Palacký University Olomouc
University of Clermont Auvergne
University of Pavia

MASTER THESIS

Ana Khundadze

Supervisor: Pascale Combes Motel

Glodep 2021

The Impact of Disaggregated Energy Consumption on Economic Growth:

Evidence from EaP and CIS Countries

Ana Khundadze

Erasmus Mundus Joint Master's Degree in International Development Studies

Supervisor: **Pascale Combes Motel**

Full professor of economics at the School of Economics, University of Clermont Auvergne

Glodep 2021

Declaration of Authorship:

I, Ana Khundadze, declare that the work presented in this Master thesis is the results of my original research completed under supervision of Professor Pascale Combes Motel. I hereby confirm, that whereas I have consulted or quoted from a published work of others, I have acknowledged and cited their papers both in the main text and in final references. I have made clear what was done before and what is my personal contribution to the topic. This thesis has not been submitted for any other degree or qualification.

Place and date: Clermont-Ferrand, 31/05/2021

Signature: Ana Khundadze

UNIVERZITA PALACKÉHO V OLOMOUCI

Přírodovědecká fakulta

Akademický rok: 2020/2021

ZADÁNÍ DIPLOMOVÉ PRÁCE

(projektu, uměleckého díla, uměleckého výkonu)

Jméno a příjmení:	**Ba. Ana KHUNDADZE, MA**
Osobní číslo:	**R190709**
Studijní program:	**N1301 Geography**
Studijní obor:	**International Development Studies**
Téma práce:	**The Relationship Between Renewable Energy Consumption, Economic growth and FDI: Empirical evidence from EaP and CIS countries within a Multivariate Framework**
Zadávající katedra:	**Přírodovědecká fakulta**

Zásady pro vypracování

The study attempts to econometrically study the relationship between renewable energy consumption, economic growth, and Foreign Direct Investment (FDI) in Eastern Partnership and Commonwealth of Independent States countries (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyz Republic, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, Uzbekistan) within the period of 1996-2015. The literature on energy does not reveal any indication of research conducted to identify causal dynamics between renewable energy consumption, economic growth, and FDI in EaP and CIS countries. Years after the collapse of Soviet Union these newly emerged economies are still on the path of transition in need of substantial foundation for policy framework. Defining the causality between our interest variables will contribute to the welfare of transition economies by supporting the formation of a policy framework endorsed by empirical evidence. For analyzing the panel data, panel cointegration methodology will be applied alongside with Heterogeneous Granger causality test (Dumitrescu & Hurlin, 2012) to identify the direction of causality between the chosen variables. As a result of this study, we intend to investigate the effect of enhanced RE consumption on economic growth as well as address the policy implications on the relevance of FDI in these states.

Rozsah pracovní zprávy:	**20-25 tisíc slov**
Rozsah grafických prací:	**dle potřeby**
Forma zpracování diplomové práce:	**tištěná**
Jazyk zpracování:	**Angličtina**

Seznam doporučené literatury:

Abidin, I., Haseeb, M., Khan, M., & Islam, R. (2015). Foreign Direct Investment, Financial Development, International Trade and Energy Consumption: Panel Data Evidence from Selected ASEAN Countries. *International Journal of Energy Economics and Policy*, 841-850.

Apergis, N., & Payne, J. (2010). Renewable energy consumption and growth in Eurasia. *Energy Economics*, 1392–1397.

Doytch, N., & Narayan, S. (2016). Does FDI influence renewable energy consumption? An analysis of sectoral FDI impact on renewable and non-renewable industrial energy consumption. *Energy Economics*, 291–301.

Dumitrescu, E.-I., & Hurlin, C. (2012). Testing for Granger non-causality in heterogeneous panels. *Economic Modelling 29 (2012)*, 1450–1460.

HÜBLER, M., & KELLER, A. (2010,). Energy savings via FDI? Empirical evidence from developing countries. *Environment and Development Economics , Vol. 15, No. 1* , 59-80.

Ibrahiema, D. M. (2015). Renewable electricity consumption, foreign direct investment and economic growth in Egypt: An ARDL approach. *Procedia Economics and Finance 30* (pp. 313-323). London, UK: Elsevier B.V.

Koçaka, E., & Şarkgüneşib, A. (2017). The renewable energy and economic growth nexus in Black Sea and Balkan countries. *Energy Policy*, 51–57.
Latief, R., & Lefen, L. (2019). Foreign Direct Investment in the Power and Energy Sector, Energy Consumption, and Economic Growth: Empirical Evidence from Pakistan. *Multidisciplinary Digital Publishing Institute*.
Pesaran , M., & Smith , R. (1995). 'Estimating long-run relationships from dynamic heterogeneous panels'. *Journal of Econometrics, 68(1). pp.* , 79-113. doi: 10.1016/0304-4076(94)06144-F.
Salim, R., Yao , Y., Chen, G., & Zha, L. (2017). Can foreign direct investment harness energy consumption in China? A time series investigation. *Energy Economics 66* , 43–53.

Vedoucí diplomové práce: **prof. Pascale Combes Motel**
University of Clermont Auvergne

Datum zadání diplomové práce: **29. ledna 2021**
Termín odevzdání diplomové práce: **31. května 2021**

L.S.

doc. RNDr. Martin Kubala, Ph.D.
děkan

doc. RNDr. Pavel Nováček, CSc.
děkan

V Olomouci dne 29. ledna 2021

Acknowledgements

I would first like to express my very profound gratitude towards my supervisor, Professor Pascale Combes-Motel, whose insightful comments about the theory and methodology as well as relevant paper suggestions always steered me in the right direction.

I would also like to acknowledge all the professors of GLODEP programme in all three universities: Univerzita Palackého v Olomouci in Czech Republic, Université Clermont Auvergne in France, and Università Degli Studi di Pavia in Italy and thank them for the knowledge and expertise.

Finally, I would also like to thank my parents and my friends for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis.

Abstract:

Since energy sector plays a tremendous role in all areas of productive economic activities in 12 Eastern Partner and CIS countries, irrespective of their natural resource endowment levels, this thesis aims to analyse the impact of renewable and non-renewable final energy consumption on economic growth within 1996-2015, while also considering the gross capital formation and foreign direct investments as a major source of financing energy extractive and transportation activities. The results of panel ARDL model suggests that in the long-run only renewable energy consumption has a significantly positive effect on economic growth, indicating that energy transformation does not necessarily have to be associated with compromise in economic growth. In the short run, the scope of impact on economic growth is larger for non-renewable energy consumption, however both exert a significant and positive effect. Country-specific short-run coefficients are proven to be quite heterogenous. The results of panel ARDL are endorsed by robustness analysis of sub-sample without Russian Federation and by analysing net energy exporters against net energy importers. Finally, studying the impact of share of renewable energy consumption in TFEC on economic growth, indicates that increasing the share of renewables in energy mix has significantly positive influence on economic growth in EaP and CIS countries.

Keywords: Economic Growth, EaP and CIS, Energy Transformation, TFEC, Energy Security, ARDL

Table of Contents

1. Introduction....1
2. Regional Framework for Development....3
2.1. Eastern Partner and CIS countries....3
2.2. Trends of Economic Growth....4
3. Overview of the Energy Sector of EaP and CIS countries....8
3.1. General Overview....8
3.2. Structure of Total Final Energy Consumption (TFEC)....11
4. Theoretical Framework....17
4.1. The theory of role of energy in economic growth....17
4.2. Overview of energy-growth empirical studies....20
5. Empirical Analysis....23
5.1. Data and Descriptive Statistics....23
5.2. Econometric Methodology....26
5.2.1. Unit root test for stationarity....26
5.2.2. Panel Cointegration Tests....27
5.2.3. Panel ARDL....29
6. Empirical Results....31
6.1. Unit Root Test Results....31
6.2. Panel Cointegration Test Results....32
6.3. Panel ARDL empirical results....33
6.4. Examining Country specific short-run relationship between economic growth and energy consumption....36
7. Robustness analysis....38
8. Conclusions and Policy Recommendations....42
References....45
Appendices:....50

List of Tables

Table 1: Energy Statistics of EaP and CIS Countries (Unit Measure (mtoe)) in 2018 9

Table 2: Description of the Variables 24

Table 3: Descriptive Statistics for EaP and CIS panel 25

Table 4: Panel Unit Root Tests 31

Table 5: Pedroni Panel Cointegration Test 32

Table 6: Kao and Westerlund Cointegration Tests 33

Table 7: Main empirical results 35

Table 8: Heterogeneous Short-run Coefficients – Country Evidence 37

Table 9: Heterogeneous Short-run Coefficients – Country Evidence 37

Table 10: ARDL Model for Panel Without Russian Federation 39

Table 11: ARDL Model for Energy-exporting and Energy-importing Countries 40

Table 12: GDP per capita and share of REC in Total Final Energy consumption 41

List of Figures

Figure 1: Annual Real GDP Growth Rates for Eastern Partner and CIS Countries (1993-2019) 5

Figure 2: Annual Averages of FDI Inflows and GCF in EaP and CIS, as a Share of GDP (1996 - 2019) 7

Figure 3: Energy intensity level of primary energy in EaP and CIS countries within 1990-2015 10

Figure 4: Total Final Energy Consumption Per Capita (TFEC) (TJ) 12

Figure 5: Breakdown of Total Final Energy Consumption (TFEC) by sources in 2018 13

Figure 6: Breakdown of Total Final Energy Consumption (TFEC) by sector in 2018 14

Figure 7: Share of Renewable and Non-renewable Energy Consumption in Total Final Energy Consumption in 2015 15

List of Abbreviations

Abbreviation	Definition
SDG	Sustainable Development Goals
RES	Renewable Energy Sources
EaP	Eastern Partnership
CIS	Commonwealth of Independent States
GDP	Gross Domestic Product
OECD	Organisation for Economic Co-operation and Development
Gt	Gigatonne
UNCTAD	United Nations Conference on Trade and Development
FDI	Foreign Direct Investment
GCF	Gross Capital Formation
EIA	Energy Information Agency
TPES	Total Primary Energy Supply
IEA	International Energy Agency
EBRD	European Bank for Reconstruction and Development
TPEC	Total Primary Energy Consumption
TFEC	Total Final Energy Consumption
MW	Megawatt
IRENA	The International Agency for Renewable Energies
ARDL	Autoregressive Distributed Lags
REC	Renewable Energy Consumption
NREC	Non-renewable Energy Consumption
ADF	Augmented Dickey-Fuller
CADF	Cross-sectionally Augmented ADF
PMG	Pooled Mean Group
MG	Mean Group
DFE	Dynamic Fixed Effects
AIC	Akaike Information Criterion
SC	Schwarz Bayesian Criterion
ECT	Error Correction Term

1. Introduction

Inclusiveness and sustainability in country's development path is a precondition for prosperity and stable economic growth (IRENA, 2019). Energy plays a critical role in every economy, fuelling the productive activities in all the sectors including agriculture, industry, service sector and so on. Inadequate access to electricity and modern forms of energy appears to hinder sustainable development, deplorable consequences of which are particularly striking among the poorest parts of population (UNDP, 2014). Therefore, energy lies in the heart of Sustainable Development Goals (SDGs), affecting economic development, job creation, security concerns or else. As a core target of SDG 7, which calls for "affordable, reliable, sustainable and modern energy for all" by 2030 (UNECE, 2019), the world must considerably increase share of renewables in total final energy consumption (TFEC) on a global and national scale, through national action plans (NAP)[1].

High share of fossil fuels in TFEC generates unfortunate consequences on global warming, air pollution and overall quality of life (Martins et al., 2019). Uneven distribution of endowments of fossil fuel energy resources intensifies the energy security issues through high dependence on energy imports for countries with 80% of world's population (IRENA, 2019) and through vulnerability to supply disruption and fluctuating oil prices, eventually prompting shocks on economic growth. Concerns also apply to fossil exporting countries, as energy transformation will endorse the redefinition of geopolitical map in which the geographic fossil fuel concentration does not devise the energy politics, wealth inequality and domination of few (IRENA, 2019), given that renewable energy sources (RES) are concentrated in most countries in one form or the other.

The need to shift towards sustainable energy is significant for 12 countries of Eastern Partnership and CIS, including Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan. Over the last two decades the annual economic growth rates in EaP and CIS countries has been on average 5.7%. The highest average GDP growth rate characterizes the region of South Caucasus (6.9%) and lowest for Russia (3.3%)[2]. Maintaining these growth rates and continuing the process of convergence with developed nations will not be possible without ensuring a long-term, secure, affordable, and environmentally sound energy sources (EBRD 2008) in the region. Some of the countries are exporting large quantities of energy, others are striving to provide reliable and affordable energy within the country, and all of them are left with the post-Soviet legacy of energy intensity, energy inefficiency and outdated infrastructure resulting in huge energy losses and hindered supply of electricity (UNDP 2014).

[1] Understanding Sustainable Development Goal 7 (SDG7): Sustainable Energy for All: https://www.seforall.org/data-and-evidence/understanding-sdg7

[2] Authors calculations according to GDP per capita (constant 2010 US$) dataset from The World Bank Development Indicators https://data.worldbank.org/indicator/NY.GDP.PCAP.KD

Utilization of renewable energy sources in all the Eastern Partner and CIS countries is a feasible option for meeting growing energy demands within countries (Chachine, 2019). Apart from also addressing the issues of climate change within region, it is believed to have an ability to foster sustainable economic growth, through development of specialized manufacturing and green jobs (UNDP, 2014).

As defined, our study covers 12 states of Easter Partner and CIS countries. From another perspective these are all the former Soviet countries with exception of Latvia, Lithuania and Estonia, EU member countries which are the only post-Soviet states belonging to the ranks of developed nations. Even though these 12 countries have chosen different paths of development and committed to their own national values and targets, the relations and the similarities between their economies remain strongly intertwined. In energy sector explicitly, these economies remain bound together with energy trade among each other and highly integrated transport network.

We thereafter formulate the research question that will be investigated throughout the forthcoming chapters. The study addresses the relationship between the disaggregated energy consumption and economic growth in Eastern Partner and CIS countries. We will try to investigate the direction at which the renewable energy consumption and non-renewable energy consumption affect the economic growth (GDP per capita) in Eastern Partner and CIS countries, while also considering the foreign direct investment and gross capital formation, to differentiate the effects of FDI and domestic investment. The robustness analysis will also address another question for this region: Whether increasing the share of renewable energy consumption in total final energy consumption (TFEC) favours or hinders economic growth within our panel.

The remainder of the thesis is structured as follows: Chapter 2 contains two subsections. The first section will introduce the EaP and CIS countries, their relationship, and general macroeconomic characteristics. The second section will outline the trends of economic growth within the region for the last couple of decades since gaining independence, as well the structure of the economy and general overview of investments. Chapter 3 will move on to presenting the energy sector in its first section, by analysing the general picture and major challenges the EaP and CIS countries are facing regarding energy issues. Second part of the chapter 3 will breakdown the energy consumption within countries by source and by economic activity. Chapter 4 will formulate the theory of the role of energy in economic growth and overview the relevant empirical literature. Chapter 5 will introduce the data and panel ARDL methodology. Chapter 6 will discuss the results of our ARDL model concerning the role of renewable and non-renewable energy consumption on economic growth. Chapter 7 will address the issues of robustness of our model and chapter 8 will finalize our paper with conclusion of our main findings and some policy recommendations.

2. Regional Framework for Development

2.1. Eastern Partner and CIS countries

Exactly three decades ago, in 1991 the dissolution of Soviet Union was followed by the creation of Commonwealth of Independent states that was comprised of all the states of former Soviet Union, with exception of Lithuania, Latvia and Estonia. In 2009, directly after the Russo – Georgian war, Georgia officially left the organization followed by withdrawal of yet another country, Ukraine in 2018. Currently, CIS incorporates 9 member states, namely Armenia, Azerbaijan, Belarus, Kazakhstan, Moldova, Kyrgyz Republic, Russian Federation, Tajikistan, and Uzbekistan. Even though Turkmenistan was never ratified as an official member state, the country continues to participate in all the official events of the organization. The European Union's six Eastern Partner countries include Armenia, Azerbaijan, Belarus, Georgia, Moldova, and Ukraine. Over the last decade economic growth has fluctuated around the average of 4.2%, which is lower than 2000-2010 average of 7.4%. This region accommodates the 20 per cent of the world oil reserves, 40 per cent of natural gas reserves and 25 per cent of coal reserves alongside 10% of world electricity production and almost 11% of renewable hydro resources (UN-Habitat, UNECE, 2016).

As of 2018 EaP and CIS countries are approaching the universal level with the rate of access to the grid as a share of population with access to electricity, which equals 99.4%. With this indicator, according to appendix 1, it is ahead of regions such as East Asia, South Asia, Latin America and Caribbean, Middle East and North Africa and falls behind OECD, EU, North America and Central Europe and Baltics[3].

In 2018, natural gas contributed to 52% of energy supply, followed by oil (20%), coal (18%) and nuclear power (7%). Energy supply from renewables including Hydro, wind and solar, Biofuels and waste accounted for only aggregate 3%. Highest share of total final energy was consumed by residential sector, followed by industry and transportation. Overall, in 2015 energy consumption from renewable sources accounted for 12.3% of total final energy consumption, lower than the global share of renewables in final energy consumption (17%)[4].

