributed to the leather goods and rice, leaving a small scope of the value added diversification exports (CDPR, 2025). Such excessive reliance on limited number of labor-intensive and resource based goods also exposes to external shocks in the form of fluctuations in global prices, supply chain shocks and energy related issues.

The transitions in energy production by sources not only show the technical paths of the energy transition, but also display the structural interdependencies that may increase or decrease the risks of energy security. Answers to this question can be found by reviewing them in concert with tendencies of export diversification, and thus strategic complementarities (a more diverse, more robust export base can support the stability and sustainability of the national energy system).

## 2.8 Graphical view of ESR & ED

As the graph below demonstrates, energy security risk increases in times when export diversification decreases, particularly in 2008-2010 and 2019-2020, which demonstrates that the country is vulnerable to external shocks. Conversely, there are minor diversification gains since

2016, which are matched by energy risk stability, indicating a potential negative correlation, in which a more diversified export base can contribute to energy insecurity by alleviating the external pressure on the energy industry.

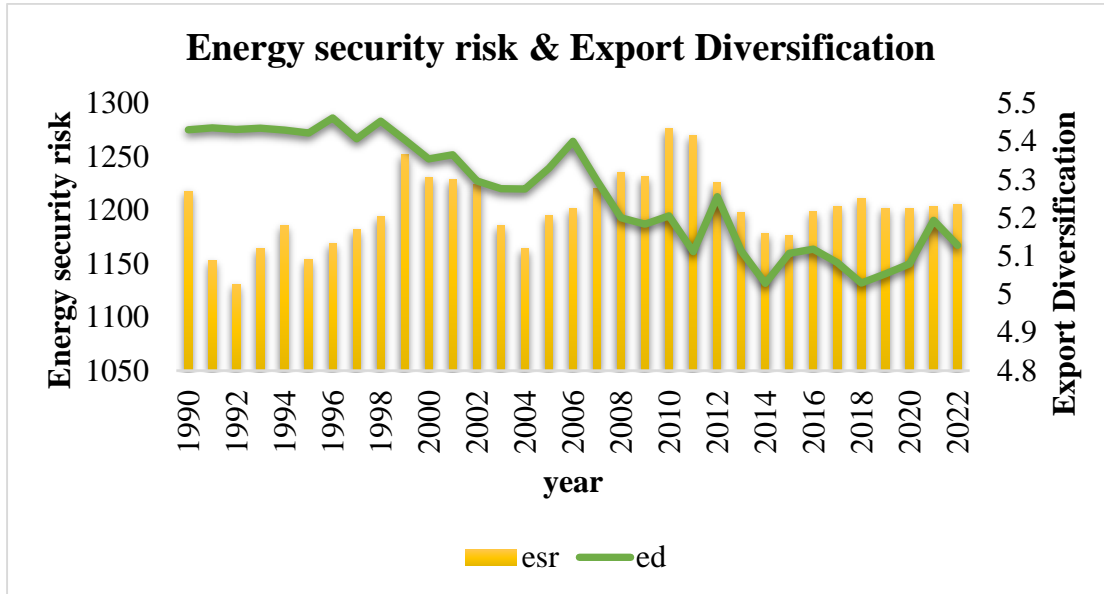


Figure. 2.8: Energy security risk & export diversification in Pakistan

### 2.9 Regional Export Comparison

The Figure below depicts the export comparison of Pakistan, Bangladesh and India and it has been showing that Pakistan has the lowest share of exports as compare to other countries. The data of export and services has been collected from WDI to distinguished the export level of these countries. According to data of WDI data, Pakistan lags behind its regional counterparts it terms of the both export volume and the diversification.



Figure 2.9: Export of Bangladesh, India and Pakistan

**Source:** WDI data

Pakistan export basket is concentrated depending on the lesser diversified products. Export Basket of Pakistan is highly concentrated and had a low level of sophistication. While the most dominant among them is the cotton. While from the past few years the products that has been classified as the manufactures of cotton accounting for almost 55% of the total share of the export. While textile leather and rice accounting for almost 70% share of the total export level. In order to upgrade the export sector of Pakistan will require an effort some of them are mentioned below (World Bank Group, 2018).

- Position trade as a central pillar of national development.
- Reform tariff structure thoughtfully.
- Advance Regional connectivity projects.
- Promote the service sector through targeted policy measures.
- Address critical supply side constraints.
- Improve coordination among key institutions.
- Build stronger partnerships with existing and new trade allies.

### 2.10 CAREC trade energy dynamic:

The existing economy of Pakistan is characterized by excessive fossil fuel dependence and a limited export coverage, but such issues can also be found in numerous states across the Central

Asian Regional Economic Cooperation Program. Similar structural features are also found in CAREC member nations including Azerbaijan, China, Kazakhstan, Pakistan, Turkmenistan, Uzbekistan where economies are highly dependent on fossil fuel causing energy security a topic of main concern in these areas (David & Causevic, 2022).

Pakistan obtain 49% of its energy requirements through imports, which makes it vulnerable to external shocks, whereas Pakistan exports are heavily segmented in textile and lower value goods. In the same way Kazakhstan and Turkmenistan use a significant amount of export income on oil and gas, and therefore their economies are vulnerable to change in fossil fuel prices. Such dependencies are against long term energy security and sustainable economic resilience (IEA, 2020). Particularly in changing international climate related policies like CBAM which charges carbon intensive imports (European Commission, 2025).

In CAREC, different intensities of clean energy transitions countries can be observed. If we look at the countries like Tajikistan and Kyrgyzstan have great access to hydropower, which makes them significant contributor in their overall mix of renewable energy (IEA, 2020). Georgia and Azerbaijan also started developing in solar and wind energy which is strengthen by International finances and projects related to the connections of the region. The clean energy transitions in Pakistan is relatively sluggish because of financial restrictions and the inconsistency in the policy framework (NEPRA, 2022).

These structural constraints are common in the energy and trade sector of the CAREC countries which are based on the overreliance on fossil fuels to fulfil their energy needs, inadequate regional trade, and poor development of the clean energy market. According to the (ADB,2022) significant implication of CAREC in energy policy, infrastructure and regulatory alignment can facilitate cross-border investment and supply stability. This means that any national strategy to enhance energy resilience and trade competitiveness are ought to be within the wider context of CAREC. A focus on green structure investment, export diversification and focus on the institutional reforms a chance to these countries to reduce its vulnerability to the external shocks and make somehow the path easier to make a transition towards renewable energy.

## 2.11 Major Export Commodities of Selected CAREC Countries

Following table 2.1 presents the major exports for the selected CAREC countries.

**Table 2. 1: Major export by selected CAREC countries**

<b>Country</b>	<b>Year</b>	<b>Total Export (\$ billion)</b>	<b>Main export Partners</b>	<b>Top export Commodities</b>	<b>Total import (\$ Billion)</b>	<b>Trade balance (\$ billion )</b>
<b>Azerbaijan</b>	2024	34	Italy, Turkey, Russia	Mineral fuels and oils, Edible fruits and nuts, Plastic	27	7
<b>China</b>	2024	3753	United States, Hong Kong, Vietnam	Electrical and Electronic equipment	3219	534
<b>Turkmenistan</b>	2023	13	China, Turkey, Italy	Petroleum gas, Refined petroleum, Nitrogenous fertilizer, crude petroleum	8	6
<b>Pakistan</b>	2024	39	United States, China, United Kingdom	Textile articles, worn clothing, Apparel, Cereals	64	-25
<b>Kazakhstan</b>	2023	90	EU, China, Italy, Russia Fed, Pakistan	Oil and related products 73%, Ferrous metals, Copper, Aluminum, Zinc , Uranium	72	18

<b>Uzbekistan</b>	2024	26	Russia, China Kazakhstan	Pearls, precious stones and metals, Cotton, Minerals fuels and oils	44	-17
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**Source:** WDI & Trading Economics

## **2.12 Does Export Concentration Lead to Energy Security Risk?**

Energy insecurity may occur in various ways when a country has export concentration; which means that they depend on a limited number of commodities or sectors. One, concentrated exportation commonly presents a potential over-reliance of the energy-intensive sector (like textiles, cement, or large manufacturing), which puts pressure on the nationwide energy reserves (Lebdioui, 2019). Second, export revenues may become disrupted by the economic shocks in global markets, which would restrict the capacity of a country to import energy or even invest in energy infrastructure.

In the case of Pakistan, historically, the fact that most exports are concentrated in a handful of low-value-added industries (such as textiles) has been straining the country on the national grid, particularly at the time of high industrial production (Kessides, 2013). Thus, export concentration can indirectly enhance energy insecurity due to reduced resilience of the economy and higher susceptibility to interruption in supply.

## **2.13 Energy Intensity of new Exports**

As much as export diversification is usually touted as one of the instruments of diminishing economic vulnerability and energy insecurity, the type of new exports is extremely important. The anticipated benefits in energy security might not be realized in case there is a shift towards either a similar or more energy intensive sector. Thus, the diversification strategy should be coordinated with sustainable industrial policy that stimulates that exports within low-energy-intensive, value-added, or green sectors (Bashir et al., 2020).

In the case of Pakistan and the Central Asian countries as well, policies that promote eco-innovation, low energy consumption criteria and clean production will allow the society to make sure that diversification does not result in an escalation of energy requirements and emissions accidentally.

## **2.14 CBAM, Diversification & Energy Security Risk**

While there has been a biggest challenge that going to hit Pakistan is the CBAM (border Adjustment Mechanism) this is basically the European Union Policy that will impose a carbon fee on the imports from the countries that uses coal for the production purpose. EU is the Pakistan largest export market. According to the experts if Pakistan continuously use coal for electricity

instead of renewable for electricity purpose it can loss competitiveness in the export market (DAWN, 2025). This policy will particularly impact Pakistan import sector such as textile and leather making it imperative to adopt low carbon and diversified export strategies. Under the policies the countries that has been failing to decarbonize their export basket would face higher tariffs that would ultimately reduce their global competitiveness.

Pakistan is already facing higher energy security risk as it heavily relies on the fossil fuels, inefficient energy utilization and the increasing financial constraints, while nearly 49% of total primary energy supply comes from the imports (Cheema et al., 2022), external shocks for example the fluctuation in the global price further strain the economy if the Pakistan fails to opt the CBAM policy and does not reduce the carbon intensity then the export sector of the Pakistan is going to suffer additional Pressure that would ultimately decreased the foreign exchange reserve and will worsen the energy security.

This study approach by examining the linkage between export diversification and energy security risk will offer valuable policy insight. By analyzing the fact that weather the export diversification increased or decreases the energy security risk, Pakistan can develop the key policies can include.

- As it will help to identify the ideal level and the composition of the export diversification to reduce the dependence on the energy intensive sectors while maintaining the economic growth.
- Promoting the sectors that mainly rely on the stable and more sustainable energy sources in order to enhance the resilience against the CBAM related trade barrier.
- Policies should be implemented that would encourage the investment in the lower carbon sector, Production that is energy efficient and the trade adjustment under CBAM.