EaP and CIS countries contribute to almost 7% of the world CO2 emissions from fossil-fuels and cement production (thousand metric tons of C), CO2 emissions per capita (metric tons of carbon) is almost 13% higher compared to world level (Gilfillan et al., 2020). Appendix 2 also outlines an interesting development in Per capita CO2 emissions (metric tons of carbon). The collapse of Soviet Union resulted in sharp decrease in CO2 emissions by the equivalent of 7.61 Gt carbon dioxide from 1992 to 2011, which was the consequence of

[3] Comparative statistics are the result of authors calculations using World Bank, Sustainable Energy for All (SE4ALL) database from the SE4ALL Global Tracking Framework led jointly by the World Bank, International Energy Agency, and the Energy Sector Management Assistance Program.
[4] See footnote 3.

structural changes in industry sector (Brizga, Feng, & Hubacek, 2013) and abandonment and massive restructuring of agricultural land, as well as the domestic food systems alongside the reduction in consumption of animal products (Schierhorn et al., 2019). Regardless, the rates of per capita CO2 emissions started to get back to its pre-independence levels.

2.2. Trends of Economic Growth

Ensuing the newly acquired independence, all 12 economies were left with aftermath of corrupt governments, distrustful judicial and law enforcement systems, structurally distorted and inefficient economies, devalued currencies, and large budget deficits. Inadequacy in support institutions necessary to ensure the smooth transition to a market economy alongside the political conflicts[5], promoted an output collapse the extent to which in some countries would far exceed even the most pessimistic predictions (Iradian, 2007).

Despite the relatively common foundation, the transition path and outcomes have varied greatly amongst them. According to World Bank country classification by income for current 2021 fiscal year, only Tajikistan belongs to the ranks of low-income economies ($1,035 or less). Kyrgyz Republic, Moldova, Ukraine and Uzbekistan are grouped under the category of lower-middle income economies ($1035 - $4945) and remaining 7 countries including Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Russian Federation, Turkmenistan have made it to the list of upper-middle income economies ($4,046 - $12,535)[6].

Regardless of strained political and economic relations over the years, countries of EaP and CIS show a sufficient level of interdependency in GDP developments (Benešováa & Smutka, 2016). Figure 1 shows that economic growth trends have been comparable across sub-regions within panel of EaP and CIS countries, emphasizing the similarities along the transition path even after 30 years. The figure demonstrates that these sub-regions respond to macroeconomic shocks in the same way, with almost same speed of adjustment. Years of negative economic growth after the collapse of Soviet Union were followed by the robust economic growth starting from Russian financial crisis until global financial crisis of 2008. According to Jenish (2013) the reason behind the steady growth was economic and structural reforms implemented by the CIS countries for creating advantageous environment for economic development. On a country level, GDP growth in Russia was boosted

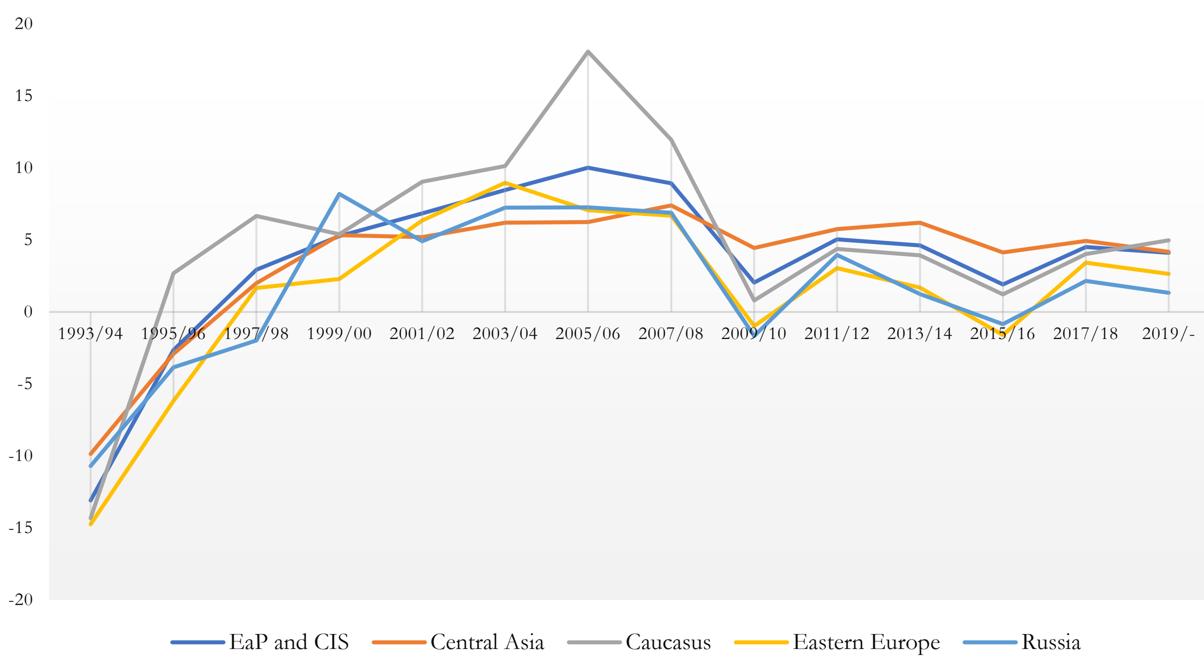
[5] De facto separations of break-away regions: war between Azerbaijan and Armenia between 1988-1994 over Nagorno-Karabakh, populated by ethnic Armenians; Region of South Ossetia and Abkhazia in Georgia in 1991 & 1992 respectively; Region of Transnistria in Moldova in 1992 over the clashes between Moldova and Russia; Clashes for over five years in Tajikistan amongst former communists and coalition of liberal democrats and islamists; attempt of Chechnya to break away from Russia in 1994 ending in short-term de-facto independence in 1996, until Russia reintegrated the region in 2008 (Hamilton, 2017).

[6] County classification by income for current 2021 fiscal year is defined by World Bank GNI per capita calculated using Atlas method. Low-income economies - GNI per capita of $1,035 or less in 2019; lower middle-income countries - GNI per capita between $1,036 and $4,045; upper middle-income countries - GNI per capita between $4,046 and $12,535; high-income countries - GNI per capita of $12,536 or more. Source: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups.

by rise in energy exports and consumption. For other oil exporting countries, namely Azerbaijan and Kazakhstan, the impact of higher oil exports on economic growth was accelerated by increased investments in oil and related sectors; lack of comparative advantage in fossil fuel extracting sectors was offset by strong domestic demand in energy importing countries of Ukraine, Georgia, Armenia and Tajikistan (Odling-Smee, 2003). We should also highlight the positive impact of 1998 Russian financial crisis on boosting exports of the CIS states following devaluation of the Russian rouble.

There are two points throughout the timeline in which economic growth plummeted drastically for EaP and CIS countries. The first one was caused by the global financial crisis in 2008. The second plunge was in 2015, following the Russia-Ukraine conflict, which resulted in western sanctions imposition on Russia and declining export and rising inflation in Ukraine, hampering economic growth in both of the economies (Havlik, 2014). Meanwhile the four oil exporting countries of Caspian Basin, Kazakhstan, Turkmenistan, and Azerbaijan along with Russia were hit substantially by oil price shocks of 2014, leading to economic slowdown. However, amid the increasing commodity prices CIS and EaP countries managed in 2018 to attain the favourable economic outcomes with accelerating growth and the prediction of 2.0% expected increase of aggregate GDP in 2019 and 2.5% increase in 2020 (UN, 2019).

Figure 1: Annual Real GDP Growth Rates for Eastern Partner and CIS Countries (1993-2019)



Source: UNCTADstat (2019)

Despite the optimistic forecasting according to UN (2021) report, the aggregate GDP is projected to have shrunk by 3.4 per cent in 2020. The sharp drop of GDP in 2020 is a result of rising unemployment, reduced remittances, and other types of investments due to ongoing pandemic and country specific restrictions. What did not help the deteriorating living standards and increased uncertainties was geopolitical tensions between Armenia and Azerbaijan over the long-disputed Nagorno-Karabakh territory and internal conflicts in Belarus, over the results of presidential elections. Only partial recovery is predicted by UN (2021) by growth of 3.4 per cent for 2021 and 3 per cent for the year 2022.

Regarding the composition of GDP by different sectors within the EaP and CIS countries, Appendix 3 reveals that service sector accounted for the highest share of GDP in all the countries of the region in 2017, followed by the sector of industry. Among others, Agriculture is reported to have contributed to GDP the least, with the highest shares present in the low-income (Tajikistan) and lower-middle income countries of the region (Kyrgyz Republic, Moldova, Ukraine, and Uzbekistan) [7]. Additionally, within the years 2010 and 2019, the share of agriculture in GDP creation has dropped in almost all the countries, whilst the Industry and Service sector appear to be establishing the dominance (Appendix 4).

New forms of economic activities accompanying the economic restructuring is associated with growing necessity of financial and investment support, for which domestic investments seem to have been inefficient in CIS countries, growing the importance of attracting the foreign direct investments (Komarov, 2002). However, the expectations of large FDI inflow was not upheld in the beginning of transition, representing consistently smaller share of world FDI inflow than in other regions, including Asia and Latin America (Shukurov, 2016). Investment climate in CIS countries was dictated by burdensome taxation, widespread corruption in all layers of government, entry barriers, violation of property rights due to poor regulatory framework and active involvement of the state (Shiells, 2003). All these factors contributed to contraction of aggregate investments after the collapse of Soviet Union and shortage of enough FDI inflow to offset the low domestic investment and support sustainable growth even within energy abundant countries.

The major share of inflows was related to natural resource extraction in energy exporting countries (Shiells, 2003) and infrastructure projects for energy transportation (oil pipelines) as well as energy sector privatisation for some energy importing countries including Georgia, Armenia and Moldova (Azizov, 2007). For other countries of the region, FDI inflows have been either limited or diversified within sectors.

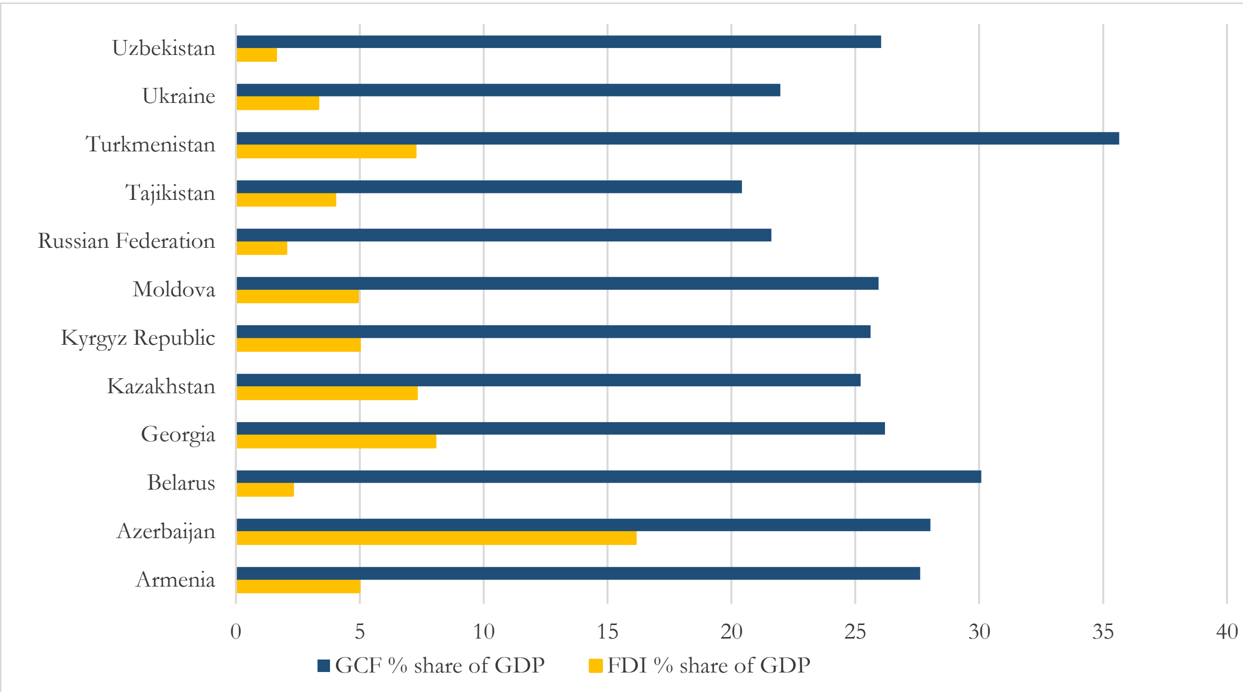
FDI inflows in EaP and CIS countries experienced boom in the recent years and have attracted a significant inflows of foreign direct investments making them prone to growing dependence on foreign capital rather than domestic capital for investment (UN-Habitat, UNECE, 2016). Kasimov et al. (2020) outlines the major determinants of inbound FDI in the countries of the region, with the comparative advantage in petroleum

---

[7] According to CIA definition **Agriculture** includes farming, fishing, and forestry. **Industry** includes mining, manufacturing, energy production, and construction. **Services** cover government activities, communications, transportation, finance, and all other private economic activities that do not produce material goods (https://www.cia.gov/the-world-factbook).

extraction and share of oil products. Attractiveness of the destination for FDI is determined by liberalization of the economies and economic freedom. As shown in the Figure 2 between 1996-2019, the annual inflows of FDI as a share of GDP has been highest for Azerbaijan, followed by Georgia, Kazakhstan, and Turkmenistan. For gross capital formation, the highest share is observed for Turkmenistan, Belarus, and Azerbaijan.

Figure 2: Annual Averages of FDI Inflows and GCF in EaP and CIS, as a Share of GDP (1996 - 2019)



Source: The World Bank Development Indicators

3. Overview of the Energy Sector of EaP and CIS countries

3.1. General Overview

Energy as a key sector of the economy is associated with broad implications for growth and macroeconomic stability in majority of the Easter Partner and Commonwealth (CIS) countries. Within the region, while some countries live off the export of large quantities of fossil fuels, others struggle to deliver reliable and affordable energy to their citizens, due to post-Soviet legacy of energy intensity and energy inefficiency (UNDP, 2014). Energy sector in greater number of states, but more severely in Central Asian and South Caucasus countries is characterised with worn out and outdated infrastructure, resulting in sufficient energy losses, constant threat of power outages and disruption. Interrupted and insufficient supply of energy causes several socio-economic and environmental consequences and impedes the sustainable economic development (UNDP, 2014).

Diversified natural resource endowments makes some of the countries overly reliant on restricted number of sources of energy generation, especially fossil fuel extracting countries including Russia, Kazakhstan, Azerbaijan, Turkmenistan, and Uzbekistan while remaining are heavily dependent on energy imports (EBRD, 2008), making them self-insufficient and vulnerable to the increasing demands of energy within nations. The rising issue of energy security, vulnerability towards volatile oil prices, inefficient and weary infrastructure generates the need for energy policies prioritizing energy mix diversification, increasing energy efficiency, deployment of sustainable energy sources and incentivizing investments in renewable energy (UNDP, 2014).

Table 1 summarises some of the key energy indicators and outlines the import dependence of energy importing countries. Overall, from energy importing economies the largest energy consumers are Ukraine and Belarus. Share of net imports in TPES, as used by Lysenko & Vinhas de Souza (2007) to measure energy import dependence of the countries, indicates that Belarus and Moldova are meeting 86% and 81% of their energy needs with imported energy, making them highly reliant and most vulnerable to outside shocks. Tajikistan is reported to be the least reliant on energy imports.

From five energy exporting countries of the region, Russia dominates in all the aspects compared to rest of the countries, rationale of which is that not just among the EaP and CIS countries, but at the world scale, Russia represents the major superpower in energy sector. It is the second largest producer of dry natural gas and crude oil, as well as one of the largest consumers of dry natural gas, Petroleum and other liquids, and other types of fossil fuels. Revenues from oil and gas contribute to one-third of federal budget revenues (EIA, 2017).

Table 1: Energy Statistics of EaP and CIS Countries (Unit Measure (mtoe)) in 2018

Energy Importing Countries

	Armenia	Belarus	Georgia	Kyrgyzstan	Moldova	Tajikistan	Ukraine
Production	0.8	4.2	1.3	2.3	-	2.7	60.9
Consumption	2.2	19.9	4.4	4.2	3.2	2.9	51.5
Net Imports	2.3	23.2	3.8	2.2	3.3	0.8	32.4
Total Primary Energy Supply	3.1	27.0	4.9	4.6	4.1	3.5	93.5
Share of net imports in TPES	75%	86%	78%	48%	81%	23%	35%

Energy Exporting Countries

	Azerbaijan	Kazakhstan	Russia	Turkmenistan	Uzbekistan
Production	55.4	177.6	1484.1	79.5	55.2
Consumption	9.2	41.9	514.4	18.1	29.5
Net Imports	-40.7	-101.6	-701.3	-51.3	-10.5
Total Primary Energy Supply	14.3	75.8	759.3	27.7	46.4

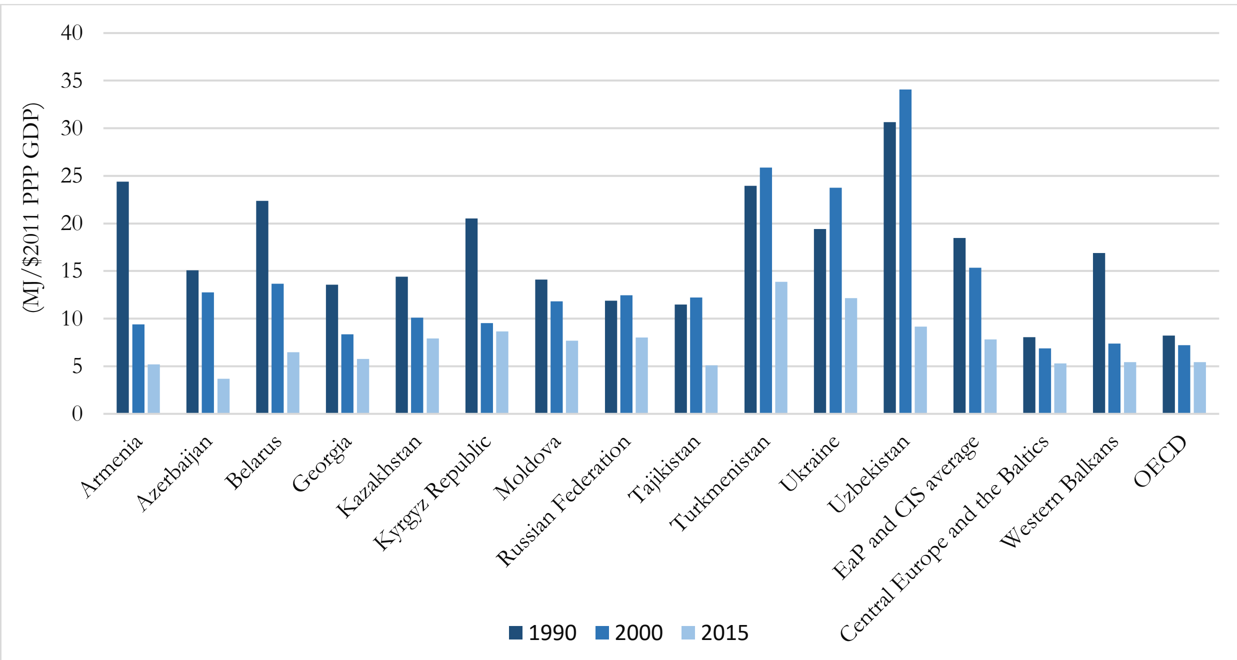
Source: International Energy Agency (iea) country datasets

Abundance of energy resources in some countries and reliance on **energy intensive** industry, are remnants of centrally planned economy, resulting in the wasteful and carbon-intensive energy usage in the region. According to EBRD (2008) report the differences between the country level energy-intensities is largely due to 1. Varying levels of efficiency in energy production and consumption; 2. Differences in GDP levels – low income countries are usually associated with higher energy-GDP ratio; 3. Discrepancies in climate - Cold continental or arid climates of Eastern Europe and Central Asia make create the increasing need of energy irrespective of the economic activity; 4. Differences in economic structures - countries who are more reliant on manufacturing sector need more energy resources then others. These structural differences will not allow the energy-intensity of these countries to converge in a long run (Lysenko & Vinhas de Souza, 2007).

Figure 3 reports the steady and steep declines in **energy intensity** of the countries of EaP and CIS over 25-year period. From energy importing countries energy intensity fall was largest for Armenia, followed by

Belarus and Kyrgyzstan, while for energy exporting economies Uzbekistan seems to have dominated the list. If we consider energy intensity in 2015 as level of primary energy use in mega joules over $2011 PPP GDP, Azerbaijan, Tajikistan and Armenia are least energy intensive countries, being ahead of the countries of Central Europe and Baltics, while Uzbekistan, Ukraine and Turkmenistan are the most energy-intensive. According to Lysenko & Vinhas de Souza (2007) energy intensity levels of some energy importing countries of the region amidst the growing income are predicted to converge with level of EU, supporting the energy intensity convergence hypothesis by Csereklyei & Rubio-Varas (2016). Overall, the EaP and CIS countries fall behind OECD level of energy-intensity, however the gap has narrowed.

Figure 3: Energy intensity level of primary energy in EaP and CIS countries within 1990-2015



Source: The World Bank Development Indicators

Figure 3 suggests insightful results. However, the diminishing rates of energy intensity is a biproduct of total primary energy consumption and GDP and therefore might have been affected by both. To dive further into this issue, we are considering the Kaya Identity which is a tool for analysing the drivers of CO2 emissions by combining the indicators of GDP, population, total primary energy consumption, and world anthropogenic CO2 emissions (Hwang et al., 2020). The equation takes a following form:

$$CO2 = \frac{CO2}{TPEC} * \frac{TPEC}{GDP} * \frac{GDP}{POP} * POP = f * e * g * P \qquad (A)$$

Where $\frac{CO2}{TPEC} = f$ and represents carbon intensity of primary energy; $\frac{TPEC}{GDP} = e$ represents energy intensity of GDP; $\frac{GDP}{POP} = g$ embodies GDP per capita and P represents the population.

Results of the EaP and CIS countries show that between years 1996-2015 CO2 emissions have been decreasing annually by 1.1%; Total primary energy consumption has been increasing annually by only 0.55%; Annual Growth rate for GDP accounted for 4.04% and population has been increasing annually by mere 0.1%. All these variables are moving in their own direction affecting each indicator on the right side of the Equation A. To better demonstrate these changes in a final equation, we are specifying Equation A modified with results:

$$CO2(\downarrow 1.10\%) = \frac{CO2(\downarrow 1.10\%)}{TPEC(\uparrow 0.55\%)} * \frac{TPEC(\uparrow 0.55\%)}{GDP(\uparrow 4.04\%)} * \frac{GDP(\uparrow 4.04\%)}{POP(\uparrow 0.10\%)} * POP(\uparrow 0.10\%) =$$

$$= f(\downarrow 1.6\%) * e(\downarrow 3.3\%) * g(\uparrow 3.9\%) * P(\uparrow 0.10\%) \qquad (B)$$

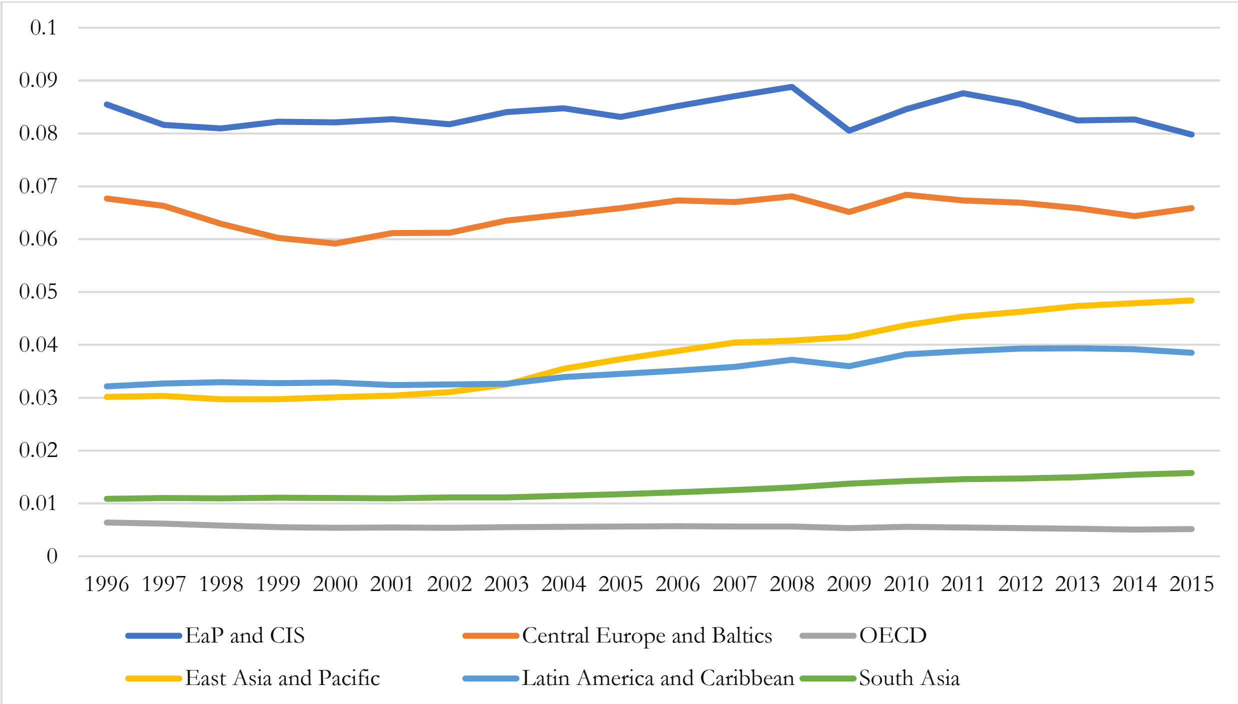
Evidently, annual 3.3% reduction in energy intensity has been more influenced by the expansion of GDP, than by the diminishing rates of energy consumption. Annual drop in carbon intensity is highly influenced by the annual decrease in rates of CO2 emission. Overall, the changes on the left side of the equation is offset by the changes in the right side of the equation[8]. Therefore, any targeted change of CO2 emissions within the region in the coming years will require close collaboration and consideration of all the other factors of the Kaya equation.

3.2. Structure of Total Final Energy Consumption (TFEC)

Analysing the structure of total final energy consumption can provide more precise picture of the energy consumption trends in the region. TFEC has been continuously increasing since 1996, mirroring the increasing energy demand of the region, however per capita consumption had the opposite trend, resulting in slightly decreased rates in 2015 compared to 1996 for the whole region, as well as for some other countries individually. According to Figure 4, On a global scale per capita TFEC in EaP and CIS countries exceeds the rates of OECD, Central Europe and Baltics, Southeast Asia and Pacific, Latin America and Caribbean, and South Asia. As observed in Figure 1 for economic growth, 2008-2009 financial crisis resulted in a much more severe plunge in TFEC in EaP and CIS countries than in any other region, emphasizing the vulnerability of the energy sector toward macroeconomic instability and fluctuating oil prices.

[8] The results are authors calculation, using the dataset from the World Bank Development Indicators and Carbon Dioxide Information Analysis Center at Appalachian State University, Boone North Carolina, https://energy appstate/CDIAC

Figure 4: Total Final Energy Consumption Per Capita (TFEC) (TJ)



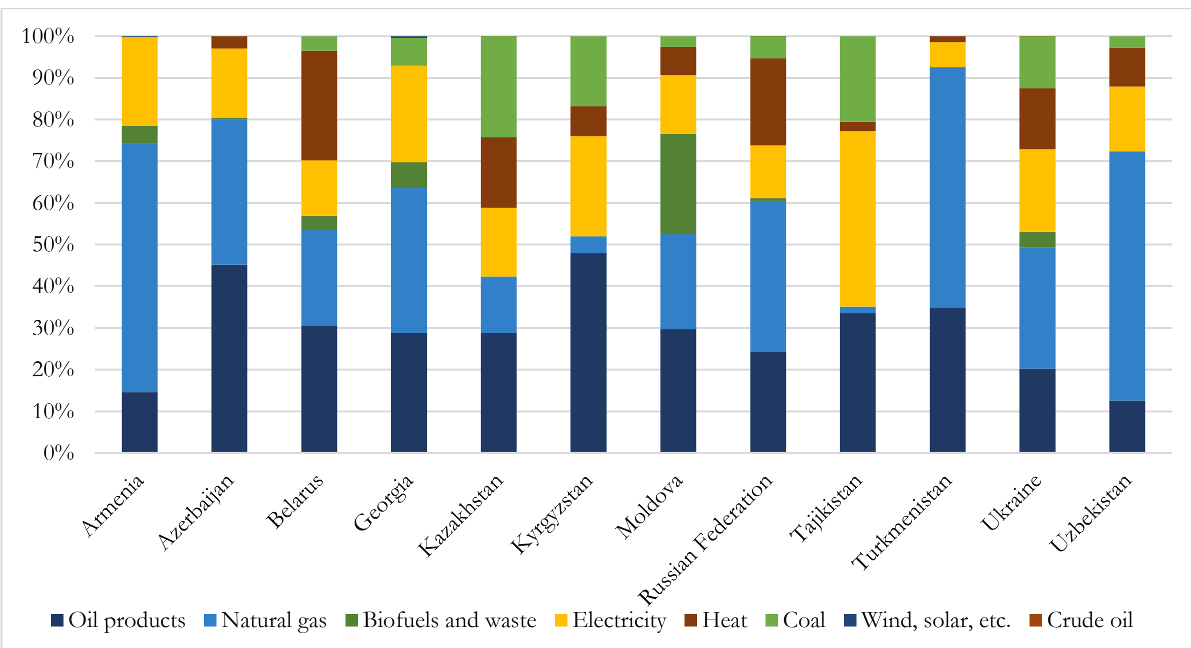
Source: Sustainable Energy for All (SEforALL) World Bank Dataset

In almost all the countries of the region, highest share of total final energy consumed is generated from oil products, natural gas, biofuels and waste, electricity, heat, and coal (Figure 5). Only negligible share of TFEC is from wind and solar RES. Armenia, Uzbekistan and Turkmenistan are largest natural gas marginal consumers, while the least share of natural gas consumption in TFEC is observable for Tajikistan, due to its high share of electricity consumption from hydroelectric sources. Almost 99% of the natural gas consumed in CIS countries is produced in Russian, Azerbaijan, Kazakhstan, Ukraine, Uzbekistan, and Turkmenistan and is exported domestically within EaP and CIS (Pirani, 2011). Largest share of oil from energy mix is consumed by Kyrgyzstan, Azerbaijan, and Turkmenistan.

Among all, energy consumption from electricity has a higher share in Armenia, Kyrgyzstan, Tajikistan, Georgia, and Ukraine. Appendix 5 highlights that in Ukraine almost 53.9% of electricity was generated from nuclear power sources. Country currently has 15 active nuclear reactors and plans to develop nuclear power sector through "Safety, Energy Efficiency, Competitiveness" (ESU) 2050 energy strategy (IAEA, 2020a). Similarly, Armenia generates almost one third of its electricity from one currently operational nuclear power plant, with an aim to open more reactors in the nearest future (IAEA, 2020b). Sustainability of Nuclear power plant In both of the countries is threatened by the risks of accidents and complex nature of management of nuclear waste (EBRD, 2008).

For three other countries, large share of final energy consumption from electricity is derived from its generation from hydropower. By the end of 2015 Georgia had 70 operational hydropower plants with 3,271 MW of installed capacity, accounting form 80% of country's generating capacity and 75 to 90% of power generation (IHA, 2016a). Tajikistan hydropower sector exhibits much larger hydropower installed capacity of 6,395 MW, generating almost 95% of electricity within country (IHA, 2020b). Another Central Asian country, Kyrgyzstan has a vast number of large and medium sized rivers with substantial hydropower potential, only 10% of which is exploited. Country's energy mix is highly reliant on hydropower, which generates almost 90% of electricity (IHA, 2020c). Despite the relatively low carbon footprint associated with hydropower generation, large-scale hydropower plants lead to significant disruption in ecosystem as well as political unrests within country (EBRD, 2008). One of the major downsides of dependence on hydropower energy supply is the disruptions in availability and reliability of power supply in winter, making countries reliant on energy imports, even if they manage to be self-sufficient and export-oriented in the warmer seasons. To deal with this issue, Tajikistan and Kyrgyzstan have applied the practice of supply shortage and electricity rationing (UNDP, 2014).