By empirically aligning the Pakistan export diversification strategies along with the consideration of the energy security could help to ensure Pakistan economic stability while also navigating the CBAM regulatory framework. This policy would provide an evidence based framework to ensure that the trade policies can't only enhance the competitiveness but could also help to decrease the vulnerabilities related to energy security risk.

### **2.15 Pakistan's CBAM Vulnerability**

Pakistan has been extremely exposed to the European Union Carbon Border Adjustment Mechanism that will introduce pricing on imported products with regards to the covered embedded emissions. The move will apply to the exporters to EU, starting in 2026 which will require them to pay a financial burden on emissions associated with carbon intensive production. Although the mechanism is currently focused on industries in cement, steel and aluminum, fertilizers, electricity and hydrogen the mechanism is likely to be broadened to textile which dominates the Pakistan export portfolio by 2030.

Such policy realignment will have a severe effect on the competitiveness on exports, particularly considering that the nation is highly dependent on coal-generated electricity. Low investment in the renewable sector and increasing reliance on the fossil fuels threatens to make Pakistan export more expensive in international markets because of carbon tariffs. Unless Pakistan switches rapidly to clean energy and carbon cutting technologies, specialist believes that the country will be less competitive with its export to EU countries especially to EU countries and especially textile industries. In this way CBAM will not only be an environmental regulations but a possible trade barrier, particularly to carbon intensive economies like Pakistan(DAWN, 2025).

### **2.16 Policy Strain**

Energy insecurity and export concentration are two structural weaknesses which are becoming limiting to the economic stability in Pakistan. On the one hand, structural flaws in the power system that are due to the old infrastructure, failure in governance and the need to use imported fuels have led to frequent load shedding and high electricity prices, which directly affect the productivity of industries and their competitiveness in exports. According to estimates provided by the World Bank (2019), the economy suffers 6.5 percent GDP annually due to these distortions in the power sector in addition to the US\$12.9 billion lost in cases of unreliable electricity supply, which is a significant factor that strongly demonstrates the harsh economic consequences of energy insecurity (WDI, 2024c).

On international scale, the increase in demand of energy due to the growth of population, technological progress, and the growth of industries has exerted pressure on the importing economies such as Pakistan. Having 73 percent of total electricity generation in the world that

remains reliant on coal, gas, and hydro, the fluctuation of fuel prices in the global market also increases the import bill of Pakistan and compounds the already small foreign exchange reserves (VIS, 2023).

At the same time, the export sector is 810 percent of GDP which is important source of foreign exchange in Pakistan. Nonetheless, the export dependence on textiles (60% of exports) has limited diversification opportunities and the ability to respond to external shocks like changes in world demand, change in trade policies and carbon-based border policies. Although GSP+ access and energy tariffs support kept volumes of exports at temporary levels, it failed to address the structural problem of concentrated exports (MPRA, 2025).

The combination of these processes produces a vicious cycle of energy insecurity increases the cost of production, reducing the competitiveness of exports, and the lack of diversification of exports reduces foreign exchange earnings, and with limited capacity to import energy and invest in energy infrastructure, restricting Pakistan in its exportation. This trade energy trap highlights how important redesign export structures are not only in terms of growth, but also as a tool of strategic device in improving energy security.

### **2.17 Pakistan Industrial Landscape**

Industrial sector is deemed as the key segment of contemporary economy, hence it generates resources (energy and materials) that are vital to overcome the trend of a quick surge. In Pakistan, the growth rate was at 1.21 percent in 2024 Fiscal Year (Finance Division, 2024) and in 2023, its contribution to GDP was 20.76 percent (Trading Economics, 2023). Nonetheless, with the transformation of the economy towards an industry-based economy, the country is experiencing increased energy consumption and carbon emissions because more than 98 percent of its energy sources are pollutants. The world pressure to curb global warming is increasing and Pakistan has to contend with the need to curb the level of industrial emissions that have been made into the environment and the level of industrial and economic competitiveness. The carbon intensity of Pakistan industries tends to be greater than that of EU countries since Pakistan industries have outdated industries, technologies, energy consumptions and dependences on coal and other fossil fuel. Due to the effect of the implementation of CBAM, there would be far-reaching consequences on their industrial exports. Concurrently, the challenge will offer Pakistan a chance of moving

toward a more sustainable industrial model and the enhanced competitiveness on the global market by 2030.

## **2.18 Conclusion**

Conclusively, both export diversification and energy security risk integration in one study would help to represent a critical pathway for the Pakistan and as well as for the selected CAREC countries to increase the economic resilience, decrease the dependency on the imported fossil fuel and also build a complete position in the global trade market.

## CHAPTER 3

### LITERATURE REVIEW

#### 3.1 Theoretical Foundation

The interlinkage between export diversification and energy security risk can be found in both economic and energy security theories. According to the Portfolio Theory (Markowitz & Todd, 2000) export diversification tends to decrease macroeconomic risk thus conclusively strengthen energy security by stabilizing income and foreign energy reserves (Hesse, 2009). Pakistan is facing severe energy crises because of its highly concentrated export structure this make national stability prone to outside repercussions that include fluctuations in the prices and supply chain interruptions (Hesse, 2009).

A framework for energy security developed by contain four vital aspects including availability, affordability, efficiency and sustainability (Ren & Sovacool, 2014). Countries that have a higher export diversification might have strengthened energy security because of the dependence on the lower volatile market and ensure the stability of the revenues for investment in the energy sector (Apergis & Payne, 2009). Export diversification therefore, is an indirect energy security measure in the sense that it increases fiscal stability as well as mitigates reliance on inconsistent single-market incomes which is pivotal in Pakistan where the energy import payment is consuming a large part of the export revenues.

According to theoretical viewpoints the process of export diversification effect disaggregated energy use through industrial transformation and technological improvements (Hausmann & Hidalgo, 2010a). According to structural change theory the energy consumption pattern of economies changes when they evolve from functioning in lower productivity sector into high productivity sectors (Sadorsky, 2014). This is evidenced by the effort by Pakistan to add other sectors to its main export which is low value since initial diversification of industries has led to the high consumption of fossil fuel. Nevertheless, according to (Kahia et al., 2016), the successful transition to higher-value and technologically advanced export groups also leads to a transition to more energy-efficient processes in countries, which eventually lowers the energy intensity in the long run.

This process is plausible based on the reasoning of the Environmental Kuznets Curve (Grossman & Krueger, 1995), according to which in early stages of diversification, energy consumption and emissions increase, but past a certain point, when the technological absorption is enhanced, the economies start to switch to cleaner patterns of energy consumption. The Pollution Haven Hypothesis (Cole, 2004) comes into play in this direction as well with respect to Pakistan: as economies have low diversification, they depend on energy-intensive, low-tech export industries, which intensifies CO<sub>2</sub> emissions; when their exports are more sophisticated, they promote adoption of cleaner industrial processes and energy efficiency.

Thus, in the example of Pakistan export diversification does not work as a trade policy but as a macro-stabilizing, an energy risk reducing process, which has an impact on energy security (via foreign exchange stability) and on energy intensity/emissions (via structural transformation and technological adjustment).

Although the theories described above offer the generalized explanation of the correlation between the export diversification, energy consumption and emission in case of South Asia, the theories need more localized interpretation. In Pakistan the energy sector is defined by a high level of import dependency, low level of technological adaptation and a lower level of energy resilience (Kalantzis & Revoltella, 2019). The South Asian Energy Transition Framework recommends that economies in the process of diversifying in this region are highly vulnerable as they become structurally dependent on imported fossil fuels and insufficient capacity of renewable infrastructure (Sapio & Spagnolo, 2020).

Equally, the Trade Dependency Framework of South Asia states that economies having a low export base face limitation in the amount of foreign exchange earnings, and thus do not have the capability of absorbing the impact of energy price shocks and invest in energy diversification (Gnangnon, 2016). Export diversification in these environment is not just a tool of economic growth but a strategic tool of providing a buffer to energy security by stabilizing the external revenue streams as well as making the system more resilient to external supply shocks.

Thus, the combination of these region-specific views helps to strengthen the thesis that the diversification of exports in Pakistan may be used as a risk-reduction tool, minimizing the risks of having to deal with the instability of the global energy market, but allowing shifting to a more stable and efficient energy framework gradually.

## **3.2 Empirical Literature Review**

Although other researchers have done studies under the macroeconomic determinants like GDP per capita, remittances, and unemployment separately when investigating the effects of energy consumption and security, a gap is evident with regards to the fact that there is no empirical framework to be used in linking export diversification with energy security risk. More crucially, the moderating nature of CO<sub>2</sub> emissions under this nexus has not been significantly tested especially when the developing economies such as Pakistan are being considered.

### **3.2.1 Implication of Energy Security Risk**

The energy security risk has created significant challenges for the economic growth and environmental sustainability in Pakistan. The repeated energy crises in the energy stem arise from Pakistan excessive use of imported fossil fuels together with inadequate management of domestic energy sources along with poor governance system (Jamil & Ahmad, 2010). The energy deficiencies reduced industrial productivity level and slow down economic development while causing large financial damages. Nonrenewable energy combined with their growing usage have created more carbon emission that are created challenges including both climate change and environmental destructions (Ali, 2010). The issue need a strategic policy direction which support both sustainable resource consumption and energy resilience to guarantee ongoing energy security.

### **3.2.2 Determinants of Energy Security Risk**

The factors that contribute to energy security risk are economic, geopolitical environmental. Climate change is a critical driver, as increasing global temperature and unpredictable weather patterns disrupt energy supply chains, and clean energy investments are necessary for mitigating the adverse effect of climate change (Iyke, 2024) The study have been done for Chinese provinces covering the time span 1980- 2018. Geopolitical scenario further worsens the scenario, as political instability and international conflicts enhance the vulnerabilities of energy supply disruptions (Lee et al., 2024), this research have been done on the panel data from 2005 to 2018 . Furthermore, Financial development is a key determinant of energy security, as empirical studies show that well-functioning financial market significantly predict and mitigate energy security risk (Kartal et al., 2024).This study utilized crossed contilogram method for estimation on quarterly data from 1980 Q2 to 2018Q4.

Governance related factors also impact energy security. Control of Corruption political stability and efficient government institutions have been found to be the long term mitigators of energy security risk, and financial market efficiency only offers short term relief (Chen et al., 2024). This has been analyzed as possible approach to strengthen energy security with studies showing that higher adoption of wind, hydroelectric and solar energy results in the depletion of vulnerabilities in energy security (Cergibozan, 2022). There are various other economic indicators that have mixed effect on energy security based on a specific country socioeconomic conditions, for example, urbanization, foreign direct investment and government expenditure (Ullah et al., 2024).The study have utilized Panel data from 1992 to 2018 and have employed Feasible Generalized Least square method for estimation.