Figure 5: Breakdown of Total Final Energy Consumption (TFEC) by sources in 2018

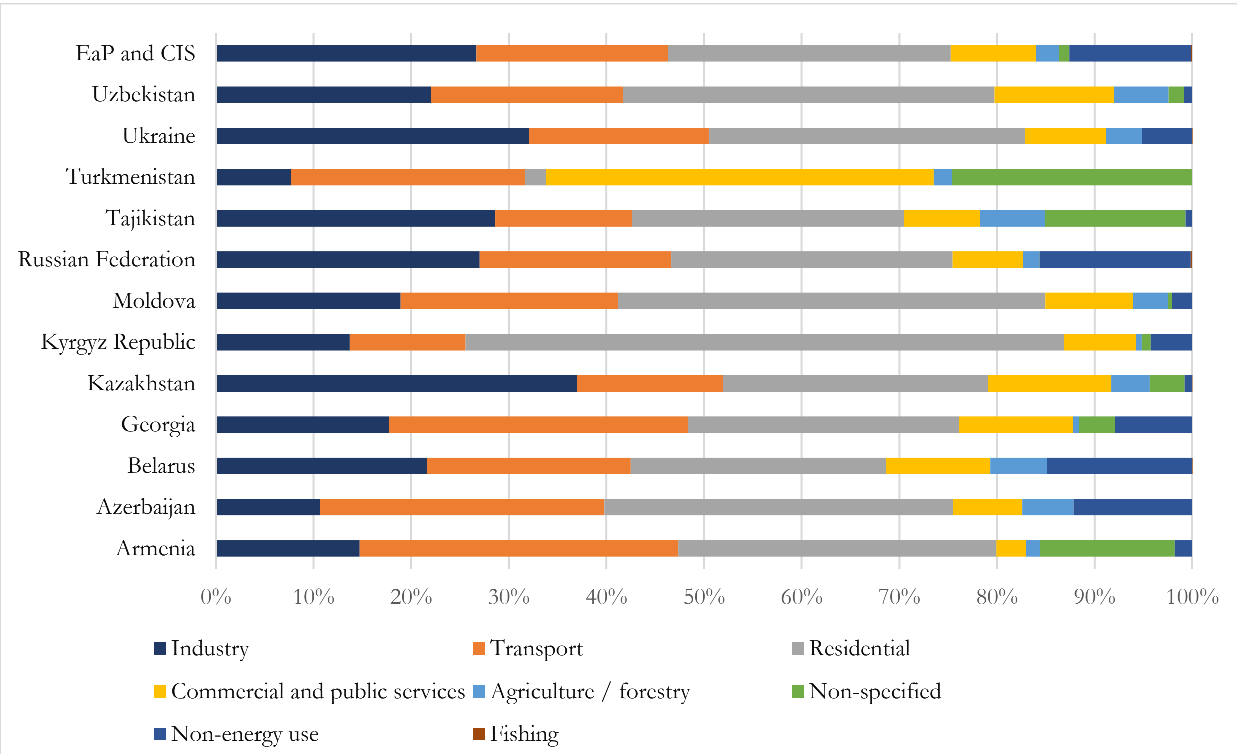


Source: Sustainable Energy for All (SEforALL) World Bank Dataset

The residential sector in the CIS region is the largest consumer of total final energy in most of the countries (Figure 6). It is characterized by extremely low energy efficiency, contributing to the urgency of prioritising energy efficiency enhancing projects, which could be mainly hindered by underdeveloped markets for energy efficient goods and services, defective financial structures and legal institutions, as well as insufficient knowledge of house-renovating companies and homeowners associations (UN-Habitat, UNECE, 2016). This creates the unique need for EaP and CIS countries, as it concerns all of them, to develop sustainable heating and construction mechanisms (UNDP, 2014).

Despite the fact, that service sector accounts for almost half of GDP in mainly all the CIS and EaP countries, its share in final energy consumption is rather small, compared to industry, transportation, and residential sectors. Contribution of agriculture and forestry in TFEC is also relatively small, due to its decreasing share in each country's GDP. The most energy-intensive industrial sector is reported for Kazakhstan, which could be explained by increasing share of fuel industry in industrial production, which more than tripled between 1998-2002 period (CASE, 2008).

Figure 6: Breakdown of Total Final Energy Consumption (TFEC) by sector in 2018

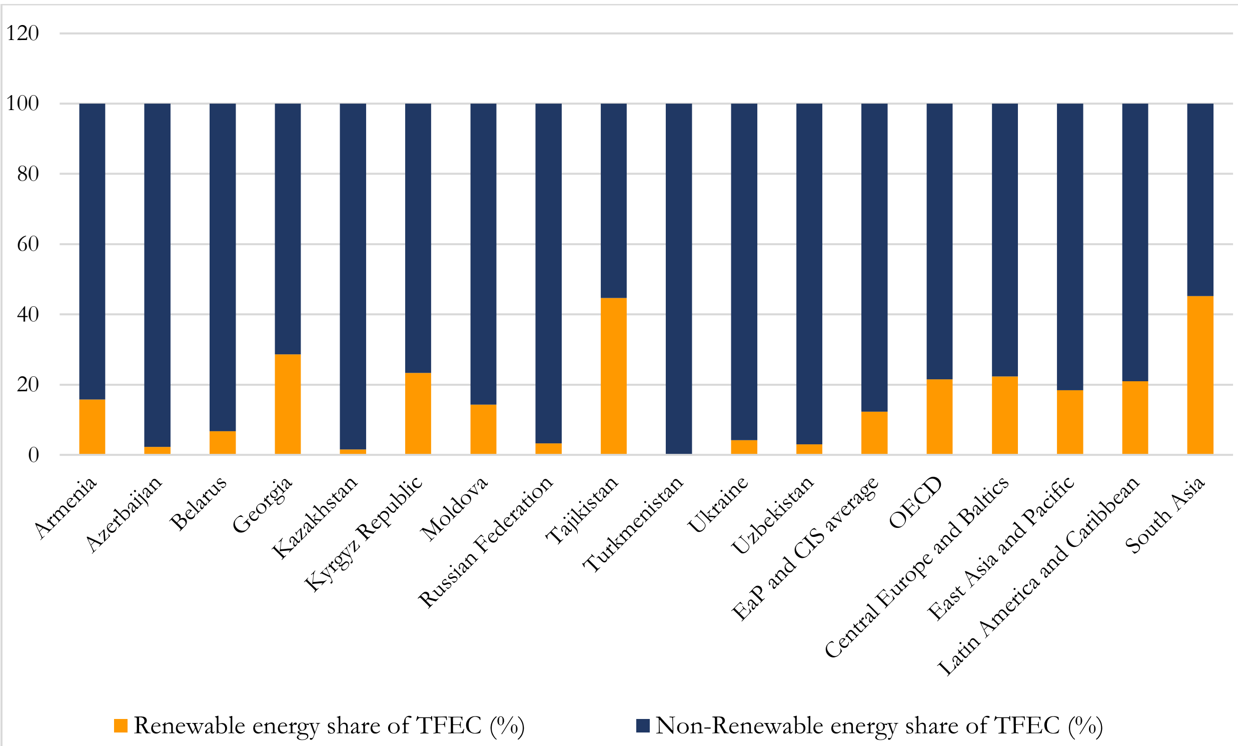


Source: The World Bank Development Indicators

Overall, according to International Energy Agency datasets, consumption of total final energy in industry sector has been decreasing over the last decades in countries other than Georgia, Kyrgyzstan, Tajikistan, Moldova, and seems to consistent for Turkmenistan. TFEC in industry diminished by almost 49% between 2000-2014 in Ukraine, characterizing the country with the most drastic fall, which is explained by IRENA (2015) report with higher gas pricing.

Finally, using Figure 7, we present the share of renewable energy consumption in the final energy consumption, in individual EaP and CIS countries as well for the whole region. As expected from the review of the energy sector, the highest share of RE consumption in TFEC is observed for Georgia, Tajikistan, and Kyrgyz republic. Overall, the REC in TFEC in the EaP and CIS region falls behind all the other regions presented, including the OECD, Central European and Baltic countries, East Asia and Pacific, Latin America and Caribbean and South Asia.

Figure 7: Share of Renewable and Non-renewable Energy Consumption in Total Final Energy Consumption in 2015



Source: The world Bank "Sustainable Energy for All" data catalogue

Despite the tremendous potential in RES, deployment rates for EaP and CIS countries is not very high, due to reasons outlined below, which are making transition towards sustainable energy more challenging in this region:

1. The abundance of fossil fuels in major energy exporting countries, justifying the "endowment effect" reported by Burke (2013), according to which economies with endowments of specific type of energy resources have smaller incentives to move up to different, diversified energy mix dominated by renewable energy sources.
2. Fossil fuel price subsidies have substantial economic consequences, aggravating fossil fuel dependence (UNDP, 2014). For example, subsidies for fossil energy sources in Tajikistan accounted for 7% of the GDP, in the Republic of Kazakhstan – 11%, in Kyrgyzstan – 26.4%, in Turkmenistan – 23.2%, and in

Uzbekistan – 26.3%. For comparison: in Canada, this indicator is at the level of 2.5%, in the USA – 3.8%, and in the UK – 1.4% (Kaliakparova, 2020).

3. Lastly, high initial cost of investment in solar, wind and geothermal energy projects and short-term oriented focus of energy policies contribute to unfavourable conditions for RES adaptation (UNDP, 2014).

Despite the institutional or structural hurdles, these 12 states have a tremendous potential of RES, utilization of which promises beneficial outcomes in the nearest future. These renewable energy source potentials are shortly outlined below according to sub-regions of our panel.

4. Theoretical Framework

The chapter of theoretical framework is divided into two sections. The first section will outline the role of energy resources and their significance in classical and neoclassical growth models, as well as the criticism of the theory by ecological economists. In the second section, we will summarise the relevant empirical literature based on the constructed theory and their results.

4.1. The Theory of Role of Energy in Economic Growth

This section of the paper outlines the relationship between energy and economic growth, by emphasizing the significance of the role of energy in economic growth and more specifically in the process of the production. Understanding the role of energy in economic growth and the role of energy in production are intertwined, thus overlooking the one and expecting to comprehend the other will be impossible.

Over the years, classical theory of economic growth has not placed enough emphasis on the merits of energy or other natural resources in the production process and in the promotion of economic growth, completely neglecting its role as an enabler of economic development (Stern, 2004). Toman & Jemelkova (2003) note that most of the literature had been focused on investigating how energy demand is determined by economic growth. Another strand of studies focuses on identifying the impact of oil and other energy prices on economic activity from the side of business and financial economists. Most of the literature has been confined within the field of environmental and resource economics, with the main focus on the implications of non-renewable resources on economic growth (Stern, 2020). Natural scientists and ecological economists stress the substantial importance of the role of energy and its availability in the process of production and overall economic growth (Stern, 2004), as energy contributes to the transformation or movements of matters in one way or the other, in accordance to the second law of thermodynamics, which makes it a vital factor in the process of production (Stern, 1997).

In the classical economic growth models, land, labour and material capital are considered as primary production factors as outlined by Kaldor (1955), whilst the fuels and materials are perceived as intermediate inputs, which are created and used up entirely during the production process. Furthermore, Stern (2011) elaborates that prices paid for intermediate goods are in fact seen as the payments to the owners of the primary inputs for the services they provide whether directly or adversely through produced intermediate inputs, an approach to taxonomy which led to a substantial focus on primary inputs, as opposed to much inferior treatment towards studying the role of energy in the growth process (Stern, 2004).

The neoclassical model of economic growth was developed by Robert Solow, with an implication that model did not include resources at all. Solow (1956) production function outlines that output is produced by capital and labour and it has constant returns to scale. Model assumes the exclusion of scarce non-augmentable resources, stating that the inclusion of exhaustible resources in the production function would lead to decreasing returns to scale in capital and labour. The restriction of the model, therefore, would be that economies will settle to a zero-growth equilibrium under conditions of constant savings rate, if it was not about the technological progress, which is considered as the only driving force for continuing economic growth, according to neoclassical theory (Solow, 1956) model.

The growth models examined before did not consider the natural resources as an input due the fact that they exist in finite stocks and flows and are exhaustible. Even some renewable resources are believed to be potentially limited. The crucial characteristic of finiteness and exhaustibility of resources interfere with the concept of indefinite economic growth as well as with the notion of attaining sustainable development (Stern, 2004). Therefore, incorporating nonrenewable, as well as renewable but finite natural resources to the basic mainstream growth models implies that capital should also be accumulated to compensate for the depletion of natural resources (Stern , 2011).

The neoclassical framework was augmented to include natural resources in 70s. Seminal papers of Stiglitz, (1974a, 1974b), and Solow (1974) appeared in the special issue of the review of Economic Studies. Solow (1974) showed that achieving sustainability was possible with a finite nonrenewable natural resource with a simultaneous assumption of non-depreciating capital, under the conditions of larger enough capital stock (Stern , 2011). Solow (1974) extends the model of production to $Q = F(K, L, R),$ in which he introduces the R, as a rate of flow of natural resources, however he also claims that the development of the economic growth model depends on the way the R is introduced. If the average product of resources is bounded, finite pool of exhaustible resources can only produce finite amount of output (Q). On the other hand, if the production process is possible without natural resources (R = 0), then it adds no new element to the production, meaning that average product of R has no upper bound, therefore, exhaustible resources will neither support, nor hinder economic growth and level of aggregate consumption will decline to zero. Solow (1974) suggests that continued technological progress is likely to be necessary for a positive consumption flow to be maintainable, which is supported by his assumptions of unlimited technological progress and limited population growth.

Stiglitz (1974a) also articulates the growth model with natural resources and draws the similarities between the way capital goods and natural resources act, stating that when both natural resources and capital goods are included in the model, a path of development which involves the higher rates of natural resource utilization in the production, is characterised with permanently lower rates of long-run growth. He elaborates that if natural resources are vital for production, even if they are exhaustible, it does not necessarily mean, that economy will eventually fall into stagnation and then decline. He identifies two offsetting forces as technical change and capital accumulation and adds, that declining inputs of natural resources could even be offset by capital accumulation alone if the share of the capital in the production is greater than share of natural resources.

Additionally, Stiglitz (1974a) formulates that under the certain conditions of technical change, sustainability of constant level of per capita consumption is feasible, even amidst slowly declining natural resources.

In the following paper, Stiglitz (1974b) stated that under the assumption of competitive market same model results in exhaustion of resources, while consumption and social welfare drops to zero. In response, neoclassical literature classifies the conditions which allow the continuing growth or at least nondeclining consumption or welfare. These conditions are summarised by (Stern, 2004) as the technical and institutional conditions. **Technical conditions** encompass the substitution between renewable and nonrenewable resources, the initial stocks of capital and natural resources, and the substitutability within inputs of production. **The institutional conditions** on the other hand, incorporate things such as market structure, the system of property rights, and the way in which the current generation values the welfare of future generations (Stern , 2011). According to Solow (1974), sustainability in the economy which uses nonrenewable energy as well as renewable energy resources is technically feasible, even if the elasticity of substitution between the nonrenewable resources and capital is less than unity. However, Stern (2011) outlines that the mainstream economists are frequently inclined to the assumption of technical feasibility of sustainable growth, unless proven otherwise. Therefore, the notion of sustainability (nondeclining social welfare) is assumed a priori, even though technical feasibility might not translate directly into sustainability.

The relationship between energy and an aggregate of output such as gross domestic product can therefore be affected by substitution between energy and other inputs within the given technology, technological change, shifts in the composition of the energy input or energy mix, and shifts in the composition of output (Stern, 2011). Additionally, shifts in the mix of the other inputs—for instance, to a more capital-intensive economy from a more labour-intensive economy — can affect the relationship between energy and output (Judson, Schmalensee, & Stoker, 1999). Csereklyei & Rubio-Varas (2016) also outline the interconnectedness of structural change of the economy and composition of energy use.

Criticism of growth theory comes from ecological economists, who stress the limits to substitution and technological progress. Daly (1997) underlined, that natural resources and capital resources are more complements in general, than substitutes, criticizing Solow (1956) for allowing a model without the natural resources and assuming that "the world can, in fact, get along without natural resources". The issue is with the substitutability of capital for resources, rather than the two types of natural resources, to which Solow (1997) retaliated by emphasising on the significance of within category substitutability, as the materials generated from renewable resources, through capital intensive production, might replace the materials produced from nonrenewable sources and use of these renewable resources have ability to persist indefinitely at a constant, positive level. This shifts in energy mix, associated with shifts in composition of output from agricultural economy, to industrial and eventually service oriented is already a reality in many countries. Changes in the composition of output is observable for EaP and CIS countries as well, as reported by Appendix 4. Burke (2013) and Csereklyei & Rubio-Varas (2016) also confirm the phenomena of "energy ladder", which recognizes the advancement of energy quality, stating that due to structural changes in the economy, relative importance of oil and other fossil fuels has been falling at all income levels over the past decades. However, throughout previous chapters we already outlined relatively slow rates of renewable energy deployment in EaP and CIS countries.

Another ecological economist, Georgescu-Roegen (1979) criticizes the Solow/Stiglitz augmented neoclassical production function, which states that R natural resources maybe as small as we wish in the production, as long as K is sufficiently high, due to perfect substitutability between capital and natural resources. The criticism of Georgescu-Roegan (1979) is wrapped around the idea, that in reality excessive use of capital will result in eventual rapid exhaustion of natural resources, indicating that casually conjuring R into classical model to augment economic growth does not align with reality. Daly (1997) also criticizes the "conjuring trick", by emphasizing that the immediate implication of just injecting R into production function deranges the logic behind the marginal physical product of each inputs. when we hold resources constant no extra unit of labour and capital can be generated due to violation of first law of thermodynamics. What we call 'production' is really transformation—of resources (energy) into useful and waste products through agents, such as capital and labour (Georgescu-Roegen, 1979). Stiglitz (1997) response to the criticism of augmented neoclassical model is that the growth model developed by Stiglitz and Solow was intended to answer questions of intermediate time frame. Intermediate term indeed allows for substitutability between capital and resources, even if capital itself uses natural resources and technical change can eventually reduce the amount of both physical capital and resources used for production of unit of output.

4.2. Overview of Energy-Growth Empirical Studies

In the following section of this chapter, we review the studies that tried to investigate the relationship between energy and growth, while differentiating between stream of literature focusing on developed and developing countries. Possible specification of the energy variables includes renewable energy consumption, non-renewable energy consumption and share of RE consumption in total final energy consumption. Main findings suggest that for majority of countries both renewable and nonrenewable energy consumption exerts a significantly positive impact on economic growth and difference in development level of the countries does not seem to have visible implications on the outcomes.