### **3.2.3 Diversification and Energy Dynamics**

Available empirical studies give contradicting results regarding how export diversification affects environmental and energy related consequences. Other studies suggest that the diversification can increase energy use and carbon emissions (manufacturing growth and higher production intensity) in the short term(Mania, 2020), whereas some studies argue that diversification will enable technological uplifting and increase in energy efficiency in the long run (Nguyen et al., 2024). As an example, empirical measurements on various economies indicate that export and import diversification have a positive effect on the economic growth and macroeconomic stability, which means that diversification enhances the ability of a nation to absorb external shocks, such as energy shortages (Can et al., 2023; Young, 2024).

Studies of energy implication of diversification reveal that it can have various impacts at various developmental stages. (Lee & Ho, 2022) state that diversification in emerging economies is likely to make the energy more intense because of the growth of industries. Nonetheless, research on the BRICS economies has shown that the more diversified the export, the more likely the country will have energy-efficient production structure, resulting in the apparent fall of energy demand in the long run (KILIÇARSLAN, 2022). The cross-country analysis of 95 economies also confirms the non-linear (inverted U-shaped) relationship between the export diversification and the energy consumption, with the energy demand rising at the initial stages of diversification and decreasing after the technological and structural threshold (Nguyen et al., 2024).The Global North evidence

is also similar with evidence indicating that, diversification helps to reduce the long run energy demand by increasing efficiency and ability to innovate (Olasehinde-Williams et al., 2023).

Although these studies focus on the connection between export diversification and energy consumption pattern, there is still a significant gap between how such transformation can be translated into energy security risk reduction, in particular, in such economies which are energy-importers such as Pakistan. Most of the available literature addresses the intensity of energy or the adoption of renewable energy, but does not directly relate diversification to the capacity of a certain country to absorb exogenous energy spikes, smooth foreign exchange reserves, and ensure an uninterrupted energy supply. Thus, the given study adds to the literature on the relationship between export diversification and the dynamics of energy consumption, as well as the risk of energy security since in Pakistan, the context-specific factors contribute to the fact that external trade structure and energy vulnerability are highly intertwined.

#### **3.2.4 Moderating Role of CO<sub>2</sub> Emission**

Analysis of CO<sub>2</sub> emission presents an initial understanding within the export diversification and energy consumption framework. Multiple econometric technique has been employed in order to examine these nexuses. The research conducted by conducted on annual data from 1971 until 2011 and the results demonstrated the positive influence of fossil fuel consumption and CO<sub>2</sub> emission. GMM panel method on emerging economy Panel data between 1990 to 2014 showed that export diversification increased renewable energy consumption when environmental policies are quite strict.

Export diversification has a positive influence on export Product diversification (Mania, 2020). This study utilized system generalized method of moment and pooled mean group estimation technique for checking the both long term and short run relationship between ED and CO<sub>2</sub> emission for the time period 1995 -2013. Similarly, the other study has been conducted for the time period 1986 to 2017. The study has utilized the second generation unit root estimation technique and it concludes that remittances and export diversification helps to reduce environmental degradation. Mostly studies that are somehow relevant have been done for the developed countries while there is a still literature gap in case of Pakistan.

### **3.2.5 GDP Per Capita Growth**

The Growth of GDP per capita is a general measure of national economic development and is intrinsically linked to a nation's energy demand, consumption behavior including investing into the energy infrastructure. When income increase the industrial activity increase as well, causing the use of more energy which effects the energy mix in a country. (Sadorsky, 2009) focused on the fact that energy consumption in the country of developing economy, in particularly fossil fuel consumption, is enormously influenced by economic growth. Meanwhile with the growth of GDP, government and private sector can afford the investment in energy efficiency and renewable energy sources. This study has been conducted for G7 countries for time span 1990-2015. In the study by (Narayan & Smyth, 2009) which evaluated the growth in GDP per capita in Middle eastern countries for time period 1974-2002 revealed that GDP per capita growth is the long run determinant of energy consumption and energy security. Likewise, a research done by (Apergis & Payne, 2011) on the economies of the Central America revealed that the consumption of renewable energy depends on a very great extent on how the per capita income changes. This study has been conducted for time period of 1980-2006 used PCSE technique for estimation. These reports illustrate the two-fold impact of economic growth, as a lever of energy demand and as an enabler of a transition of energy. Given the situation in Pakistan and other emerging economies, it is important to include GDP per capita growth as the control variable that will reflect the macroeconomic mechanism and its impact on energy security and export diversification patterns.

### **3.2.6 Remittances**

Remittances inflows have emerged as a significant source of finances in developing economies and obviously Pakistan is also a part of it. They help build household income, economic resilience and foreign exchange reserve of a nation which may indirectly effect energy security. On household level remittances household ability to adopt modern energy sources, invest on clean energy solutions and energy efficiency. (Adams Jr & Cuecuecha, 2013) discovered that household that receives remittances are more exposed to investing in the energy efficient durable and housing that influence the energy consumption behavior. This paper basically estimated the influence of the Internal remittances from the Ghana and the international remittances from Africa on the investment and poverty in Ghana. The finding further demonstrate that remittances can help to reduce poverty level and increase investment in the energy sector. This is the survey based study

from 2006-2007. An empirical evidence by (Das et al., 2021) revealed that remittances boost energy consumption because it makes it more affordable to purchase durable goods and to upgrade their life styles. This study has been conducted for Bangladesh using annual data for time period 1980-2017 by using VAR model. One other study by (Rahman et al., 2021) that have examined the impact of remittances on renewable energy consumption for South Asia using time period 1976-2019 ,DOLS,FMOLS,VECM estimation technique. The result demonstrates that when the remittances increase by 1% then the renewable energy consumption increased by 0.045%. Remittances can help to ensure economic and social sustainability and policy effectiveness in the economy. This study would take account of remittances to understand in better way the influence of financial inflows on pattern of renewable and fossil fuel consumption.

### **3.2.7 Unemployment**

Unemployment indicates some inefficiencies in labor markets and it has direct and indirect impact on energy security and energy demand. Usually high unemployment indicated by low economic activity and low energy consumption. Nevertheless, it restrains the ability of the private and fiscal sector to invest in clean energy technologies and energy infrastructure. The importance of the renewable energy consumption has been increased on a large scale over the years. Renewable energy consumption has an negative and significant impact on the renewable energy consumption according to (Rahman et al., 2021). This study has been conducted for South Africa for the time period 1990-2014 using ARDL model to capture the short run and long run relationship among main variables. The other study by (Akarca & Long II, 1979) demonstrate that the employment response to the provision of energy inversely. In developing countries, the creation of job in energy related sectors can not only facilitate the development of the economy but also enhance energy access and decreasing energy insecurity. In addition, the sector of energy is by itself labor dependent, particularly by renewable energy undertaking and therefore dynamic of labor market facilitate green energy transformations. Hence unemployment is the significant control variable in the study as it reminds the socioeconomic status that influence household and industry level energy choices.

### 3.2.8 Pakistan Specific:

Table 3. 1 Pakistan Specific Literature

Study	Time period	Method	Key Findings	Author
Energy Security in Pakistan Perspective and policy implication from a quantitative analysis	2011-2017	4-As	1-The problem of energy security is persistent despite of investing in the energy infrastructure from the last five years. 2-The study suggests that there is a need to shift towards greener source of energy	(S. Malik et al., 2020)
Energy Security index of Pakistan	1991-2040	PCA	Declining energy security performance btw 1991-2020. Pakistan energy security policies is not effective now while it is suggested that it may be improve as energy security showing upward trend till 2040.	(Abdullah et al., 2021)
Energy policy evaluation in Pakistan	1990-2024	Systematic Literature review	The study suggests that there is a need to increase the fiscal incentives and to increase the institutional support to enhance energy security and climate resilience.	(Q. Shahzad & Aruga, 2025)
Impact of electricity generation, consumption , energy trade and ICT on the environment in Pakistan	1993-2020	ARDL-NARDL	The results suggest that the consumption of electricity, whether there has a +ive or -ive shock it have an tendency to emit more.	(Khaliq et al., 2024)
Sectoral growth Exports and Energy consumption a case of Pakistan.	1990-2019	ARDL	Results showed the –ive effect of energy consumption on industry, personal expenditures, and exports of goods and have an +ive affect agriculture and services.	(Urooj & Zafar, 2022)

Analysis of energy consumption and change structure in major economic sectors of Pakistan	1990-2019	Logarithmic mean Divisia index method	Change in the mixed energy and the sectoral income have shown the -ive effect and energy intensity and population have an increasing trend	(Bai & Raza, 2024)
Dynamic linkage between, industrialization, energy consumption, emission and agriculture product export for Pakistan		ARDL	Increase in industrialization, emission and transportation decrease export of agriculture by one percent.	(Z. A. Khan et al., 2021)

## CHAPTER 4

### DATA AND METHODOLOGY

#### 4.1 Conceptual Framework

Export product diversification reduces the energy security risk through stabilization of economic conditions and decrease market dependency on the volatile energy market according to (Hesse, 2009; Markowitz & Todd, 2000). The narrower export diversification of Pakistan is making it more vulnerable to external energy shocks and increasing the energy security risk. Countries with high export diversification can reduce these vulnerabilities by bringing efficiency in the technological sector and by promoting transformation in the industrial sector (Hausmann & Hidalgo, 2010a; Sadorsky, 2014).

Existing studies by reveals essential factors that can effect energy security risk such as geopolitical risk, financial development, governance and climate change (Iyke, 2024; Kartal et al., 2024). The extent of export diversification controls how nation consume their energy resources because research demonstrates conflicting results between increased in energy intensity and adoption of cleaner source of energy as some studies demonstrate that export diversification increased energy intensity while other indicates that export diversification increased the consumption of renewable energy (KILIÇARSLAN, 2022; Lee & Ho, 2022).

In order to empirically examine these nexus, this study would use an export diversification index that is being constructed by using both intensive and extensive margin (U. Shahzad et al., 2021). The first model is being constructed to capture the nexus between export diversification and energy security risk (Hansen, 2000). Second model is being constructed to capture the impact of export diversification on both renewable and nonrenewable energy we are following the study by (Rehman et al., 2023) to construct our model. And the third model demonstrate the moderating role of  $CO_2$  between the relationship of export diversification and energy security risk.

#### 4.2 Sample Selection

The countries in this cross-sectional analysis like Azerbaijan, China, Turkmenistan, Kazakhstan, Pakistan, and Uzbekistan, are all a part of CAREC (Central Asia Regional Economic Cooperation) program. The main rationale underlying the decision of using this particular group is the

availability and reliability of consistent data on the set of selected variables, which is inevitable in the maintenance of the strength and validity of the econometric analysis.

In addition to the availability of data, such countries have a distinct energy mix and trade relationship. Particularly, four of the six countries (Azerbaijan, Kazakhstan, Turkmenistan, and Uzbekistan) are large exporters of fossil fuels, and their economies are highly reliant on energy exports. They are especially pertinent to the study of the relationships between energy security threat, trade diversification, and clean energy investment as they heavily depend on the hydrocarbons.