According to meta-analysis by Sebri (2015), obtained results in the study of energy-growth are determined gravely by general study characteristics, model specification, cointegration approach used for assessing the long-term relationship, causality test employed in the study for defining the direction of causality, type of data sample (time series or panel) and the development level of the considered country. Chen et al. (2020) adds RE consumption threshold level to this list and states that for countries, which are placed above the RE consumption threshold level, RE consumption growth positively and significantly affects the Economics growth. Countries, which consume RE below the threshold level, show the insignificant effect of RE consumption growth on Economic growth. As a conclusion, if countries manage to exceed the renewable energy consumption threshold, growth in RE consumption will have positive and significant effect on economic growth.

First, we consider the body of literature that studies the impact of energy consumption (meaning renewable and non-renewable separately) on economic growth in developed nations. Ozturk et al. (2012) assessed the relationship for G7 countries within 1980-2009 using ARDL representation of both classical and augmented Cobb-Douglas production functions and reported that both renewable and non-renewable energy consumption have a positive impact on economic growth for all seven countries, however the significance of elasticities indicates the superiority of augmented production function, for which the elasticities of RE consumption ranges from 0.009 for Italy to 0.177 for Germany, and elasticities of non-renewable energy consumption ranges from 0.286 for Canada to 1.681 for Japan.

After investigating the impact of renewable energy consumption on economic growth in new EU member countries for the period of 1990-2009, Alper & Oguz (2016) came to conclusion that renewable energy consumption has statistically significant positive effect on economic growth only for Bulgaria, Estonia, Poland and Slovenia.

In the Long-run economic output is positively and significantly dependent on both RE consumption and non-renewable energy consumption in the study of top 38 countries according to "Renewable Energy Country Attractiveness Index (REAI)" conducted by Bhattacharya et al. (2016). Interestingly, in short-term period, only non-renewable energy consumption has an impact on economic output. For countries which show no significant relationship between economic output and RE consumptions, authors explain this lack of causality by the inability of a country to make effective use of generated RE into production process.

Moving on to the studies focusing on developing nations, Destek & Aslan (2017) found the evidence for the impact of renewable energy consumption on economic growth for only 3 out of 17 emerging economies, using bootstrap panel causality test to take into consideration the cross-sectional dependence and country-specific heterogeneity. Non-renewable energy consumption seemed to contribute to economic growth in only 5 of the selected emerging economies. Author suggests, that to increase the significance of the renewable energy consumption on economic growth, countries should incentivize the RE consumption growth, which supports the threshold hypothesis by Chen et al. (2020).

After analysing augmented neoclassical growth model for panel of five South Asian countries over the period of 1990-2014 Velayutham & Rahman (2020) stated that both renewable energy consumption and non-renewable energy consumption exert a significantly positive impact on economic growth for the whole panel in the long run, however the scope of RE consumption impact is higher and more significant than for non-renewable energy consumption. Interestingly, non-renewable energy consumption has a negative effect on economic growth for Bangladesh in the Long run, possibly due to harmful effects of non-renewable energy consumption on the environment, which indirectly affects the economic growth.

Koçaka & Şarkgüneşib (2017) examined 9 Balkan and Black sea countries within 1990-2012 and revealed that the renewable energy consumption has a positive and significant impact of GDP growth. Apergis & Payne (2010) report the similar results for 12 Eurasian economies within 1992-2007, indicating that either for sample with or without Russian Federation, renewable energy consumption positively contributes to economic growth. Sample A (with Russia) shows that 1% increase in RE consumption increases real GDP by 0.195%, while the analysis of sample B (without Russia) indicates that 1% increase in RE consumption will increase Real GDP by 0.074%.

The study of 15 West African countries within 1995-2014, by Maji et al. (2019) reveals an interesting result. There exists significant negative effect of renewable energy consumption on economic growth, explained by the supremacy of traditional biomass consumption in western and sub-Saharan countries, the effect of which is detrimental for environmental degradation, while causing respiratory and pulmonary disease in humans, affecting the labour force productivity and causing the negative adverse impact on economic growth.

Number of studies also include foreign direct investments when analysing the impact of energy consumption on economic growth, for FDI affects GDP directly and adversely through transfer of innovative technology, knowledge and practices. Amri (2016) analysed 75 developed and developing countries and reported that RE consumption and non-RE energy consumption both prompt economic growth, but the scope of impact is higher for developed countries, due to higher rates of both RE consumption per capita and non-RE consumption per capita. Significantly positive impact of electricity consumption and FDI on economic growth has been reported in India between 1981-2013 by Kumari & Sharma (2018) and in Pakistan by Latief & Lefen (2019) within 1990-2017, putting emphasis on efficient energy usage and ensured availability, which according to Stern & Kander (2012) is one the determinants of whether energy promotes or hinders economic growth. Energy consumption seems to have engendered an economic growth in 17 MENA countries between 1990-2012 (Abdouli & Hammami, 2017).

Despite the voluminous empirical literature focused on investigating the relationship between energy and economic growth, through either augmented neoclassical growth models, different panel, and time-series cointegration methods, the only paper that examined the all 12 countries of EaP and CIS was Apergis & Payne

(2010), who tried to investigate the relationship between energy and economic growth within 1992-2007. However, he only studied RE consumption as a share of TFEC and used Heterogeneous Panel Cointegration test alongside the Granger causality test. Other than our study, no other paper has studied the impact of disaggregated energy consumption on economic growth within Eastern Partner and CIS countries. The differentiating the renewable energy consumption from non-renewable energy consumption allows us to estimate the separate impact. Additionally, none of the studies in the region have used Autoregressive Distributed Lag (ARDL) model, to define short-run and long-run impact of energy consumption.

5. Empirical Analysis

5.1. Data and Descriptive Statistics

Data used in the study is collected for 12 countries of Eastern Partnership (EaP) and Commonwealth of Independent States (CIS). We employ a panel annual dataset over the period of 1996-2015 providing 20 observations per cross-sectional unit. As seen in literature review, the elasticity of energy consumption to GDP seems to vary over time and cross-sections, creating a need to further explore the LR as well SR relationship while distinguishing the impact of fossil fuel energies on economic growth from the effect of renewables.

Data for the variables is collected mainly from The World Bank Development Indicators, while data for energy consumption is collected from The World Bank "Sustainable Energy for all (SE4ALL)" data catalogue. Main variables of interest included in the model are GDP per capita in constant 2010 US$ prices, renewable energy consumption per capita and non-renewable energy consumption per capita (both final consumption), Foreign Direct Investments as a share of GDP, and domestic investments (Gross Capital Formation) as a share of GDP. Table 2 discusses the variables more in detail. Using these variables, a linear logarithm equation is specified as follows:

$$lnGDPpc_{i,t} = \beta_0 + \beta_1 lnRECpc_{i,t} + \beta_2 lnNRECpc_{i,t} + \beta_3 \ln(FDI/GDP)_{i,t} + \beta_3 \ln(DI/GDP)_{i,t} + \varepsilon_{i,t} \quad (1)$$

Where $GDPpc$ denotes Gross Domestic Product per capita in constant 2010 US$, $RECpc$ denotes renewable energy consumption per capita, $NRECpc$ is non-renewable energy consumption per capita, FDI/GDP represents share of Foreign Direct Investments in GDP and DI/GDP is share of domestic investments (gross capital formation) in GDP. The description of the variables is presented in table 1, along with availability of data, sources, and units of measurement.

Table 2: Description of the Variables

Name of the Variable	Unit of Measurement	Description	Source
GDP per capita (GDPpc)	Constant 2010 US$	As gross domestic product (sum of gross value added by all resident producers in the economy plus any product taxes, deducted any subsidies not included in the value of the products) divided by mid-year population of a country.	World Bank development indicators https://data.worldbank.org/ **Yearly data:** 1996-2015
Renewable energy consumption per capita (RECpc)	Gigajoules (GJ) per capita	This indicator includes energy consumption from all renewable resources: hydro, solid biofuels, wind, solar, liquid biofuels, biogas, geothermal, marine, and waste, divided by the population	The World Bank: "Sustainable Energy for all (SE4ALL)" **Yearly data:** 1996-2015
Non-renewable energy consumption per capita (NRECpc)	Gigajoules (GJ) per capita	Non-renewable energy includes the consumption of energy from fossil fuels, including natural gas, oil products, coal, nuclear power.	The World Bank: "Sustainable Energy for all (SE4ALL)" **Yearly data:** 1996-2015
Share of REC in total final energy consumption (shareREC)	Share if TFEC (%)	Share of renewable energy in total final energy consumption.	The World Bank: "Sustainable Energy for all (SE4ALL)" **Yearly data:** 1996-2015
Foreign direct investment, net inflows (FDI/GDP)	Share of GDP (% of GDP)	Our panel data displays net inflows (new investment inflows minus disinvestment) from foreign investors divided by GDP.	World Bank development indicators https://data.worldbank.org/ **Yearly data:** 1996-2015
Domestic Investments (DI/GDP)	Share of GDP (% of GDP)	Gross Capital Formation - Private and public investment in fixed assets, changes in inventories, and net acquisitions of valuables	World Bank development indicators https://data.worldbank.org/ **Yearly data:** 1996-2015

Table 3 below provides us with descriptive statistics for the overall panel of 12 countries as well as within and between statistics. For GDP per capita, renewable energy consumption per capita and non-renewable energy consumption per capita, when we compare the between and within statistics of standard deviations we see, that compared to between statistics, there is relatively small differences over time within each panel groups. Opposite is true for foreign direct and domestic investments as shares of GDP, for which volatility seems to be higher within countries, than between them.

Table 3: Descriptive Statistics for EaP and CIS panel

Variable		Mean	Std. dev.	Min	Max	Observations
GDP per capita	overall	3370.9	2758.0	366.9	11731.4	N = 240
(GDPpc)	between		2501.5	618.5	8904.6	n = 12
	within		1358.9	-59.5	6772.0	T = 20
Share of RE consumption	overall	13.4	18.5	0.002	64.60825	N = 240
In total final EC	between		19.0	0.1	58.6	n = 12
	within		3.5	-0.5	28.5	T = 20
Renewable energy	overall	3.3	3.1	0.0	13.0	N = 240
Consumption per	between		3.1	0.1	10.8	n = 12
Capita (RECpc)	within		0.7	0.5	6.0	T = 20
Non-renewable energy	overall	49.1	35.4	4.1	136.5	N = 240
Consumption per	between		35.8	5.0	107.6	n = 12
Capita (NRECpc)	within		8.7	19.3	77.9	T = 20
FDI share of GDP	overall	5.9	6.8	-0.4	55.1	N = 240
(FDI/GDP)	between		4.4	1.4	18.1	n = 12
	within		5.3	-9.7	42.9	T = 20
Domestic Investments	overall	26.0	8.0	9.1	58.0	N = 237
Share of GDP (DI/GDP)	between		4.4	19.5	35.7	n = 12
	within		6.9	9.0	54.9	T = 19.75

After examining the overall picture, we must discern between the whole panel and panel without the inclusion of Russian Federation, as one of the largest energy producer and consumer of the world. Appendix 7, therefore, provides us with descriptive statistics for the panel of 11 countries of EaP and CIS, excluding Russia. The first thing we notice is that the average GDP per capita and non-renewable energy consumption per capita variables are smaller for the panel without Russian. More specifically, average GDP per capita seems to have reduced by almost 15% and non-renewable energy consumption per capita decreased by 11%. For these two variables, difference is evident in between statistics as well, which indicates that for panel without Russian Federation, there is evidently less standard deviation between countries. These varying results are relevant, once we consider the descriptive statistics of only Russian Federation in Appendix 8, which highlights the substantially above average GDP per capita and non-renewable energy consumption per capita indicators. The difference is rather small in case of renewable energy consumption per capita, FDI and Domestic Investments. Share of renewables in TFEC increases once we remove Russia.

Appendix 9 focuses on another set of contrasting sub-samples. We divide our sample 5 energy exporting countries, namely Azerbaijan, Kazakhstan, Russia, Turkmenistan and Uzbekistan and rest of the energy-importing countries. It is apparent from the Appendix 9, that GDP per capita as well as non-renewable energy consumption are substantially higher in energy exporting countries. More specifically, GDP per capita for energy exporting countries and non-renewable energy consumption per capita are on average 121% and 151% (respectively) higher than GDP per capita for countries reliant on energy imports. The opposite is true for renewable energy consumption per capita, which is dominant for energy importing countries, determined by inclusion of main renewable energy producer countries in the sub-sample (Kyrgyz Republic, Georgia, Tajikistan). REC as a share of TFEC is over ten times larger in energy importing countries.

FDI as a share of GDP is almost double the size for energy exporting countries, explained by the fact, that energy exporting countries of Caspian Basin, attract the highest share of FDI in extractive activities of natural gas and oil, due to their abundant natural resources. There is a relative equality in terms of share of domestic investments in GDP between our sub-samples.

5.2. Econometric Methodology

This section will outline the main specification of econometric methodology for panel data analysis. Initially, we will test our vairables for stationarity using unit root test procedure to determine the order of integration. Then we will test whether the variables are cointegrated in the long-run and in case of the existance of cointegrating vector, we will move on to analysing final part, panel ARDL to determine the short-run and long-run elasticties of our interest variables.

5.2.1. Unit Root Test for Stationarity

The first step towards analysing panel data is to test the stationarity of the variables, for determining order of integration. Without conducting the panel unit root tests, the variables which might be trending over time, may lead us to a statistically significant results, while in fact the regression results are spurious.

To investigate the time-series properties of our variables we apply the first-generation unit root tests, which hold the assumption of cross-sectional independence, namely Im, Pesaran and Shin (IPS) (2003) and Fisher type unit root tests, Fisher-ADF and Cross-sectionally Augmented ADF (CADF), that does not assume cross-sectional independence.

For unit root testing Im, Pesaran and Shin (IPS) (2003) suggested testing procedure by averaging Augmented Dickey-Fuller (Dickey and Fuller, 1979) unit root test statistics computed for each group of heterogeneous panels. The IPS test is advantageous because it allows for heterogeneity of the error variances across groups as well as residual serial correlation. It also allows individual specific auto regressive structures (Hlouskova and Wagner, 2005). On the other hand, the advantage of using Fisher type tests is that unlike previously existed unit root tests, it does not require the number of panel groups to be finite, therefore holds no assumptions on N and T. In addition to this, the test also does not assume the same number of time series for all the groups of panels. The idea behind the test is that it combines the p-values from a unit root test applied to each group (Choi, 2001)

Im, Pesaran and Shin (IPS) (2003) propose a stochastic process y_i, generated by the first order autoregressive process for the sample of N cross sectional units and T time periods. The general equation for stochastic process is specified below:

$$\Delta y_{i,t} = \alpha_i + \beta_i y_{i,t-1} + \varepsilon_{i,t} \qquad (1)$$

The null hypothesis, according to the above equation becomes $H_0\colon \beta_i = 0$ for all cross section $i = 1, \dots, N$ and alternative hypothesis will be $H_1\colon \beta_i < 0$ for $i = 1, \dots, N_1$, $\beta_i = 0$, $i = N_1 + 1, N_1 + 2, \dots, N$. The advantage of formulating alternative hypothesis in a given manner is that it allows different β_i across groups as well as the possibility for individual series to have unit roots under the alternative hypothesis.

Additionally, we will test the stationarity of variables using cross-sectionally augmented ADF (CADF), proposed by (Pesaran, 2007), allowing for cross-sectional dependence in panels. Pesaran (2007) augmented the standard DF (ADF) regressions with cross-section average of lagged levels and first-differences of individual serials of panel. The general equation for stochastic process is specified as follows:

$$\Delta y_{i,t} = \alpha_i + \beta_i y_{i,t-1} + \gamma_i f_t + \varepsilon_{i,t} \qquad (2)$$

Where, f_t is the only difference between the equations (1) and (2) and depicts unobserved common effect. The null and alternative hypothesis are similarly formulated: $H_0\colon \beta_i = 0$ for all cross section $i = 1, \dots, N$ and alternative hypothesis will be $H_1\colon \beta_i < 0$ for $i = 1, \dots, N_1$, $\beta_i = 0$, $i = N_1 + 1, N_1 + 2, \dots, N$.

5.2.2. Panel Cointegration Tests

After unit root test results are attained and we learn about the order of integration of variables, we proceed with understanding whether there is a long-run equilibrium relationship between our dependent and independent variables. This requires us to test for cointegration, which will indicate whether our integrated series are in a long-run equilibrium, whether they move together, despite the possibility that some of the groups of these series might be wandering arbitrarily. According to Engle and Granger (1987) even if each element of a vector of time series x_t becomes stationary at the first difference, but a linear combination of non-stationary time series is already stationary, the time series seems to be cointegrated. This implies that deviations from equilibrium are stationary, with finite variance. Pedroni (1999) refers to the vector of slope coefficients that makes this combination stationary as the cointegrating vector, which might not be unique inferring many cointegration relationship among certain set of variables.