China and Pakistan are big emerging economies at the same time with elevated energy requirements and increment in the investments in infrastructure and trade incorporation, and renewable energy casting-offs. Their addition gives a comparative vision as to how the countries that import energy and export it through the same structure of regional interaction deal with similar issues by adopting divergent solutions.

Besides, CAREC and Belt and Road Initiative (BRI) are located in the same regional cooperation frameworks in all six countries which also foster trade connectivity, infrastructure development, and energy cooperation. This common ground lends analytical plausibility to the collective by permitting the inspection of local trends, the influence of policies involved, as well as integration initiatives in a more or less comparable rating. Accordingly, the selected sample does not only meet the criteria of data feasibility but also represents an interesting combination of economic systems, energy reliance, and policy orientations in the CAREC region.

## **4.3 Methodology**

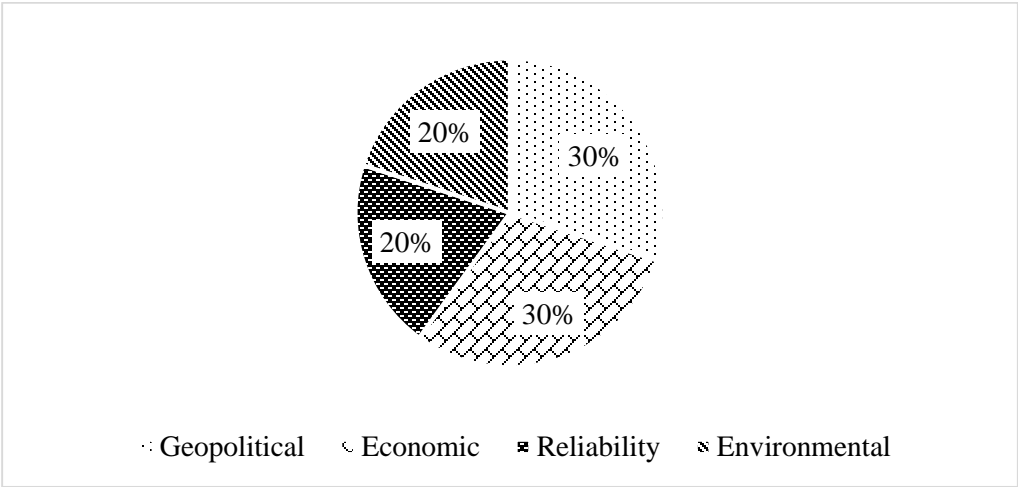
### **4.3.1 Research Design**

In order to check the influence of export diversification on energy security risk and disaggregated energy Consumption for CAREC countries including (Azerbaijan, China, Turkmenistan, Pakistan, Tajikistan, Uzbekistan) we have collected data for our variables. We collected data for Energy security risk from US chamber of Commerce they made an index by the weighted average of four main factors including economic, geopolitical, environmental and reliability , the data is available for it until 2018 (US Chmaber Of Commerce, 2020). The data renewable energy we will gather from WDI, while the data of non-renewable energy will be gathered from Handbook of statistics

from Pakistan economy and energy yearbook 2022. The data of other control variable including GDP per capita growth has been collected from WDI. Data of Remittances and unemployment has been gathered from WDI. The data for the respective variables is available for the time period 1990-2023. So, the empirically analyses would be done for this time period for both panel data and time series estimation.

**4.3.2 Energy Security Risk Index**

Energy Security Risk has been calculated by using four main factors including economic, geopolitical, environmental, reliability to do this the input share of these four factors to make a final index is assigned with the following shares.



*Figure4. 1:Share of Four Sub Indexes*

**Source:** US chamber of Commerce

**4.3.3 Categories of Energy Security Matrix**

Following are the categories along with their descriptions that have been used in order to have an index for ESR and these all are divided into further more variables (US Chmaber Of Commerce, 2020).

Table 4. 1: Energy Security Risk Matrix

<b>Category</b>	<b>Description</b>
<b>Global Fuel</b>	It basically measures the diversity and the reliability of the supply of oil and the global reserves. If there have been high diversity that indicates lower risk to energy Security.
<b>Fuel Imports</b>	Measures the exposure of the economy to the most concentrated and the unreliable supply of the oil and the import cost of the NG. If there is an increasing cost and higher reliability indicates the lower energy security risk.
<b>Energy Expenditure</b>	Measure the extent of the energy cost towards the economy and the consumer exposure towards the shocks of prices. If the cost and the exposure is lower that indicates the lower ESR.
<b>Market and Price Volatility</b>	Exposure of economy towards the movement of energy prices. If the volatility in the energy prices are lower indicates the lower threat to energy security.
<b>Energy Use intensity</b>	Measure how much energy has been utilized in order to have a certain amount of the output. If the energy use is lower that indicates the lower level of the ESR
<b>Electric Power Sector</b>	Diversity and the reliability of the electricity power generation. If both Diversity and Reliability is high means there is an lower ESR.
<b>Transportation sector</b>	Efficiency of the vehicles and the diversity of the fuel has been measured through this. Higher level of efficiency indicates lower ESR.
<b>Environmental</b>	Measure exposure of the economy towards greenhouse gas emission. Lower emission rate means lower ESR.

<b>Research and Development</b>	New technologies and development of the capital has been measured through this. If there is an higher amount of investment in new and efficient technologies the ESR would be lower.
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*Source: US Chamber of Commerce*

**4.3.4 Export Diversification Index**

Export diversification index have been created by using the both intensive and extensive margin. Theil index is basically used to make an export diversification index which is the sum of both intensive and extensive margin. Intensive margin referred to as in the increase of export from the existing export basket while extensive margin is an increase of export of new product (U. Shahzad et al., 2020).

$$EXD_b = \sum n \left( \frac{TE_{gs}}{TE} \right) \left( \frac{RA_{gs}}{RA} \right) + \ln \left( \frac{RA_{gs}}{RA} \right) \dots\dots\dots 4.1$$

gs in the equation represents the commodities and services that is being used domestically and also being exported to both of the developed and the developing countries.  $TE_{gs}$  and  $\frac{RA_{gs}}{RA}$  in the above equation represents the total export and comparative mean export value . However, each enormous export value for Pakistan is being determined separately.

$$EXD_b = \sum g_s \left( \frac{TE_{gs}}{TE} \right) \left( \frac{RA_{gs}}{RA} \right) \ln \left( \frac{1}{TE_{gs}} \right) \sum i \partial \ln \left\{ \frac{Z_i}{RA_{gs}} \right\} \ln \left\{ \frac{Z_i}{RA_{gs}} \right\} \dots\dots\dots 4.2$$

z here represents the export earning of the nation while by taking calculated mean value of both export values including both intensive and the extensive the export diversification index has been created for each of the country.

Further in order to analyze our objective independently following would be the models that we will goanna use further for our estimation technique.

**Model 1**

We will follow (Ben Jebli et al., 2022) as three mechanisms of EKC would elaborate the relationship between export diversification and energy security risk. We develop our model as follows.

$$ESR = \alpha + \beta_1 ED + \beta_2 GDPPG + \beta_3 REM + \beta_4 UNEMP + \varepsilon \dots\dots\dots 4.3$$

In the model ESR is our dependent variable that is energy security risk. Ed represents export Diversification. GDPPG gdp per capita growth, REM remittances UNEMP are unemployment these three are the set of control variable that will be used in our analysis.

This first model overall explains the nexus between export diversification and energy security risk.

**Model 2**

We would follow (Rehman et al., 2023) to construct our model for our objective 2 as we would analyze both separately in our models .

Model 2 examining the impact of export diversification on Renewable energy and non-renewable energy would be examined separately for estimation determining how export diversification influences these specific energy categories.

$$E = \beta_0 + \beta_1 ED + \beta_2 GDPPCG + \beta_3 REM + \beta_4 UNEMP + \varepsilon \dots\dots\dots 4.4$$

- Here E represents the Disaggregated energy.
- ED represents export diversification.
- GDPPCG represents GDP per capita growth.
- REM represents remittances.
- UNEMP represents unemployment

This equation will be estimated individually for both renewables and non-renewables.

$$RE = \beta_0 + \beta_1 ED + \beta_2 GDPPCG + \beta_3 REM + \beta_4 UNEMP + \varepsilon \dots\dots\dots 4.5$$

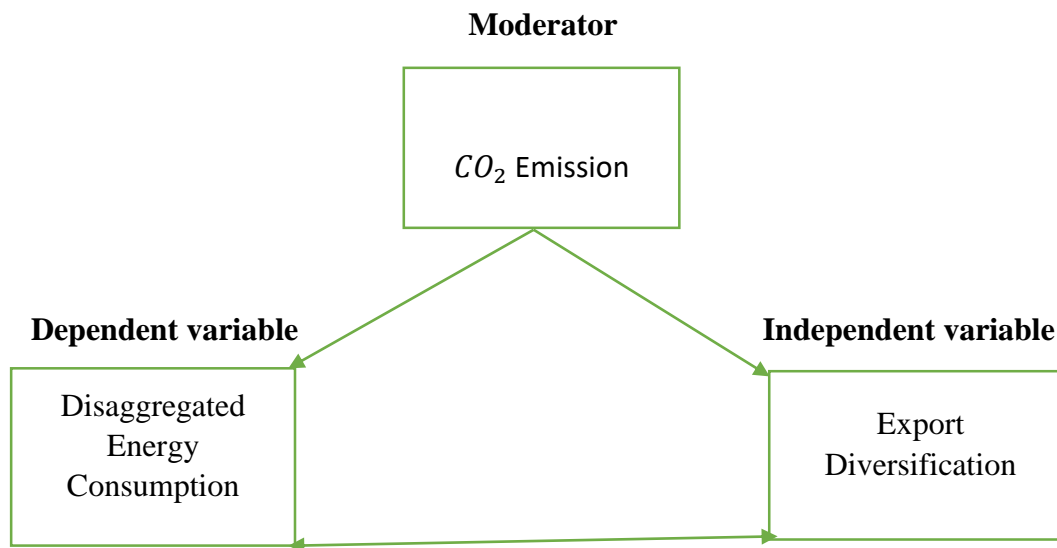
Here RE in this equation represent Renewable energy.

$$NRE = \beta_0 + \beta_1 ED + \beta_2 GDPPCG + \beta_3 REM + \beta_4 UNEMP + \varepsilon \dots\dots\dots 4.6$$

While, NRE represents nonrenewable energy.

**Moderating role of CO<sub>2</sub>**

The study would analyze the moderating role of **CO<sub>2</sub>** between export diversification and Disaggregated energy consumption.



### Model 3

$$E = \beta_0 + \beta_1 ED + \beta_2 CO_2 + \beta_3 ED \times CO_2 + \beta_4 X + \varepsilon \dots \dots 4.7$$

Here in the model E represents Dis aggregated energy. This model will be utilized for analyzing the moderating role of CO<sub>2</sub>, whereas X represents the set of the control variables.

CBAM has a significant implication in the export sector as it imposes tariffs on the high energy intensive product that indirectly influence the CO<sub>2</sub> emission. As the study is examining the moderating role of CO<sub>2</sub> emission between export diversification and disaggregated energy consumption hence CBAM influence on the CO<sub>2</sub> emission can alter the relationship.

#### 4.4 Incentivizing Lower Carbon Exports

Because of the increased in the cost of the CO<sub>2</sub> under CBAM can encourage Pakistan to increased export diversification towards the lower carbon products. This might help to decline the dependence on the higher energy intensive sector and can resultantly reduce energy security risk.

#### 4.5 Potential Challenges

If the industries would continuously depend on the energy intensive sector would might affect the export sector by increasing the cost of the imports will ultimately increase the energy security risk and will hinder the transition towards the renewable energy.

The finding would mainly highlight the aligning of the Pakistan export diversification strategies along with the global climate goal. Policymakers can further leverage these findings and can further develop and implement a strategy that can increase export diversification along with declining ESR that can help to develop sustainable energy consumption. Specifically, the moderating role of the CO<sub>2</sub> emission ensures the need of an export of the lower carbon products to ensure the energy security in the long run along with increasing economic resilience in the face of the evolving global trade policies like CBAM.

## **4.6 Panel data estimation**

### **4.6.1 FGLS and PCSE**

For the empirical analysis of this study, I followed the following approach. First, I checked the descriptive statistics of the data to find the mean, standard deviation, and percentile values. Second, to examine cross-sectional dependence in data, I conducted the Pesaran (2004) test. Third, to minimize the possibility of spurious regression findings, I analyzed whether data is stationary at level or first difference by employing Im, Pesaran and Shin (Im et al., 2003), Fourth, I checked co-integration among the variables of the study by employing second-generation co-integration tests such as Wester Lund techniques (Westerlund, 2007).

Fifth, as we have small panel data, this study employs feasible generalized least squares (FGLS) as the main estimation technique due to its effectiveness in handling small panels with cross-sectional dependence (Liao & Cao, 2013). Moreover, for a robustness check, this study also employs another effective small panel technique, namely panel corrected standard error (PCSE), and also its accurate estimation in the presence of panel error structure (Beck & Katz, 1995; Marques & Fuinhas, 2012).

## **4.7 Time Series Estimation**

### **4.7.1 Engle Granger Co-integration**

Co-integration is one of the most important tool to measure long run relationship between the variables. The most common method to analyze the co-integration is Engle Granger that has been introduced in 1987. If we look at one side co-integration utilize the theory of a unit root while on the other side it provides a statistic base significance of the long run and short run relationship

among the main variables. If the linear combination of the two non-stationary variables are stationary, then we say that the variables are perfectly co-integrated. For example if we have two variables that is  $Y_t \sim I(1)$  and  $X_t \sim I(1)$  then the linear combination of both would be  $\varepsilon_t = y_t - \alpha - \beta X_t$  if here  $\varepsilon_t \sim I(1)$  then we say that  $X_t, Y_t \sim CI(1,1)$ .

#### 4.7.2 Long Run Relationship

After regressing the main equation that  $Y_t = \alpha + \beta X_t + \varepsilon_t$  we will get an residual series of it. And get the residuals  $\hat{\varepsilon}_t$ . Check for the order of integration of the residuals

$$\Delta \hat{\varepsilon}_t = \rho \hat{\varepsilon}_{t-1} + \sum_{i=1}^l \gamma_i \Delta \hat{\varepsilon}_{t-i} + u_t$$

- $H_0: \rho = 0$
- $H_A: \rho < 0$

Compare the calculated value of  $t_\rho$  with the critical values provided by Engle and Granger (1987)  $\text{Cal} < \text{critical} \rightarrow$  reject  $H_0$  and conclude  $Y_t$  and  $X_t$  are cointegrated series, in this case estimation under step two is no more spurious and representing the LR RS among the variables and if  $\text{Cal} > \text{critical} \rightarrow$  do not reject  $H_0$  and conclude  $Y_t$  and  $X_t$  are not cointegrated series, in this case estimation under step two spurious and representing meaning less RS among the variables we will proceed further and will Estimate the error correction model (ECM). If the variables are CI, the residuals from the equilibrium regression can be used to estimate the ECM that is

$$\Delta Y_t = b_0 + b_1 \Delta X_t + \pi \hat{\varepsilon}_{t-1} + v_t \quad (\text{ECM})$$

Where,

$$\hat{\varepsilon}_{t-1} = Y_{t-1} - \alpha - \beta X_{t-1}$$

Equ (ECM) include both LR and SR information.  $b_1$ ; is the impact multiplier (SR effect) that measure the immediate effect of  $\Delta X_t$  on  $\Delta Y_t$ .  $\pi$ ; feed back effect, adjustment parameter and show how much disequilibrium being corrected.  $\pi$  lies between  $0 < \pi < 1$ .

### 4.7.3 Variable Description

Table 4. 2: Variable description

Variable	Description	Source
<b>Dependent Variable</b>		
Energy Security Risk	Measured as an weighted average of four major areas of energy security risk economic, geopolitical, environmental and reliability	US Chamber Of Commerce
Renewable Energy	Consumption of RE as a percentage of total final energy Consumption	WDI
Non Renewable Energy	Fossil fuel energy use % of total final energy consumption	Energy Year book, Handbook statistics on Pakistan economy
<b>Independent variable</b>		
Export diversification	Theil index sum of both intensive and extensive	UNCTAD
<b>Moderating Variable</b>		
CO <sub>2</sub> emission	CO <sub>2</sub> emission from manufacturing industries and combustion	WDI
<b>Control variable</b>		
GDP per capita growth(annual %)	GDP per capita is the gross domestic divided by midyear population.	WDI
Personal Remittances received (% of GDP)	Personal remittances comprise e of the personal transfers and compensation of the employees.	WDI
Unemployment rate	Unemployment rate basically refers to the share of the labor force that is without work but	WDI

	available for and seeking employment.	
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## CHAPTER 5

### RESULTS AND DISCUSSION

#### 5.1 Descriptive Statistics

Table 5.1 shows the results of descriptive statistics for independent, dependent, moderating, and control variables. The average of energy security risk in all countries is 7.36, which states that the areas experiences a high level of energy security risk in general. Interestingly, China has the lowest energy security risk score as compared to other countries and this is because China has a diversified energy structure and more intensive renewable investment and Turkmenistan and have the largest risk score because they heavily rely on fossil fuels and have low renewable energy capacity.

The level of fossil fuel consumption is very high in the region whereas the regional average stands at 89.85%. Some countries like Turkmenistan have an 100% reliance on the fossil fuels and Uzbekistan have an 98.75% that is showing almost complete reliance on the fossil fuels. Such a high dependence highlights susceptibility to the energy price fluctuations and disruptions in supply and lead intensively the risk to be higher in terms of the energy security(IEA, 2025; Wang et al., 2018).

Renewable energy consumption % of total energy consumption dominates in both countries including Pakistan and China accounting for 46% and 20%. That can resultantly be the cause of lowering energy security risk. The amount of CO<sub>2</sub> emission shows wide difference with the highest emission level in Kazakhstan and Turkmenistan reflecting their coal and gas based energy networks accounting for 12.07 tons to 9.07 tons. While Pakistan has the lowest emission level which relates to the lower industrial development. Pakistan is one of the most vulnerable country to the climate change. The growth in GDP per capita is also discontinuous with average economic growth of 3.39% and a large standard deviation which illustrate that the economy of the region is volatile. A high variation is shown by Azerbaijan and Turkmenistan. (Sadorsky, 2010) adds that this volatility is a possible barrier to investing in long term clean energy solutions thus contribute to enhance the energy security risk.

In general, statistics demonstrate that the energy security risk in CAREC countries is preconditioned by poor fossil fuel dependence, underdevelopment renewable infrastructure, emission intensity and economic exposure. Such results demonstrate the necessity to change the policy of becoming dependent by investing in the clean energy investment, diversification and economic stability as the primary measure to eliminate the risk associated with energy(Wenten et al., 2024).

Table 5. 1: Descriptive Statistics

Country	N	Mean	Sd	Min	Max
<b>(Azerbaijan)</b>					
<b>LNESR</b>	34	7.65404	0.55476	6.86244	8.5238
<b>LNED</b>	34	2.02885	0.05984	1.89627	2.10742
<b>FFC</b>	34	97.7641	3.74866	77.04	100
<b>RC</b>	34	4.04518	7.30031	0.7	32.756
<b>CO2e</b>	34	4.09859	1.16047	3.01188	7.58526
<b>REM</b>	34	2.06151	1.38338	0.1241	5.01225
<b>GDPPCG</b>	34	2.26202	12.3506	-24.257	33.0305
<b>UN</b>	34	5.18	3.71076	0.11	16.25
<b>(China)</b>					
<b>LNESR</b>	34	6.9382	0.11297	6.81574	7.25329
<b>LNED</b>	34	1.32386	0.08976	1.1572	1.43485
<b>FFC</b>	34	84.7743	5.53556	74.83	91.59
<b>RC</b>	34	20.5977	8.3754	11.3	33.9
<b>CO2e</b>	34	5.04161	2.17903	2.15403	8.36681
<b>REM</b>	34	0.17514	0.09118	0.03343	0.47722
<b>GDPPCG</b>	34	8.05455	2.7709	1.99556	13.6358
<b>UN</b>	34	3.75194	0.94977	1.63984	5.61
<b>(Pakistan)</b>					
<b>LNESR</b>	34	7.09153	0.02669	7.03048	7.15175
<b>LNED</b>	34	1.65961	0.02836	1.61502	1.69763
<b>FFC</b>	34	59.5969	3.52504	52.39	66.28
<b>RC</b>	34	46.0559	12.4032	0.1	58.1
<b>CO2e</b>	34	0.75171	0.12204	0.56203	1.03518
<b>REM</b>	34	4.4697	2.14245	1.08057	8.98436
<b>GDPPCG</b>	34	1.62446	2.11002	-3.0389	5.20246
<b>UN</b>	34	4.01947	2.32149	0.398	7.83