To test for cointegration, we use cointegration tests developed by Pedroni (1999), Kao (1999) and Westerlund (2005), which are all Residual-based tests for cointegration. According to Pedroni (1999), in case of T time series observations, N cross-section, and M number of regressor variables, the most general case of the cointegration regression, according to which the regression residuals should be computed, takes the following form :

$$y_{i,t} = \alpha_i + \delta_i t + \sum_{m=1}^{M} \beta_{mi,t}\, x_{mi,t} + e_{i,t} \qquad (3)$$

Where α_i is a cross-section specific intercept, and $\delta_i t$ is a deterministics time trend. Both the intercept and time trends can vary across individual members of the panel. From panel regression (3) we arrive to testing the null hypothesis of no cointegration by testing the regression residuals for a unit root using the autoregression (Westerlund, 2005):

$$\hat{e}_{i,t} = \rho_i \hat{e}_{i,t-1} + u_{i,t} \qquad (4)$$

where ρ_i is the AR parameter, allowed to be panel specific for Pedroni (1999) and Westerlund (2005) cointegration tests; $u_{i,t}$ is a stationary error term. Null hypothesis for all three tests is that there is no cointegration between $y_{i,t}$ and $x_{mi,t}$ variables. All tests share the same alternative hypothesis stating that variables are cointegrated in all the panels, with an exception of Westerlund "Some Panels" option, according to which alternative hypothesis is that some panels are cointegrated.

Each of the cointegration tests hold certain assumptions and are characterized by different features. Kao (1999) test assumes the independent $(u_{it}, \varepsilon_{it})$ meaning that it does not allow the cross-sectional dependence across panel. Pedroni (1999) test does not uphold the assumption of homogeneity of the co-integrating vectors amongst individual panel members. Valuable feature of this test is that under the alternative hypothesis it allows the presence of different co-integrating vectors across cross-sections, avoiding incorrect imposition of homogeneity. Regarding Westerlund (2005) test, its' advantages include the ability to accommodate short-run dynamics, individual specific time trends and intercepts and individual specific slope parameters. Additionally, the test shows that out of all discussed cointegration tests, size distortions are the smallest in case of small sample size.

5.2.3. Panel ARDL

Once we confirm the existence of long-run equilibrium relationship between our variables, using panel cointegration equations (3) and (4), we move on to analysing dynamic panel-data model and defining the long-run and the short-run elasticities using Autoregressive Distributed Lag (ARDL) methodology. Initial work on the ARDL model for panel was published by (Pesaran, Shin, & Smith 1997, 1999) who suggested a two-step strategy. For the first stage lags must be selected using Akaike Information Criteria (AIC) or Schwarz Bayesian Criterion (SC). On the second stage, long-run and short-run coefficients will be estimated. This two-step estimation strategy gives us consistent estimation results irrespective of whether variables are integrated at level (I (0)) or integrated at order one (I (1)) (Pesaran & Shin, 1995).

For N cross-sectional units and T time series we formulate Autoregressive Distributed Lag (ARDL) $(p, q_1, \dots, q_k)$ model, proposed by (Pesaran , Shin, & Smith 1999) and cited by (Blackburne & Frank, 2007) as follows:

$$y_{i,t} = \sum_{j=1}^{p} \lambda_{ij}\, y_{i,t-j} + \delta_i t + \sum_{j=1}^{q} \delta'_{i,j}\, x_{i,t-j} + \mu_i + \varepsilon_{i,t} \qquad (5)$$

Where i = 1, … , N; t = 1, …, T. $X_{i,t}$ is a k x 1 vector of explanatory variables; $\delta_{i,t}$ are k x 1 coefficient vectors; λ_{ij} are scalars and μ_i is the groups specific effect. Index j represents optimal number of lags for dependent and independent variables.

Model (5) allows us to generate the error correction model in which short-run dynamics of the variables are being influenced by the deviation from the equilibrium. Reparametrizing model (5) into error correction equation can be presented as follows:

$$\Delta y_{i,t} = \phi_i\left(y_{i,t-1} - \theta'_i X_{i,t}\right) + \sum_{j=1}^{p-1} \lambda^*_{ij}\, \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta'^{*}_{i,j}\, \Delta X_{i,t-j} + \mu_i + \varepsilon_{i,t} \qquad (6)$$

Where ϕ_i is an error correcting speed of adjustements and in case of correct specification of the model, is expected to negative and significant; $\phi_i = -(1 - \sum_{j=1}^{p} \lambda_{ij})$, $\theta_i = \sum_{j=0}^{q} \delta_{i,j} / (1 - \sum_k \lambda_{i,k})$, $\lambda^*_{ij} = -\sum_{m=j+1}^{p} \lambda_{i,m}$, j = 1, 2, … , $p-1$, and $\delta^*_{i,j} = -\sum_{m=j+1}^{q} \delta_{i,m}$; j = 1, 2, … , $q-1$.

According to the model formulated as (6), the dependent variable will be affected by its own lagged values, as well as the lagged values of the independent variables, the error correction term, and the residual term ((Menegaki, 1999)). Additionally, (Pesaran & Shin, 1995) state that the ARDL tests statistics computed using Δ method perform much better in small samples.

General advantages of ARDL model, aside the small sample properties, is that it allows the simultaneous estimation of long-run and short-run coefficients. If we choose appropriate number of lags, residual correlation is eliminated, which helps alleviating the problem of endogeneity (Menegak, 2019). Model also allows the estimation of single form equation, rather than system of equations.

Another significant advantage of using ARDL model is that it provides three different estimators, namely Mean Groups estimator (MG), Pooled Mean Group estimator (PMG) and Dynamic Fixed Effects estimator (DFE). Each estimator has its own set of assumptions. On one side there is mean group **(MG)** estimator, introduced by Pesaran & Smith (1995), which does not consider the possible homogeneity of parameters across groups, therefore only allows different short-run and long-run parameters for each group. Dynamic fixed effects **(DFE)** estimator allows the slope coefficients and error variances to be the same across panel, however it might constrain the model if homogeneity does not hold (Pesaran, Shin, & Smith 1997, 1999). Finally, we will be using pooled mean group estimator **(PMG)** which according to Pesaran, Shin, & Smith (1997, 1999) is an intermediate estimator including both pooling and averaging. It allows different intercepts, short-run coefficients, and error variances, however, also assumes the homogeneity of long-run parameters. Additional advantage of PMG estimator is that by not imposing the equality of short-run slope coefficients, it allows the number of lags to differ for each panel groups (Pesaran, Shin & Smith 1999).

6. Empirical Results

6.1. Unit Root Test Results

For understanding the stationarity properties of variables, panel unit root tests have been implemented. For each test, time trend is included, and cross-sectional means have been subtracted. The null hypothesis for each test is the existence of unit roots in all the panels. However, there is slight difference in alternative hypothesis. IPS unit root test alternative hypothesis assumes that some panels are stationary, whilst the Fisher-ADF assumes that at least one panel is stationary.

Table 4: Panel Unit Root Tests

Im, Pesaran and Shin **(IPS)** Panel Unit Root Test		
Variables	level	First difference
lnGDP	2.0676	-2.5613***
lnREC	-5.6215***	-9.5692***
lnNREC	-1.2048	-4.9555***
lnFDI	1.3303	-5.2172***
lnDI	-0.7345	-3.7558***
Fisher-**ADF**		
	level	First difference
lnGDP	2.1429	-3.8920***
lnREC	-1.7915**	-8.0109***
lnNREC	0.5492	-9.1195***
lnFDI	-1.1717	-7.1527***
lnDI	-1.4423*	-6.6781***
Cross-sectionally Augmented ADF **(CADF)**		
	level	First difference
lnGDP	-0.351	-2.945***
lnREC	-1.908**	-4.071***
lnNREC	1.062	-2.870***
lnFDI	-1.168	-3.028***
lnDI	-1.720	-2.571***

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$, IPS reveals Im, Pesaran and Shin W-stat. ADF reveals Augmented Dickey-Fuller Fisher Chi-square. IPS and ADF assume individual unit root process. For the definition of variables, please see Table …
IPS: Ho: All panels contain unit roots / Ha: Some panels are stationary. Time trend is included in the test.

Fisher ADF: Ho: All panels contain unit roots / Ha: At least one panel is stationary

The results of the panel unit root tests are shown in table 2. Evidently, the only variable for which we can reject the null hypothesis of existence of unit root is renewable energy consumption (lnREC). However, for all the variables under each test applied, the null hypothesis can be rejected at the first difference, meaning that variables are stationary in first difference, hence there are integrated of order one, I (1). The next logical step, therefore, is to test for presence of possible long-run relationship between variables, by applying the panel cointegration tests.

6.2. Panel Cointegration Test Results

Pedroni proposes tests for cointegration that allow for heterogeneous intercepts and trend coefficients across cross-sections. These seven statistics can be observed in table 3, out of which three are based on pooling along within-dimension and other two are based on pooling along between-dimensions. The test allows for specification of AR parameter to be either panel specific or same for all panels.

Table 5: Pedroni Panel Cointegration Test

AR parameter is panel specific	Statistics	AR parameter is same for all panels	Statistics
		Modified variance ratio	-6.2788***
Phillips-Perron t	-2.1157**	Phillips-Perron t	-10.3155***
Augmented Dickey-Fuller t	-1.0179	Augmented Dickey-Fuller t	-1.9481**

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$, ***. Pedroni test of no cointegration. Ho: No cointegration / Ha: All panels are cointegrated. Tests include panel-specific time trends. Lag structure is specified for ADF regressions and lag length is determined by Akaike Information Criterion (AIC).

According to results, all statistics are significant, with an exception of Augmented Dickey-Fuller t statistics for panel specific AR parameter. Results allow us to reject null hypothesis of no cointegration and indicates the existence of long-run equilibrium relationship between our interest variables. Lag length is determined by Akaike Information Criterion (AIC).

Besides the Pedroni (1999) cointegration test, we use Kao and Westerlund Cointegration tests for checking the robustness of the results of Pedroni panel cointegration test. All five Kao cointegration tests reject the null hypothesis of no cointegration at 1% significance level. Westerlund (2005) test proposes variance ratio statistic, constructed under assumption of common AR parameter across panels. The result for this test allows us to reject null hypothesis of no cointegration, coinciding with findings of Pedroni cointegration test, that there exists long-run relationship between the variables of economic growth, renewable energy consumption, non-renewable energy consumption, Foreign Direct Investments and Domestic Investments.

Table 6: Kao and Westerlund Cointegration Tests

Kao test for Cointegration	Statistic
Modified Dickey-Fuller t	-5.4562***
Dickey-Fuller t	-4.7343***
Augmented Dickey-Fuller t	-3.1307***
Unadjusted modified Dickey-Fuller t	-6.8066***
Unadjusted Dickey-Fuller t	-5.0924***
Westerlund test for cointegration	**Statistic**
All panels are cointegrated	
Variance ratio	-1.6092 **

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$, ***.
Kao test of no cointegration: Ho: No cointegration / Ha: All panels are cointegrated.
Westerlund test of cointegration: a) Ho: No cointegration / Ha: All panels are cointegrated; b) Ho: No cointegration / Ha: Some panels are cointegrated. Tests include panel-specific time trends. Lag structure is specified for ADF regressions and lag length is determined by Akaike Information Criterion (AIC).

Each of this method has its own advantages. E.g. Pedroni cointegration test has higher explanatory power, given that it is providing us with 5 statistics. Kao cointegration test is useful for small samples and Westerlund cointegration test does not assume cross sectional independence, which might be the case for heterogeneous panel data (Menegak, 2019).

6.3. Panel ARDL Empirical Results

We believe that dynamic fixed effects (DFE) estimator would not be justifiable for our analysis. Allowing the long-run homogeneity is plausible, considering the similarity between EaP and CIS countries regarding their long-term tendencies in development as well as homogeneity in the trends of our interest variables. The homogeneity is also expressed by the way in which the countries similarly respond to macroeconomic shocks, including comparable economic growth trends as shown in Figure 1. Nevertheless, constraining the analysis with the identical short-term estimators will not be backed by theoretical background. Despite the close to similar path of transition, multiple factors can drive the substantial differences in short-run coefficients. For example, each country has its' own set of energy policies and level of energy market liberalisation, as well as the coping mechanisms for mitigating the results of power supply shortages and so on. Additionally, the conflicts between countries in each region, or systematic civil unrests within countries, can affect the short-run outcomes, supporting the heterogeneity of short-run estimators. To conclude, we rule out the DFE estimator, because in case the slope coefficients are in fact not identical for short run, the fixed effects approach will produce inconsistent and potentially misleading results (Blackburne & Frank, 2007).

We start our analysis by defining optimal lags for each variable. The lag selection process for panel ARDL is not as straightforward as in the case of time-series, for which the statistical software usually defines the optimal lag length by itself. Setting the order of panel ARDL depends on the results of the lag selection for the individual cross-sectional unit. The most common practice is to choose the number of lags for each variable, with highest rates of occurrence while considering each cross-section. Another dilemma concerns the choice of optimal lag selection criteria, for which Pesaran & Smith (1995) suggest either Akaike Information Criterion (AIC), or the Schwarz Bayesian Criterion (SC), but due to the better performance of ARDL-SC estimators in different experiments, they give their preference to Schwarz Bayesian Criterion (SC), which is also a default lag selection criteria for Stata software.

According to appendix 10, optimal lag lengths are defined as following: $p = 2;\ q_k = 2,$ where k represents the number of explanatory variables and $k = 1, 2, 3, 4.$ To assess the impacts of renewable and non-renewable energy consumption on GDP, we look at the results of PMG and MG, under the Table 7, and try to check the consistency of PMG estimators with our first robustness check. We estimate the mean group (MG) estimator, differing from PMG by allowing for heterogeneity in short-run coefficients as well as in long-run coefficients (Pesaran & Smith, 1995). For both. PMG and MG, ECT is negative and significant. The results of Hausman test rejects the null hypothesis of non-systematic difference between the PMG and MG estimators and indicates, that there is a systematic difference between coefficients, which in turn provides us with evidence for doubting the efficiency of MG estimators[9].

Analysing the results of PMG under Table 7, **Error correction term**, which specifies the speed of adjustment, is negative and significant, which indicates the correct specification of the model as well as convergence from short run to long run and shows a causal relationship of our explanatory variables with dependent variable. More specifically, error correction coefficient equals -0.05, meaning that around 5% of disequilibrium of GDP per capita caused by shocks or other deviations, will be adjusted back to the long-run equilibrium state. Therefore, the ECT works to push dependent variable back to equilibrium (Wooldridge, 2016).

[9] The detailed rationale behind the results of the Hausman test, which is an implementation of Hausman (1978) specification test, is that we compare two estimators, one of which ($\hat{\theta}_1$) is believed to be consistent (PMG estimator in our specification), another estimator ($\hat{\theta}_2$) which is efficient under the assumption being testing (MG estimator in our specification). Null hypothesis is that there is no systematic difference between the two estimators meaning, that $\hat{\theta}_2$ estimators are indeed efficient (and consistent). Rejecting the null hypothesis means that there is a systematic difference between the estimators, and we have basis for doubting the efficiency of $\hat{\theta}_2$ (Blackburne & Frank, 2007). Which is why, we deem the MG estimator non-efficient, meaning that assumption of heterogeneity of long-run coefficient does not hold.

Moving on to the main results, both renewable and non-renewable energy consumption exert a positive effect on economic growth. In the long run, 1% increase in renewable energy consumption is associated with 0.36% rise in GDP per capita, whereas 1% increase in non-renewable energy consumption causes the 0.14% growth in GDP per capita. Furthermore, we can observe, that the extent of their impact varies over time and while the non-renewable energy consumption seems to have a larger impact on GDP per capita in the short run, the long-term period suggests the reversed outcomes, emphasising the relative dominance of renewable energy consumption per capita on economic growth. These outcomes comparable with findings of Rahman & Velayutham (2020), reporting that for five South Asian countries in the long run, impact of REC on economic growth is larger than for NREC. Lower effect of NREC on Economic growth could be influenced by the negative impact of NREC on economic growth in energy importing countries, which we will focus on in the robustness analysis part of this paper. Additionally, in the long run deployment of renewable energy sources and increasing the consumption from it might be affecting the trade dynamics of energy related goods and decelerating the trade of fossil fuels, resulting in enhanced energy security and less import dependence for energy importing countries (IRENA, 2016). Long-run time frame also allows the consideration of spill over effects of irrational consumption and production of fossil fuels, diminishing its scope of positive influence on economic growth, compared to RES. Alternatively, in the short term fossil fuel still constitutes the major part of the economy in each EaP and CIS countries, accounting for largest share in consumption across all sectors of the economy, justifying the greater impact on GDP in the short run, compared to RE consumption.

Table 7: Main empirical results

Dependent variable	Log (GDP per capita)	
Estimator	PMG	MG
Error correction term (ECT)	**-0.05***** (0.018)	**-0.08**** (0.044)
Long run coefficients		
Renewable energy consumption	0.361*** (2.127)	0.095 (0.350)
Non-renewable energy consumption	0.135 (0.386)	-0.352 (2.127)
FDI share in GDP	-0.147 (0.097)	0.193 (0.176)
Domestic Investments share in GDP	0.568*** (0.208)	0.499 (0.505)
Short run coefficients		
(Renewable energy consumption)	0.022* (0.013)	0.015 (0.016)
(Non-renewable energy consumption)	0.091** (0.042)	0.055 (0.040)
(FDI share in GDP)	0.008* (0.005)	0.009*** (0.003)
(Domestic Investments share in GDP)	0.072** (0.035)	0.069** (0.035)
Constant	0.282*** (0.098)	-0.161 (0.305)
Observations	209	209
Countries	12	12
Log likelihood	448.89	

Hausman Test p value	0.0000

Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The effect of domestic investment on GDP per capita is significantly positive in long and short-term as well and its impact exceeds the effect of FDI in the short run.