<b>(Turkmenistan)</b>					
<b>LNESR</b>	34	7.68657	0.19033	7.28944	8.00673
<b>LNED</b>	34	2.10214	0.05597	1.93932	2.2108
<b>FFC</b>	34	100	0	100	100
<b>RC</b>	34	0.17659	0.31099	0.1	1.42
<b>CO2e</b>	34	9.067	1.31274	6.31751	11.5243
<b>REM</b>	34	7.51648	1.60442	0.18581	8.17304
<b>GDPPCG</b>	34	3.65997	9.184	-18.992	31.8527
<b>UN</b>	34	1.58749	1.10035	0.31633	4
<b>(Uzbekistan)</b>					
<b>LNESR</b>	34	7.66135	0.35081	6.95191	8.23917
<b>LNED</b>	34	1.91158	0.01925	1.86331	1.95246
<b>FFC</b>	34	98.7529	0.25667	98.29	99.18
<b>RC</b>	34	1.278	0.29681	0.7	1.7
<b>CO2e</b>	34	4.31303	0.70318	3.15963	5.25822
<b>REM</b>	34	9.0638	2.39649	5.61878	17.2173
<b>GDPPCG</b>	34	2.65225	4.49493	-13.358	7.94887
<b>UN</b>	34	3.16562	3.03303	0.2	9.35
<b>(Kazakhstan)</b>					
<b>LNESR</b>	34	7.14095	0.3729	6.59805	7.73367
<b>LNED</b>	34	1.91746	0.05509	1.81889	2.04744
<b>FFC</b>	34	98.2293	0.7364	96.58	99.19
<b>RC</b>	34	1.74482	0.40942	1.1	2.8
<b>CO2e</b>	34	12.7032	2.37914	7.71652	16.2246
<b>REM</b>	34	0.18889	0.12703	0.00541	0.56984
<b>GDPPCG</b>	34	2.06601	6.27146	-11.642	12.9575
<b>UN</b>	34	6.83375	3.5612	0.05	13.46
<b>(Total)</b>					
<b>LNESR</b>	204	7.36211	0.44517	6.59805	8.5238
<b>LNED</b>	204	1.82392	0.26878	1.1572	2.2108
<b>FFC</b>	204	89.8529	14.8247	52.39	100
<b>RC</b>	204	12.3164	17.9596	0.1	58.1
<b>CO2e</b>	204	5.99585	4.15022	0.56203	16.2246
<b>REM</b>	204	3.91259	3.78428	0.00541	17.2173
<b>GDPPCG</b>	204	3.38654	7.41179	-24.257	33.0305
<b>UN</b>	204	4.08971	3.11238	0.05	16.25

## 5.2 Cross-Sectional Dependence

Cross sectional dependence in panel data implies that a shock or transformation in one nation can have an influence on others it is particularly frequent in those studies that refers to global or regional problems such as climate change, energy or macroeconomics, where nations are linked together.

In table 5.2 the findings of the cross sectional dependence would be demonstrated. The given results indicate the presence of the substantial degree of cross sectional dependence energy security risk, gdp per capita growth and remittances consisting in the statistically significant value of cross sectional dependence test ( $P < 0.01$ ). It means whether the shocks or shift of these variables in a given country, the other country of the panel is likely to be effected as well. Such results are in line with those provided by (Pesaran, 2004), who pointed out the fact that the macroeconomic panels are frequently effected by the cross section dependence under pressure of the unobserved common factors.

This strong association of the GDP per capita growth can be explained by the economic spillover effects among the south Asian countries due to economic interdependencies on trade, investment and shared infrastructure (Pesaran, 2015). The same applies to the reliance on remittances which correlates with the findings of (WDI, 2024b) which states that worldwide migration and remittances patterns are frequently concentrated in regions, especially in regions with comparable migrant-sending systems.

(Shah et al., 2019) supports the high level of dependency that was experienced in energy security risk, and as they could note, energy security matters in south Asia are regionally intertwined with the with the common shared import dependency, geopolitical risk and insignificant diversification in the energy sources.

In contrast export diversification lacks relevant cross sectional dependence ( $p = 0.279$ ), which implies that it's critical dependence is related to the domestic-structural specifics, i.e. the patterns of exportation, the ability of industry and trade regulations of the country. This indicates that the patterns of diversification can be quite different between the countries based on its internal economic policies and the degree of industrialization. The absence of meaningful cross-section independence is in line with (Cadot et al., 2011), which points out that the export diversification

has been attributed to being caused by mainly by country specific learning and capacity building. The result of unemployment is also insignificant which implies that it may vary for each country.

*Table 5. 2: Cross-Sectional Dependence*

<b>Variables</b>	<b>CD-test</b>	<b>P-values</b>
<b>LNESR</b>	7.061***	0.000
<b>LNED</b>	-1.082	0.279
<b>GPDPCG</b>	5.596***	0.000
<b>REM</b>	5.415***	0.000
<b>UNEMP</b>	5..806***	0.254

### **5.3 Panel Unit Root**

It is important to examine the stationarity of data, meaning that it should not contain unit roots, in order to minimize the possibility of spurious regression results in panel data. Following these recommendations, I tested the data stationarity through Im, Pesaran, and Shin (Im et al., 2003) unit root test. The findings in Table 5.3 show that GDP per capita growth and Export diversification, are stationary at the level, having P-value<0.05 while Energy security risk, remittances and unemployment are stationary at first difference that have P-value >0.05.

Table 5. 3: Panel Unit Root

Variables	<i>Level</i>		<i>First Difference</i>	
	Statistic	P-value	Statistic	P-value
<b>LNESR</b>	-0.7343	0.231	-8.4769***	0.000
<b>LNED</b>	-1.621*	0.052	-14.339***	0.000
<b>GPDPG</b>	-4.495***	0.000	-15.576***	0.000
<b>REM</b>	-0.962	0.168	-12.482***	0.000
<b>UNEMP</b>	-0.991	0.160	-12.030***	0.000

#### 5.4 Panel Co-Integration Test

It is crucial to note that the variables of the study must be co-integrated in order to examine the nexus between them in the long run. Thus, in Table 5.4, this study employs co-integration tests. While we can see that the variance ratio is 1.806 along with the P value of 0.035 that is less than 0.05 ( $p < 0.05$ ) that resultantly demonstrate that there have been presences of long run relationship (co-integration) among the main variables.

It means that the energy security risk, export diversification, GDP per capita growth, unemployment and remittances are not being pulled apart over the period of time but instead these variables are moving together in the long term. Perhaps as a result of structural economic relations and policy connectivity between nations. These results are similar to those of whose co-integration test (Westerlund, 2007) was made robust under cross sectional dependence and heterogeneity. Furthermore, similar results were also reported in the past studies by (Pedroni, 2004) and (Kao, 1999) where they found that in panel data the macroeconomics and energy related

variables are likely to have long run co-integration particularly in developing economies in sharing structural similarities.

*Table 5. 4: Panel Co-Integration Analysis*

<b>Westerlund test for co-integration</b>		
<b>Variance ratio</b>	1.806**	0.035

### **5.5 Feasible Generalized Least Square and Panel-Panel Corrected Standard Error Analysis**

In Table 5.5, we analyzed the impact of Export Diversification on energy security Risk by employing the FGLS (Feasible generalized least square) and PCSE (Panel corrected standard error) technique.

#### **5.5.1 Impact of Export Diversification on Energy Security Risk**

In both models, export diversification is statistically significant at level 1% P value is less than 0.01( $P < 0.01$ ) with the coefficient of -1.974 that means that the higher level of export diversification reduces the energy security risk in CAREC countries. This follows the argument by (Cadot et al., 2011) and (Hausmann & Hidalgo, 2010) to the effect that diversified economies are more robust to external shocks such as volatility in energy markets. Remittances shows a significant and positive effect 0.028, P value  $< 0.01$ , which implies that the higher the inflow of remittances the greater would be the energy security risk that's may be related to the increased level of energy demand and consumption. These findings align with the (Ratha, 2005) and (WDI, 2020) which shows remittances flows has the potential to influence energy use in the developing countries. While on the other hand unemployment has a negative and significant coefficient that is -0.032 and the P value  $< 0.01$  which means that when the unemployment decrease, the level of energy security increase which can be due to the increased productivity or the lack of economic burden. The same factor was discussed by (Apergis & Payne, 2009) they found that the period of economic slowdown or the labor market slack typically coincides with the low energy intensity. GDP per capita growth has an insignificant effect, in other words the direct relationship between energy security risk and GDP per capita growth does not exist. Overall the result demonstrates that 1% in the export diversification decrease the energy security risk by 1.974%. The value of R square

is 0.844 which implies that 84% variation in the dependent variable has been explained by the independent variable that is export diversification for a given regression model.

*Table 5. 5: The Impact of Export Diversification on Energy Security Risk*

	<b>FGLS</b>	<b>PCSE</b>
	<b>(1)</b>	<b>(2)</b>
<b>Variables</b>	<b>LNESR</b>	<b>LNESR</b>
<b>LNED</b>	-1.974*** [0.000]	-1.974*** [0.000]
<b>GDP</b>	-0.004 [0.124]	-0.004 [0.241]
<b>REM</b>	0.028*** [0.000]	0.028*** [0.000]
<b>UNEMP</b>	-0.032*** [0.000]	-0.032*** [0.000]
<b>Constant</b>	12.009*** [0.000]	12.009*** [0.000]
<b>Year effect</b>	Yes	Yes
<b>Country effect</b>	Yes	Yes
<b>Observations</b>	204	204
<b>R-squared</b>		0.844
<b>Number of countries</b>	6	6

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

### **5.5.2 The Impact of Export Diversification on Renewable and Fossil Fuel Consumption**

Table 5.6 discusses the influence of export diversification over the renewable energy Consumption and fossil fuel consumption utilizing both FGLS and PCSE technique. The positive and strong effect 46.326, P value <0.01 of export diversification is on renewable energy consumption and a negative and significant impact -27.089, P value<0.01 on fossil fuel Consumption. That means when there would be more diversification in the export sector in the CAREC countries more they are likely to increase the consumption of renewable energy and will cut down the consumption of fossil fuel. GDP per capita growth also contribute positively to renewable energy consumption

0.088, P value <0.01 and negatively to fossil fuel consumption -0.073, P value<0.01 which indicates that the shift towards the cleaner energy sources in the region is linked to economic growth.

The result demonstrates that 1% increase in the export diversification would result in increasing the renewable energy consumption by 46.33%. This indicates that export diversification gives countries an efficient way of allocating their resources and enables the transition to clean energies by increasing the flexibility and resilience of the economy to import fossil fuels.

These studies correlates with the existing studies that indicates that export diversification is likely to amplify other studies of sustainability and innovations, which subsequently support increased renewable energy investment (Apergis & Payne, 2011; Sadorsky, 2010).