Additionally, an increase in FDI as a share of GDP seems to be associated with the lower GDP in the long-run and higher GDP in the short-run. The explanation for negative elasticity of FDI could be found in the nature of FDI within region, being mainly concentrated in fossil fuel extractive activities in major energy exporting countries. Alfaro (2003) claims that not all forms of FDI result in positive spillovers in the economy through technology transfer and are beneficial. FDI in primary sector (agriculture and mining) seems to exert a robustly negative impact on economic growth in developing countries. Mencinger (2003) also discovers the negative relationship between FDI and economic growth for eight EU candidate countries in the post transition period, explaining the direction of the elasticity by differences in characteristics of the FDI and positive link between FDI and current account balance deficit, which is also relevant for selected CIS countries as investigated by Aristovnik (2006). Additionally, despite the significance of FDI as means of financing the transition from centrally planned economy to the market-based economy and for the achievement of sustainable development goals, Shapiro et al. (2018) stresses the limitations of positive spillovers of FDI, when it is mainly concentrated in extractive sector operations.

6.4. Examining Country Specific Short-run Relationship Between Economic Growth and Energy Consumption

As declared above, one of the advantages of using pooled mean group (PMG) estimator is that it allows the heterogeneity of the short-run estimators across groups of panel, which in turn permits us to move on to taking a closer look at the country-specific short-run elasticities after examining our whole panel model with PMG estimator. Our concern is our model might overlook the wide range of variables, which is why we investigate whether the country level differences modifies the relationship between energy consumption variables and GDP per capita.

The results for the extended PMG estimator are presented in Table 8 and Table 9. For each individual cross-section, error correction term is negative and mostly significant, highlighting the quality of the estimators. The short-run relationship between REC per capita and GDP per capita on one hand and NREC per capita and GDP per capita on the other hand, agrees with the long-run outcomes, indicating that both REC and NREC exert a positive impact on GDP per capita in most of the countries in our panel. Positive coefficients of REC per capita range from 0.004 for Turkmenistan and 0.216 in Kyrgyz Republic. Positive Coefficients for NREC range between 0.021 for Tajikistan and 0.309 for both Ukraine and Turkmenistan, demonstrating the heterogeneity of elasticities in the short run, while overall range of NREC to GDP elasticities is higher than elasticities for REC to GDP.

For the majority cross-sectional units GDP per capita seems to be positively affected by FDI in the short run. However, these links are not significant in several countries. On the contrary, same positive impact of domestic investment as a share of GDP, is supported by significance for most of the cross-sectional units.

Table 8: Heterogeneous Short-run Coefficients – Country Evidence

Short-run coefficients by country						
	Armenia	***Azerbaijan***	***Belarus***	***Georgia***	***Kazakhstan***	***Kyrgyz Republic***
Error correction term	-0.077 (0.069)	-0.028** (0.014)	-0.022 (0.027)	-0.015 (0.019)	-0.023* (0.013)	-0.017* (0.011)
(Renewable energy consumption)	-0.016 (0.051)	0.034 (0.088)	0.0355 (0.122)	-0.009 (0.048)	0.013 (0.069)	0.216*** (0.084)
(Non-renewable energy consumption)	0.119 (0.11)	-0.065 (0.167	0.281* (0.157)	0.041 (0.056)	0.053 (0.063)	-0.021 (0.06)
(FDI share in GDP)	0.005 (0.021	0 .009 (0.021)	0.002 (0.005)	0.021*** (0.006)	-0.011 (0.02)	0.045*** (0.011)
(Domestic Investments share in GDP)	0.275** (0.121	-0.21*** (0.069	0.119** (0.056)	0.061*** (0.019)	0.106* (0.064	0.097* (0.06)
Constant	0.431 (0.361)	0.207* (0.117)	0.115 (0.149)	0.075 (0.098)	0.098 (0.089)	-0.112* (0.059)

Standard errors in parentheses ∗ $p < 0.10$, ∗∗ $p < 0.05$, ∗∗∗ $p < 0.01$

Table 9: Heterogeneous Short-run Coefficients – Country Evidence

Short-run coefficients by country						
	Moldova	***Russia***	***Tajikistan***	***Turkmenistan***	***Ukraine***	***Uzbekistan***
Error correction term	-0.229** (0.111)	-0.022 (0.016)	-0.030** (0.013)	-0.083** (0.042)	-0.056 (0.035)	-0.016** (0.008)
(Renewable energy consumption)	0.103*** (0.038)	-0.113 (0.112)	0.069 (0.057)	0.004 (0.011)	0.011 (0.031)	-0.041** (0.019
(Non-renewable energy consumption)	0.144 (0.127)	0.027 (0.185)	0.021 (0.014)	0.309** (0.127)	0.309*** (0.092)	-0.04* (0.036)
(FDI share in GDP)	0.030** (0.016)	0.029** (0.014)	0.006*** (0.002)	-0.013 (0.019)	-0.034*** (0.009)	0.0001 (0.006)
(Domestic Investments share in GDP)	-0.031 (0.079)	0.237*** (0.043)	-0.001 (0.007)	0.131* (0.072)	0.222*** (0.041)	0.032 (0.026)

Constant	1.213** (0.537)	-0.001* (0.103)	0.123** (0.057)	0.561** (0.277)	0.317 (0.224)	0.117* (0.067)

Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

7. Robustness Analysis

Within this chapter we will elaborate more on ways with which we are going to check the robustness of our model and its outcomes. The key question, hereafter will be how robust the outcomes of empirical results are towards a sensible change in model specification. **First**, we exclude the Russian Federation from the panel, and implement the ARDL model for remaining 11 countries of EaP and CIS. **Second**, we divide our panel with sub-samples of energy exporting and energy importing countries. Energy exporting countries will include Azerbaijan, Russian Federation, Kazakhstan, Turkmenistan, and Uzbekistan. The remaining 7 countries will be categorized under energy importing economies and included in the ARDL model accordingly. For our **final** robustness check, we introduce and new variable as a "Share of renewable energy consumption in total final energy consumption" instead of renewable energy and non-renewable energy consumption per capita.

Examining a panel without Russia for the next robustness check is supported by the analysis of regional framework, emphasising the dominance of Russian Federation in energy sector across the region and the world alike. The second raw of the Table 10 shows the results of panel ARDL model, without the inclusion of Russian Federation. For comparative analysis we also include the PMG estimator results for overall panel. The first thing we declare is that error correction term is negative for the panel without Russia, and it shows significance at 10% level, weakly supporting the modelling choice. The direction of the elasticities is analogous with PMG for the overall panel, however in the long run the scope of the impact of both renewable and non-renewable energy consumptions per capita on GDP per capita is larger. The pooled mean group estimator for panel without Russia agrees with the findings of the model for the overall sample of 12 countries. Renewable and non-renewable energy consumption per capita have positive impact on economic growth both in long-run and in short term period. Additionally, Long run elasticities of energy variables for panel without Russia are lower and elasticity of non-renewable energy consumption to GDP is higher than for REC to GDP in both long- and short-run period, which is not surprising given that the largest share of energy consumed in absolute terms from both sources in the region is by Russia (Apergis & Payne, 2010). The negative long-term elasticity of FDI is still supported by the model based on sample of 11 countries, while domestic investments seem to be positively contributing to the augmentation of GDP per capita rates in short run and long run period.

Another important aspect is that, excluding Russian Federation from the overall panel results in strengthening the significance of the long- and short-run elasticities. However, greater importance should be given to error correction term, which is significant even at 1% significance level and its absolute value is greater for the overall panel, demonstrating the higher speed of adjustment of disequilibrium for GDP per capita in case of inclusion of Russia.

Table 10: ARDL Model for Panel Without Russian Federation

Dependent variable		Log (GDP per capita)	
Estimator		PMG	
Panel		With Russia	Without Russia
Error correction term (ECT)		-0.0498*** (0.018)	-0.0268* (0.017)
Long run coefficients			
	Renewable energy consumption	0.361*** (2.127)	0.923*** (0.212)
	Non-renewable energy consumption	0.135 (0.386)	2.989*** (0.435)
	FDI share in GDP	-0.148 (0.097)	-0.642*** (0.162)
	Domestic Investments share in GDP	0.568*** (0.208)	0.775*** (0.183)
Short run coefficients			
	(Renewable energy consumption)	0.022* (0.013)	0.032*** (0.010)
	(Non-renewable energy consumption)	0.091** (0.042)	0.075* (0.042)
	(FDI share in GDP)	0.008* (0.005)	0.008** (0.004)
	(Domestic Investments share in GDP)	0.072** (0.035)	0.054* (0.033)
	Constant	0.282*** (0.098)	-0.135* (0.083)
Observations		209	191
Countries		12	11
Log likelihood		448.893	414.741

Standard errors are in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The second robustness check, as outlined above will divide our sample into two different sub-samples. Sample A will represent the panel of energy exporting countries, while energy importing countries will be denoted by Sample B. ECT is negative and significant for both samples, but the speed of adjustment seems to be higher for energy exporting countries. Short-run elasticities are somewhat similar to the findings of ARDL for overall panel, with all the independent variables including renewable energy consumption and non-renewable energy consumption engendering economic growth. Regarding the long-run coefficients, increasing non-renewable energy consumption has a negative impact on GDP per capita for 8 energy importing countries, however this coefficient is not statistically significant. The direction of other long-run elasticities supports the outcomes of overall panel ARDL.

Table 11: ARDL Model for Energy-exporting and Energy-importing Countries

Dependent variable	Log (GDP per capita)	
estimator	PMG	
	Energy-exporting countries	Energy importing countries
Error correction term (ECT)	-0.128* (0.088)	-0.029*** (0.011)
Long run coefficients		
Renewable energy consumption	0.044 (0.23)	0.599* (0.354)
Non-renewable energy consumption	1.894*** (0.406)	-0.067 (0.75)
FDI share in GDP	-0.151 (0.166)	-0.487 (0.345)
Domestic Investments share in GDP	0.372*** (0.138)	0.296 (0.432)
Short run coefficients		
(Renewable energy consumption)	0.084* (0.045)	0.040*** (0.015)
(Non-renewable energy consumption)	0.119 (0.142)	0.158** (0.067)
(FDI share in GDP)	0.024* (0.012)	0.008 (0.006)
(Domestic Investments share in GDP)	0.081* (0.045)	0.064** (0.027)
Constant	-0.163 (0.168)	0.215** (0.084)
Observations	67	143
Countries	4	8
Log likelihood	130.22	314.07

Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

For the third and final robustness check, we replace the renewable and non-renewable energy consumption per capita with the new variable, namely share of renewable energy consumption in total final energy consumption. The relationship between the share of renewable energy consumption and economic growth has been a recurrent subject of research in the recent years. The error correction term of the ARDL model, according to Table 12 is negative and significant at 1% significance level. Estimation of the model reveals the significantly positive relationship between the share of REC in the TFEC and GDP per capita in the long-run and negative relationship in the short-run. 1% increase in energy consumption from renewable sources as a share in total final energy consumption, results in 0.4% increase in GDP per capita in the long run. On the contrary, same growth in the short run causes small, but still negative change in GDP per capita, however the coefficient does not seem to be statistically significant. The long-run relationship between the share of renewables in the energy mix and GDP corresponds with IRENA (2016), predicting that doubling the share of renewable energy consumption on TFEC will result in 1.1% growth in global GDP by 2030, improving the well-being of people and creating new job opportunities. However, major energy exporting countries of EaP and CIS heavily depend on energy related export revenues, which will be diminished if RE consumption in energy importing as well as energy exporting countries themselves starts substitution consumption of fossil fuels, until they find a way to adjust to new reality and start diversification. This process might be outline by the negative short-term elasticity of REC as a share of TFEC.

The impact of Foreign Direct Investments on economic growth continues to be robustly negative in long run and positive in the short run. Yet again, the increase in share of gross capital formation (DI) in GDP, exerts a robust, significantly positive influence on economic growth both in the long-run and short-run period.

Table 12: GDP per capita and share of REC in Total Final Energy consumption

Dependent variable	Log (GDP per capita)
Estimator	PMG
Error correction term (ECT)	-0.041*** (0.015)
Long run coefficients	
Renewable energy consumption / Total final energy consumption	0.421*** (0.121)
FDI share in GDP	-0.147 (0.099)
Domestic Investments share in GDP	0.597*** (0.194)
Short run coefficients	
(Renewable energy consumption / Total final energy consumption)	-0.002 (0.018)
(FDI share in GDP)	0.004 (0.005)
(Domestic Investments share in GDP)	0.089** (0.040)
Constant	0.240*** (0.077)
Observations	209
Countries	12
Log likelihood	436.01

Standard errors are in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0$

8. Conclusions and Policy Recommendations

The purpose of this study is to explore the relative performance of renewable and non-renewable energy consumption on economic growth in 12 Eastern Partner and CIS countries within the period of 1996-2015. For mitigating omitted variable bias we also included foreign direct investment (FDI) as a main source of financing energy generation and transportation within countries and gross capital formation. Study utilized Annual data, extracted from World Bank development indicator and Sustainable Energy for All database. We conducted Pedroni (1999), Kao (1999), and Westerlund (2005) tests to confirm the long-run cointegrating relationship between variables and implemented panel ARDL model for obtaining short-run and long-run elasticities of REC and NREC. To account for major structural differences between countries, for robustness analysis we divided our sample into sub-panels with and without Russian Federation and sub-panels for net energy-exporting and importing countries. Finally, we substituted both energy variables with REC as a share of TFEC to examine whether the relative change in renewable energy consumption share accounts for positive change in economic growth.

The results from Autoregressive Distributed Lag (ARDL) model indicate that both renewable energy consumption and non-renewable energy consumption exert a positive impact on economic growth either in long-run or short-run period, however only REC is significant. Additionally, the impact of renewable energy consumption exceeds the impact of non-renewable energy consumption in long-run, however, is smaller in the short-run, due to high concentration of non-renewable energy consumption in in every sector of economy. FDI seems to have engendered a negative change in economic growth, which according to Alfaro (2003) is common for countries in which the highest share of FDI is directed to primary sector including mining and extracting. Gross capital formation has a positive impact on GDP per capita and exceeding the impact of FDI in the short term.

The outcomes of robustness analysis are corresponding with main empirical results. Despite the increase of overall significance of long run estimators after excluding Russia, speed of adjustment to the economic shocks in larger for whole panel. Non-renewable energy consumption seems to be significant factor for economic growth only in energy exporting countries, while renewable energy consumption has significant impact only in energy importing economies. As a final result, increasing the share of renewable energy consumption has a highly significant and positive impact on economic growth in the long-run, while it exerts a negative impact in the short-run, given the huge reliance on fossil fuel energy sources in all 12 countries of EaP and CIS.

The optimistic outlook on renewable energy sources derived from the outcome of our model, endorses the notion of viability of RES as an alternative energy source, which can reconcile the issues of climate change without compromising the sustainable economic growth. However, significantly long-term effect and the negative short-term effect of increasing the share of renewables in energy mix suggests that the substitution of non-renewable energy sources with renewable energy sources is imperative for guaranteeing energy security and sustainable economic growth, however, this transition in the region needs to happen gradually, with carefully considered economic policies and relevant incentive mechanisms for development and advanced market accessibility of RE. The incentives should include tax credits and benefits as well as RE production and consumption subsidies to reciprocate the fossil fuel subsidies, which is considered the biggest challenge on the way of RES deployment.

Substantial importance should be given to the establishment of regional energy markets and institutions, supporting the consistent trade beneficial for all the involved parties as well as formation of harmonized policies and regulations for enhanced cooperation to promote the expansion of RES. Additionally, as the demand for energy grows extensively in all the countries of EaP and CIS, transformation of energy markets from non-renewable to renewable energy sources will require the proportionate investment in energy infrastructure and innovative technologies towards the direction of renewable energy. This will help reap the potential benefits from RES, diversify and democratize energy sector and mitigate the dominating position of fossil fuels due to high share of FDI in extractive activities and its negative impact on long-term economic growth within the region.

Scarcity of the research conducted on the region of EaP and CIS countries concerning the topic of energy and economic growth, including the significance of not only fossil fuels but also renewable energy sources and their consumption generates a gap that needs to be exploited and utilized. In the future studies multiple directions could be taken to assure more country- or sector-specific results which will give way to perceptibly accurate policy recommendations. More comprehensive analysis can be upheld by considering the impact of renewable and non-renewable energy consumption for individual cross-section using time series data while further disaggregating the renewable energy sources. Studies might also consider disaggregating not only consumption, but also GDP per capita according to various economic sectors to see the scope of impact of energy consumption on each one of the them separately. The limitation of our study, which could emphasize on additional gap in literature, is the lack of uniform data on FDI in energy sector in each EaP and CIS countries. It would be insightful to investigate the impact of FDI in energy and power sector on either energy consumption or economic growth. The outlined topic within the EaP and CIS region offers a promising opportunity for further, detailed research.