*Table 5. 6:* The Impact of Export Diversification on Renewable and Fossil Fuel Consumption

Variables	FGLS	PCSE	FGLS	PCSE
	(1) REC	(2) REC	(3) FFC	(4) FFC
<b>LNED</b>	46.326*** [0.000]	46.326*** [0.000]	-27.089*** [0.000]	-27.089*** [0.000]
<b>GDP</b>	0.088*** [0.002]	0.088*** [0.008]	-0.073*** [0.001]	-0.073*** [0.001]
<b>REM</b>	0.412*** [0.000]	0.412*** [0.000]	-0.251*** [0.000]	-0.251*** [0.000]
<b>UNEMP</b>	-0.204*** [0.004]	-0.204*** [0.004]	0.067 [0.219]	0.067 [0.200]
<b>Constant</b>	-88.392*** [0.000]	-88.392*** [0.000]	151.209*** [0.000]	151.209*** [0.000]
<b>Year effect</b>	Yes	Yes	Yes	Yes
<b>Country effect</b>	Yes	Yes	Yes	Yes
<b>Observations</b>	192	192	198	198
<b>R-squared</b>		0.988		0.989
<b>Number of countries</b>	6	6	6	6

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

### 5.5.3 Moderating Role of CO<sub>2</sub> Emission

Export Diversification has been found to have significant and negative influence on energy Security risk having a coefficient -3.081 having P-value<0.01, and this confirms that export diversification significantly reduces energy security risk in CAREC countries. 1% increase in the export diversification would reduce the energy security risk by 3.08 units and therefore it is true that diversified export structure would reduce vulnerabilities of countries to external energy shocks and accessibility to finite energy resources. This what align with the existing literature that establishes the relationship between export diversification and better energy stability (Cherif & Hasanov, 2014). CO<sub>2</sub> emission has also a strong and negative influence on ESR having coefficient value -0.771 and P value < 0.05. The moderating role that is represented by the term LNED\*CO<sub>2</sub> is positive and significant which shows that CO<sub>2</sub> emission counter the positive effect of export diversification on energy security risk. The impact of GDP is negative, though quiet weak significant in FGLS and not significant in PCSE indicates a minor influence of it on ESR. The impact of Remittances is positive and significant on energy security risk, which suggests that increase in remittances inflows leads towards the increase in vulnerabilities as well as the energy demand. Negative and significant relationship has been found between energy security risk and unemployment that is statistically significant. R square is 85% that indicates that 85% variation in the dependent variable have been explained by the independent variable. Conclusively export diversification declines energy security risk but this relation weakens when the emission level increase.

*Table 5. 7:* The moderating Impact of Co2 Emission in the Nexus Between Export Diversification and Energy Security Risk

Variables	FGLS	PCSE
	(1)	(2)
	LNESR	LNESR
<b>LNED</b>	-3.081*** [0.000]	-3.081*** [0.000]
<b>CO2</b>	-0.177** [0.012]	-0.177** [0.018]
<b>LNED × CO2</b>	0.099*** [0.007]	0.099*** [0.010]
<b>GDP</b>	-0.005* [0.065]	-0.005 [0.152]
<b>REM</b>	0.024*** [0.004]	0.024** [0.016]
<b>UNEMP</b>	-0.023*** [0.001]	-0.023*** [0.001]
<b>Constant</b>	14.123*** [0.000]	14.123*** [0.000]
<b>Year effect</b>	Yes	Yes
<b>Country effect</b>	Yes	Yes
<b>Observations</b>	204	204
<b>R-squared</b>		0.850
<b>Number of countries</b>	6	6

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

#### 5.5.4 Moderating Role of CO<sub>2</sub> Emission in Relationship Between ED\$RC, FFC

Table 5.8 demonstrate that Export Diversification has a positive and significant impact on Renewable energy consumption the coefficient value is 17.100 along with P value<0.05, while Export diversification has a negative and significant impact on fossil fuel Consumption -15.931 having P value<0.05 through both FGLS and PCSE technique. While CO<sub>2</sub> has a negative and significant association with REC and positive association with fossil fuel consumption that when there is a high level of emission is associated with the high dependence on fossil fuel to fulfill an energy needs. Higher emissions weakens the impact of export diversification on renewable energy consumption (Rehman et al., 2023). LNED\*CO<sub>2</sub> has an positive and significant impact on Renewable energy consumption having P value<0.01 that shows that the countries having high

emission level export diversification often leads towards higher level of RC and have an negative and significant relationship with fossil fuel consumption which implies that export diversification is an more important way to decrease fossil fuel reliance in pollution intensive economies, either as a result of policy pressure, international trade policies such as CBAM, or a result of their dedication towards energy independence. That's what showing that CO<sub>2</sub> emission enhance the positive impact of export diversification on renewable energy and reduce the fossil fuel consumption.

*Table 5. 8:* The Moderating Impact of Co2 Emission in the Nexus Between Export Diversification and Renewable and Fossil Fuel Consumption

	<b>FGLS</b>	<b>PCSE</b>	<b>FGLS</b>	<b>PCSE</b>
<b>Variables</b>	<b>(1)</b>	<b>(2)</b>	<b>(3)</b>	<b>(4)</b>
	<b>REC</b>	<b>REC</b>	<b>FFC</b>	<b>FFC</b>
<b>LNED</b>	17.100*** [0.003]	17.100** [0.013]	-15.931*** [0.001]	-15.931*** [0.002]
<b>CO2</b>	-4.493*** [0.000]	-4.493*** [0.000]	1.657*** [0.009]	1.657** [0.030]
<b>LNED × CO2</b>	2.224*** [0.000]	2.224*** [0.000]	-0.768** [0.020]	-0.768** [0.040]
<b>GDP</b>	0.070*** [0.009]	0.070** [0.018]	-0.066*** [0.002]	-0.066*** [0.003]
<b>REM</b>	0.175* [0.086]	0.175* [0.078]	-0.142* [0.063]	-0.142** [0.047]
<b>UNEMP</b>	-0.079 [0.290]	-0.079 [0.297]	0.036 [0.547]	0.036 [0.546]
<b>Constant</b>	-29.290** [0.011]	-29.290** [0.037]	128.059*** [0.000]	128.059*** [0.000]
<b>Year effect</b>	Yes	Yes	Yes	Yes
<b>Country effect</b>	Yes	Yes	Yes	Yes
<b>Observations</b>	192	192	198	198
<b>R-squared</b>		0.990		0.990
<b>Number of countries</b>	6	6	6	6

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

## 5.6 Engle Granger Co-integration

Co-integration is a statistical concept that determines the existence of the long run relationships between the main variables. Engle granger co-integration is more preferred here because we are dealing with most of the non-stationary variables.

### 5.6.1 Impact of Export Diversification on Energy Security Risk

Table 5.9 represents that export diversification has a negative and significant impact on Energy security risk reducing dependency on the fossil fuel consumption -0.702, P-value<0.05 that shows that 1% increase in the export diversification decrease the energy security risk by 70%. And increasing renewable energy consumption increased by 89% when there is an 1% increase in the Export and diversification. While export diversification increase in case of Pakistan in general decline the fossil fuel consumption by 68%. These results align with the studies including (Lee & Ho, 2022).The remittances which contributes to an decrease in the energy security risk are associated with the increase in fossil fuel consumption and decline in the renewable energy consumption. Energy security risk can be minimized through economic growth but this might still be leaning towards the traditional fuel as opposed to renewable energy in the present system.

*Table 5. 9:* The Impact of Export Diversification on Energy Security Risk, Renewable and Fossil Fuel Consumption

<b>Variables</b>	<b>(1) LNESR</b>	<b>(1) REC</b>	<b>(1) FFC</b>
<b>LNED</b>	-0.702*** [0.000]	89.480*** [0.000]	-68.156*** [0.000]
<b>GDP</b>	-0.004*** [0.000]	-0.212*** [0.001]	0.012 [0.834]
<b>REM</b>	-0.007*** [0.000]	-0.382*** [0.001]	0.378*** [0.000]
<b>UNEMP</b>	-0.002*** [0.001]	0.184*** [0.003]	0.036 [0.491]
<b>Constant</b>	8.303*** [0.000]	-98.768*** [0.000]	170.976*** [0.000]
<b>Observations</b>	33	31	32
<b>R-squared</b>	0.266	0.457	0.430

## 5.6.2 Moderating Role of CO<sub>2</sub> Emission

From table 5.10, we can see in case of Pakistan that export diversification reduce energy security risk at it has an negative and significant impact with Energy security risk having coefficient value -2.902 and P value <0.05, while on the other hand it has an positive influence on Renewable energy consumption 286.915 ,P<0.05 and negative influence on Fossil fuel consumption -163.588 ,P value< 0.05 that is statistically significant while if we look at the statistics it shows that higher emission are associated with increase in REC .The moderating term LNESR\*CO<sub>2</sub> is showing positive impact on the ESR that represents that in case of the higher emission the export diversification combating impact on ESR becomes weaken, and it has a negative and significant impact on REC and positive and significant impact on FFC. Pakistan heavily rely on fossil fuels. Thus the energy system may not be changing when exports are changing. Pakistan might lack green policies to match the trade expansion with clean energy (Cergibozan, 2022; Wang et al., 2018).

Table 5. 10: Moderating Role of Co2 Emission

Variables	(1) LNESR	(2) REC	(3) FFC
<b>LNED</b>	-2.902*** [0.000]	286.915*** [0.000]	-163.588*** [0.000]
<b>CO2</b>	-5.391*** [0.000]	511.506*** [0.000]	-272.531*** [0.000]
<b>LNED × CO2</b>	3.338*** [0.000]	-325.097*** [0.000]	179.568*** [0.000]
<b>GDP</b>	-0.006*** [0.000]	-0.053 [0.133]	-0.105*** [0.000]
<b>REM</b>	-0.008*** [0.000]	0.154** [0.020]	-0.215*** [0.000]
<b>UNEMP</b>	-0.001** [0.016]	0.040 [0.250]	0.106*** [0.000]
<b>Constant</b>	11.851*** [0.000]	-408.001*** [0.000]	312.981*** [0.000]
<b>Observations</b>	33	31	32
<b>R-squared</b>	0.639	0.943	0.908

pval in brackets

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

### 5.6.3 Augmented Dicky Fuller test

In table 5.11 there has been a statistic of the ADF test that has been employed in order to check whether the long run relationship among the main variables exist or not. This is what the second step of the Engle Granger approach. We have applied ADF test by created residual series from the main regression results and then we had applied ADF test on the Residual series. The P values for all the objectives remain significant that concludes that there has been presence of long run relationship among main variables so now in order to check the short run relationship we will move towards ECM error correction model.

*Table 5. 11:* Augmented Dicky Fuller Test

<b>Variable</b>	<b>t statistics</b>	<b>P value</b>
LNED&LNE SR	-3.530***	[0.0009]
NED& FFC	-2.594**	[0.0112]
LNED &RC	-3.140***	[0.0027]
CO2*LNED&FFC	-3.207***	[0.0022]
CO2*LNED&RC	-2.951***	[0.0044]

Pvalu in Brackets

\*\*\*P<0.01,\*\*p<0.05,\*p<0.1

#### **5.6.4 Error Correction Model**

Error correction model has been employed in order to analyze the short run relationship among the main variables however there hasn't been found any short term relationship among the main variables because the result was statistically insignificant hence there is an existence of the only long run relationship between variables for time series data the results could be seen from the tables that is in the appendix.

#### **5.7 Policy Implications and Forward Looking Insights**

Both panel and time series analysis confirm long-run associations between the export diversification and energy security risk and the moderating position of CO<sub>2</sub> emissions with negligible short-run consequences. On the basis of the results, some of the implications as far as they relate are as follows:

##### **5.7.1 Trade Reforms to Energy Transition**

Trade reforms that promote exports of low-carbon and energy-efficient goods and services can help transform Pakistan toward cleaner forms of energy to limit import oil dependence. Export diversification to the goods related to technology-intensive, renewable-linked commodities can assist the national economies to adapt to clean energy usage and living up to their reduction of carbon intensity and keep economic growth and its environmental objectives fulfilled with one another.

##### **5.7.2 Harmonization of Renewable Sectors within Trade Policy**

In trade agreements, investment and technology transfer in the fields of renewable energy (solar, wind, biomass) should be encouraged to contribute to boosting the rate of energy transition.

##### **5.7.3 Exporter Capacity Building**

Policies that aim to hone the skills, ensure the provision of infrastructure and provide the funding mechanisms that will enable the exporters to compete successfully in the green markets internationally need to be put in place.

#### **5.7.4 Advantage long-Term Energy Security**

Export diversification can protect the economy against the external shock in energy prices and supply, so long term energy security can improve.

#### **5.8 Clear Takeaways**

- Export diversification is a growth strategy as well as the means toward cleaner and safer energy systems.
- Energy transition is one of the direct contributions of trade reforms that incorporate the consideration of renewable energy to Pakistan.
- The future policy should connect the trade and industrial policy with the energy policy to create sustainable energy security.

## CHAPTER 6

### CONCLUSION AND RECOMMENDATION

The study has explored the relationship between the energy security risk and export diversification under the light of the energy crises that has been noticed globally. Even the most developed countries are not safe from this. Existing empirical literature has found that economic and social factors play a significant role in enhancing or reducing energy security risk in different economies. Based on this issue, previous literature has documented various antecedents that can play a significant role in energy security risk. These factors include environmental regulation financial development, geopolitical risk, and climate change. The literature is not conclusive especially regarding variables related to trade. Thus, contributing to the existing literature, this study examines the relationship between Export diversification and energy security risk. This study argues that export diversification can may significantly reduce energy security risk.

The study investigates how export diversification, CO<sub>2</sub> emission and energy security in CAREC region, and in Pakistan in general through panel as well as time series approach. The research helps us in understanding the impact of change in the structure of trade (export diversification) in shaping the level of energy consumption and risks in a particular country particularly when there are environmental constraints. This paper provides an endeavor into the interrelation between energy, trade and environment, both at a regional and a national level by using long run approximation based on Fully Modified OLS (FMOLS) and short run patterns through Error Correction Models(ECM).

At the initial step, the research concludes that export diversification co-integrates with other important variables in the energy sector like energy security risk (ESR), Renewable energy consumption and fossil fuel energy Consumption (FFC). The FMOLS and PCSE output on the CAREC panel shows that the advancement in export diversification creates a decline in the fossil fuel consumption and a subsequent growth in the renewable energy. This confirms to the institutionalized assumption that more diverse countries in exporting stand a better chance to integrate the new fresher technology, adopt to efficient source of energy, and de-center there over reliance on fossil fuel. Besides the FMOLS and PCSE estimation of time series analysis in Pakistan also demonstrate that export diversification has adverse impact on energy security risk and fossil

fuel consumption and positive influence on the renewable energy consumption, which indicates same trend in regional and national circumstances.

More insights come in the second stage where CO<sub>2</sub> emission have been introduced as the moderating variable. Export diversification and CO<sub>2</sub> emission interaction terms indicates the statistically significant result with all the three dependent variables. Within the CAREC context, the finding employ that the impact of export diversification is even stronger when environmental degradation is taken into consideration which boost the adoption of source of renewable energy and as well as reducing the dependence on fossil fuels. Analogously, the moderating impact of CO<sub>2</sub> emission was negative and significant in the model of Pakistan in the case of renewable consumption and Energy security risk hence there is positive relationship between export diversification and clean energy transition and less energy security risk with increased in CO<sub>2</sub> emission. Such observation is in conformity with the hypothesis of Environmental Kuznets curve(EKC) and support further evidence that export diversification can be utilized to address the challenges of the environment and energy.

The situation is different when it comes to short-run outcomes. The ECM estimation of Pakistan indicates that the majority of the exogenous variables such as export diversification, CO<sub>2</sub> emission, GDP per capita, remittances and unemployment do not have any significant relationship with the energy indicators in the short run perspective. Notwithstanding this, the error correction terms in the first ECM model are highly significant and negative which proves that a long run equilibrium exist and deviation are corrected gradually with time. It means that even policy measure aimed at diversification of exports, as well as energy reforms, are not to be able to see measureable results after some time and not immediately after policy implementation. In the short run when CO<sub>2</sub> moderate the model the error correction terms become insignificant and this implies that the short run environmental variations might be dysfunctional and therefore they possible established long run relationship.

Collectively, the results of these findings have a number of implication. First export diversification is a key point of enhancing energy security and long term clean energy uptake because of the explicit consideration of the environmental issues in trade and energy policies. Second the short run effect appeared to be weak and insignificant but the existence of significant error correction terms conforms that structural reforms in trade can have its influence on energy outcomes in the

long run. This what undermines that there must be long term consistency in the policy and the coordination between the trade and energy sector.

The particular scenario of Pakistan depicts that export concentration has led to the increased in the energy insecurity and put stress on the environment although the emission in Pakistan is lower but still it's one of the most effected countries by climate change, and the way to reduce this risk and environmental burden is to shift towards export that are more diversified so that they are more adoptive to change, the following shift should be followed by institutional changes, the renewable infrastructure funding, and compliance with the international climate standards to guarantee the sustainability of the energy, as well as its global competitiveness. At a wider CAREC region level, the finding serve as an indication of one common issue of the dependence on fossil fuel and a potential role of trade reforms as a tool of energy transition. To sum up, the paper can be regarded as a contribution to the increasing volume of literature linking the problem of export diversification to energy sustainability and environmental protection. It supports the notion of the fact that trade strategies should be formulated in the light of the environment and energy motives.

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## Appendix

### Appendix A

Dependent Variable: D\_LN\_ESR

Method: Least Squares

Date: 06/25/25 Time: 00:37

Sample (adjusted): 1991 2023

Included observations: 33 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D_LN_ED	-34.88794	63.66267	-0.548013	0.5880
D_GDPPCG	-2.088031	1.576720	-1.324288	0.1961
D_CO2E	-2.736319	74.78234	-0.036590	0.9711
D_UNEMP	-3.968200	2.344847	-1.692306	0.1017
R_OLS_1	-555.6531	192.3662	-2.888517	0.0074
R-squared	0.366626	Mean dependent var	-0.330927	
Adjusted R-squared	0.276144	S.D. dependent var	25.71071	
S.E. of regression	21.87460	Akaike info criterion	9.147257	
Sum squared resid	13397.95	Schwarz criterion	9.374001	
Log likelihood	-145.9297	Hannan-Quinn criter.	9.223549	
Durbin-Watson stat	1.493511			

## Appendix B

Dependent Variable: D\_FFC

Method: Least Squares

Date: 06/25/25 Time: 00:39

Sample (adjusted): 1991 2023

Included observations: 33 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D_LN_ED	-1.818524	3.055699	-0.595126	0.5565
D_GDPPCG	-0.051858	0.077147	-0.672203	0.5070
D_REM	-0.004738	0.256892	-0.018444	0.9854
D_UNEMP	-0.176684	0.114142	-1.547932	0.1329
R_OLS_2	-0.198117	0.090810	-2.181660	0.0377
R-squared	0.103072	Mean dependent var		0.374949
Adjusted R-squared	-0.025061	S.D. dependent var		1.060186
S.E. of regression	1.073388	Akaike info criterion		3.118245
Sum squared resid	32.26054	Schwarz criterion		3.344988
_log likelihood	-46.45104	Hannan-Quinn criter.		3.194537
Durbin-Watson stat	1.825802			

## Appendix C

Dependent Variable: D\_RC

Method: Least Squares

Date: 06/25/25 Time: 00:43

Sample (adjusted): 1991 2023

Included observations: 33 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D_LN_ED	1.619006	3.884027	0.416837	0.6800
D_GDPPCG	-0.086108	0.095945	-0.897471	0.3771
D_REM	-0.120036	0.317623	-0.377921	0.7083
D_UNEMP	0.257786	0.143677	1.794202	0.0836
R_OLS_3	-0.238609	0.100898	-2.364860	0.0252
R-squared	0.128514	Mean dependent var	-0.452525	
Adjusted R-squared	0.004016	S.D. dependent var	1.336118	
S.E. of regression	1.333432	Akaike info criterion	3.552117	
Sum squared resid	49.78516	Schwarz criterion	3.778860	
Log likelihood	-53.60993	Hannan-Quinn criter.	3.628409	
Durbin-Watson stat	1.900885			

## Appendix D

Dependent Variable: D\_FFC  
 Method: Least Squares  
 Date: 06/25/25 Time: 00:45  
 Sample (adjusted): 1991 2023  
 Included observations: 33 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D_LN_ED	-1.245602	29.42639	-0.042329	0.9665
D_LN_ED*CO2E	1.403696	37.38051	0.037552	0.9703
D_GDPPCG	-0.045145	0.096358	-0.468511	0.6432
D_REM	-0.079414	0.335972	-0.236372	0.8149
D_UNEMP	-0.146463	0.125486	-1.167165	0.2533
R_OLS_4	0.018897	0.152031	0.124297	0.9020
R-squared	-0.048771	Mean dependent var		0.374949
Adjusted R-squared	-0.242988	S.D. dependent var		1.060186
S.E. of regression	1.181994	Akaike info criterion		3.335249
Sum squared resid	37.72198	Schwarz criterion		3.607341
Log likelihood	-49.03160	Hannan-Quinn criter.		3.426800
Durbin-Watson stat	1.872149			

## Appendix E

Dependent Variable: D\_RC  
 Method: Least Squares  
 Date: 06/25/25 Time: 00:47  
 Sample (adjusted): 1991 2023  
 Included observations: 33 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D_LN_ED	-0.319888	4.129782	-0.077459	0.9388
D_LN_ED*D_CO2E	86.06768	85.34822	1.008430	0.3222
D_GDPPCG	-0.089959	0.106330	-0.846033	0.4050
D_REM	-0.065431	0.348564	-0.187715	0.8525
D_UNEMP	0.243933	0.162250	1.503440	0.1443
R_OLS_5	-0.138346	0.200809	-0.688945	0.4967
R-squared	-0.001546	Mean dependent var	-0.452525	
Adjusted R-squared	-0.187017	S.D. dependent var	1.336118	
S.E. of regression	1.455705	Akaike info criterion	3.751823	
Sum squared resid	57.21504	Schwarz criterion	4.023915	
Log likelihood	-55.90508	Hannan-Quinn criter.	3.843374	
Durbin-Watson stat	1.813401			