Future research opportunities should be supported by increasing availability and accessibility of regional as well as micro level data on energy related topics. A great example of successful initiatives is the Central Asia

Data Gathering and Analysis Team (CADGAT) established in 2009, supporting the creation of open access cross-regional data to be used freely by researchers, journalists, and policymakers.

References

Alfaro, L. (2003). Foreign Direct Investment and Growth: Does the Sector Matter? *Harvard Business School*.

Apergis, N., & Payne, J. (2010). Renewable energy consumption and growth in Eurasia. *Energy Economics 32*, 1392–1397.

Aristovnik, A. (2006). Current account deficit sustainability in selected transition economies. *Zbornik Radova Ekonomskog Fakulteta u Rijeci / Proceedings of Rijeka School of Economics* .

Azizov, A. (2007). *Determinants of FDI in CIS countries with Transition economies.* Aarhus, Denmark.

Benešováa, I., & Smutka, L. (2016). The post-soviet countries – development and structure of economy: Is there any potential for future regional integration? *19th International Conference Enterprise and Competitive Environment 2016, ECE* (pp. 10–11). 2016: Procedia - Social and Behavioral Sciences 220 (2016) 30 – 39.

Blackburne , E., & Frank, M. (2007). Estimation of nonstationary heterogeneous Panels. *The Stata Journal (2007) 7, Number 2*, 197-208.

Brizga, J., Feng, K., & Hubacek, K. (2013). Drivers of CO2emissions in the former Soviet Union: A country levelIPAT analysis from 1990 to 2010. *Energy 59*, 743-753.

BURKE, P. J. (2013). The national-level energy ladder and its carbon implications Author(s). *Environment and Development Economics , Vol. 18, No. 4, SPECIAL SECTION ON BIODIVERSITY-BASED DEVELOPMENT IN SMALL ISLAND DEVELOPING STATES* , 484-503.

CASE (Centre for Social and Economic Research). (2008). The economic aspects of the energy sector in CIS countries. *Economic Papers 327*.

Choi, I. (2001). Unit root tests for panel data. *Journal of International Money and Finance 20 (2001)* , 249–272.

Csereklyei, Z., & Rubio-Varas, M. (2016). Energy and Economic Growth: The Stylized Facts. *The Energy Journal, Vol. 37, No. 2. Copyright by the IAEE* .

D. Gilfillan, G. M. (2020.). *Carbon Dioxide Information Analysis Center at Appalachian State University, Boone North Carolina, Global, Regional, and National Fossil-Fuel CO2 Emissions.* . Retrieved from https://energy appstate/CDIAC: https://energy appstate/CDIAC

Destek, M., & Aslan, A. (2017). Renewable and non-renewable energy consumption and economic growth in emerging economies: Evidence from bootstrap panel causality. *Renewable Energy 111* , 757-763.

EBRD. (2008). *Securing sustainable energy in transition economies.* London, UK: European Bank for Reconstraction and Development .

Engle, R. F., & Granger, C. W. (1987). CO-INTEGRATION AND ERROR CORRECTION: REPRESENTATION, ESTIMATION, AND TESTING. *Econometrica, Vol. 55, No. 2 (March, 1987),*, 251-276.

Hamilton, R. E. (2017). *The Post Soviet Wars: Part I.* The Foreign Policy Research Institute.

Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica 46*, 1251–1271.

Havlik, P. (2014). Economic Consequences of the Ukraine Conflict. *Policy Notes and Reports, No. 14, The Vienna Institute for International Economic Studies*.

Hlouskova and Wagner. (2005). The Performace of Panel Unit Root and Stationarity Testing: Results from a Large Scale Simulation Study. *European University Institute: Department of Economics*.

Hwang et al. (2020). Evaluating the Causal Relations between the Kaya Identity Index and ODIAC-Based Fossil Fuel CO2 Flux. *Energies, 13, 6009*.

IAEA. (2020a). *Country Nuclear Power Profiles: Ukraine*. Retrieved from https://cnpp.iaea.org: https://cnpp.iaea.org/countryprofiles/Ukraine/Ukraine.htm

IAEA. (2020b). *IAEA Country Nuclear Power Profiles: Armenia*. Retrieved from https://cnpp.iaea.org: https://cnpp.iaea.org/countryprofiles/Armenia/Armeni

IHA. (2016a). *iha country profiles: Georgia*. Retrieved from https://www.hydropower.org: https://www.hydropower.org/country-profiles/georgia

IHA. (2020b). *iha country profile: Tajikistan*. Retrieved from www.hydropower.or: https://www.hydropower.org/country-profiles/tajikistan

IHA. (2020c). *iha country profile: Kyrgyzstan*. Retrieved from www.hydropower.org: https://www.hydropower.org/country-profiles/kyrgyzstan

Im, Pesaran, Shin. (2003). Testingfor unit roots in heterogeneous panels. *Journal of Econometrics 115 (2003)* , 53 – 74.

Iradian, G. (2007). *Rapid Growth in the CIS: Is It Sustainable?* wiiw Research Reports | 336.

IRENA. (2015). *REMAP 2030: RENEWABLE ENERGY PROSPECTS FOR UKRAINE.* IRENA.

IRENA. (2016). *Renewable Energy Benefits: Measuring the Economics.* Abu Dhabi: IRENA.

IRENA. (2019). *A New World: The Geopolitics of the Energy Transformation.* International Renewable Energy Agency.

Jenish, N. (2013). Regional Trade and Economic Growth in CIS Region. *University of Central Asia: INSTITUTE OF PUBLIC POLICY AND ADMINISTRATION: WORKING PAPER NO.13*.

Judson, R., Schmalensee, R., & Stoker, T. (1999). Economic Development and the Structure of Demand for Commercial Energy. *The Energy Journal 20(2):*, 29–57.

Kaliakparova. (2020). International Economic Cooperation of Central Asian Countries on Energy Efficiency and Use of Renewable Energy Sources . *International Journal of Energy Economics and Policy, 10(5),* , 539-545.

Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data. *Journal of Econometrics 90* , 1-44.

Kasimov et al. (2020). Foreign Direct Investment, Natural Resources, Economic Freedom, and Sea-Access: Evidence from the Commonwealth of Independent States. *Sustainability: Multidisciplinary Digital Publishing Institute*.

Koçaka, E., & Şarkgüneşib, A. (2017). The renewable energy and economic growth nexus in Black Sea and Balkan Countries. *Energy Policy 100* , 51–57.

Komarov, V. (2002). INVESTMENTS IN THE CIS. *Society and Economy 24, 3*, 363-379.

Lysenko, T., & Vinhas de Souza, L. (2007). *European Neighbourhood Policy: Economic Review of EU Neighbour Countries.* Directorate-General for Economic and Financial Affairs of European Comission.

Martins et al. (2019). Analysis of Fossil Fuel Energy Consumption and Environmental Impacts in European Countries. *Energies, 12, 964* .

Mencinger, J. (2003). Does Foreign Direct Investment Always Enhance Economic Growth? *KYKLOS, Vol. 56 – Fasc. 4,*, 491–508.

Menegak, A. N. (2019). The ARDL Method in the Energy-Growth Nexus Field; Best Implementation Strategies. *Economies , 7, 105;* .

Menegaki, A. N. (1999). The ARDL Method in the Energy-Growth Nexus Field: Best Implementation Strategies . *Economies: MDPI*.

Obozov & Loscutoff. (1998). Opportunities for Renewable Energy Sources in Central Asian Countries. *National Renewable Energy Laboratory -210-25047*.

Odling-Smee, J. (2003). Economic Performance and Trade in the CIS. *10th Anniversary of the National Currency of the Kyrgyz Republic.* Bishkek .

Ozturk et al. (2012). Renewable and non-renewable energy consumption and economic growth relationship revisited: Evidence from G7 countries. *Energy Economics 34* , 1942–1950.

Pedroni, P. (1999). CRITICALVALUES FOR COINTEGRATION TESTS IN HETEROGENEOUS PANELS WITH MULTIPLE REGRESSORS . *OXFORD BULLETIN OF ECONOMICS AND STATISTICS, SPECIAL ISSUE (1999) 0305-9049*.

Pesaran , H., Shin, Y., & Smith, R. (1997). Pooled Estimation of Long-run Relationships in Dynamic Heterogeneous Panels.

Pesaran, M. H. (2007). A SIMPLE PANEL UNIT ROOT TEST IN THE PRESENCE OF CROSS SECTION DEPENDENCE. *JOURNAL OF APPLIED ECONOMETRICS J. Appl. Econ. 22:*, 265–312.

Pesaran, M., & Shin., Y. (1995). An Autoregressive Distributed Lag Modelling Approach to Cointegration Analysis. *n Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium. Edited by Steinar Strøm. Cambridge: Cambridge University Press*.

Pesaran, M., & Smith, R. (1995). Estimating Long-Run Relation- ships From Dynamic Heterogeneous Panels. *Journal of Econometrics, 68,*, 79-113.

Pesaran, M., Shin, Y., & Smith, R. (1999). Pooled Mean Group Estimation of Dynamic Heterogeneous Panels. *Journal of the American Statistical Association , Jun., 1999, Vol. 94, No. 446*, 621-634.

Pirani, S. (2011). Elusive Potential: Natural Gas COnsumption in the CIS and Quest for Efficiency. *The Oxford Inwstitute for Energy Studies* .

Rahman, M., & Velayutham, E. (2020). Renewable and non-renewable energy consumption-economic growth nexus: New evidence from South Asia. *Renewable Energy 147* , 399-408.

Schierhorn et al. (2019). Large greenhouse gas savings due to changes in the post-Soviet food systems. *Environmental Research Letters 14 065009*.

Shapiro, D., Hobdari, B., & Oh, C. (2018). Natural resources, multinational enterprises and sustainable development. *Journal of World Business 53* , 1–14.

Shiells, C. R. (2003). FDI and the Investment Climate in the CIS countries. *IMF Policy Discussion Paper 03/5: European II Department*.

Shukurov, S. (2016). Determinants of FDI in Transition Economies: The Case of CIS Countries. *Journal of International and Global Economic Studies, , 9(1),* , 75-94.

Stern . (2011). The role of energy in economic growth. *"Ecological Economics Reviews." Robert Costanza, Karin Limburg & Ida Kubiszewski, Eds. Ann. N.Y. Acad. Sci. 1219:*, 26–51.

Stern. (1997). Limits to substitution and irreversibility in production and consumption: A neoclassical interpretation of ecological economics. *Ecological Economics 21*, 197-215.

Stern. (2004). Economic Growth and Energy. *Encyclopedia of Energy, Volume 2. Elsevier Inc.*

Stern. (2020). Energy and economic growth. In U. S. Sarı, *Routledge Handbook of Energy Economics* (pp. 28-47). Oxford: Routledge.

U.S. Energy Information Agency. (2017, October 31). *U.S. Energy Information Agency.* Retrieved from www.eia.gov: https://www.eia.gov/international/analysis/country/RUS

UN. (2021). *World Economic Situation and Prospects 2021: CHAPTER III REGIONAL DEVELOPMENTS AND OUTLOOK.* UNDP.

UNDP. (2014). *Sustainable Energy and Human Development in Europe and the CIS.* New York, NY: United Nations Development Programme.

UNECE. (2019). Progress in the Areas of Energy Efficiency and Renewable Energy in Selecting Countries of the UNECE region. *ECE ENERGY SERIES No.59*.

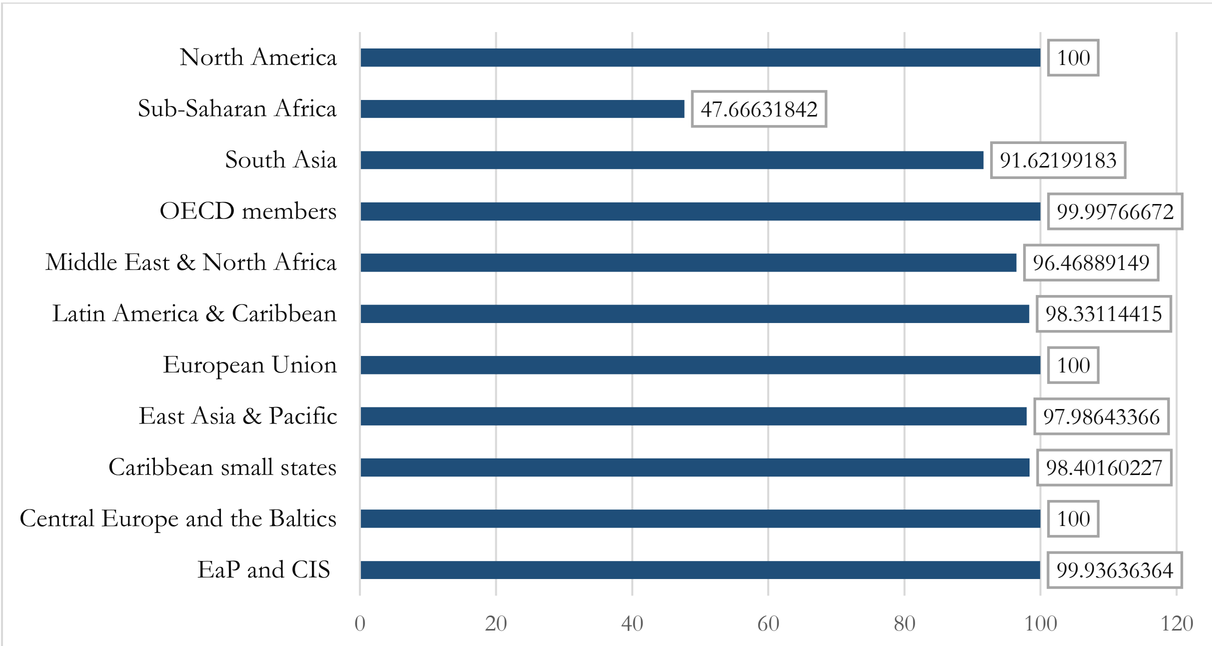
UN-Habitat, UNECE. (2016). CIS Cities: Towards Sustainable Future The Commonwealth of Independent StatesRegional Report. *For the United Nations Conference on Housing and Sustainable Urban Development, Habitat III.* United Nations Human Settlements Programme (UN-Habitat) & United Nations Economic Commission for Europe.

Westerlund, J. (2005). New Simple Tests for Panel Cointegration. *Econometric Reviews, 24:3,* , 297-316.

Wooldridge, J. M. (2016). *Introductory Econometrics: A Modern Approach.* Boston, MA 02210: 2016, 2013 Cengage Learning.

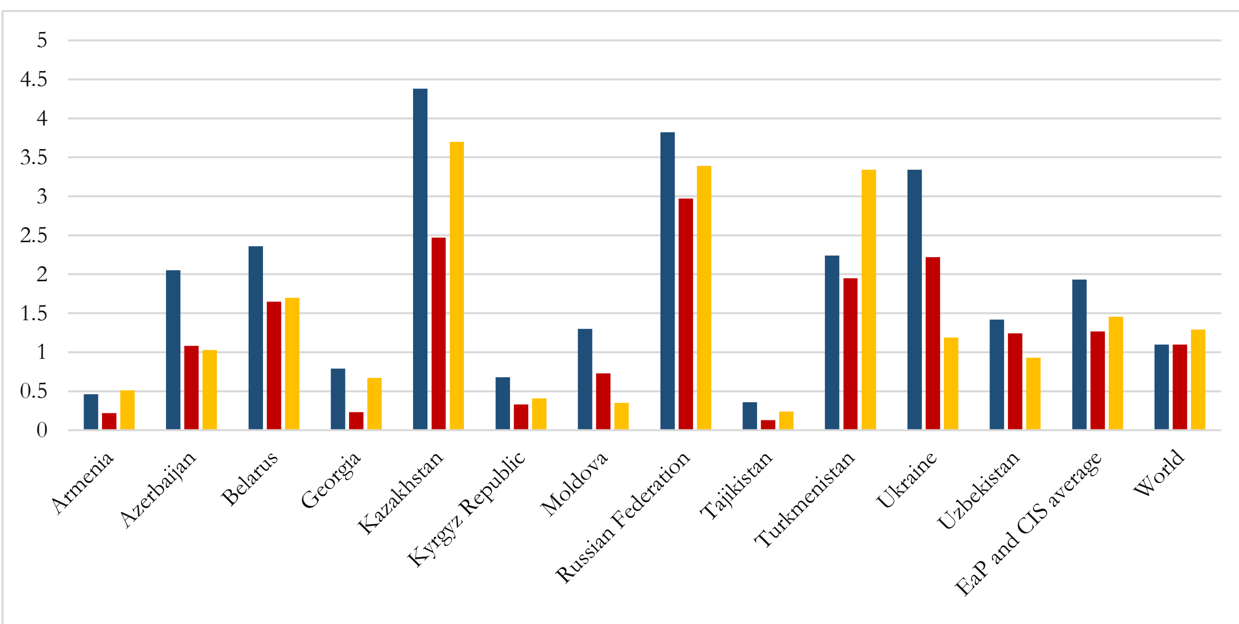
Appendices:

Appendix 1: Access to electricity (% of population) (2018)



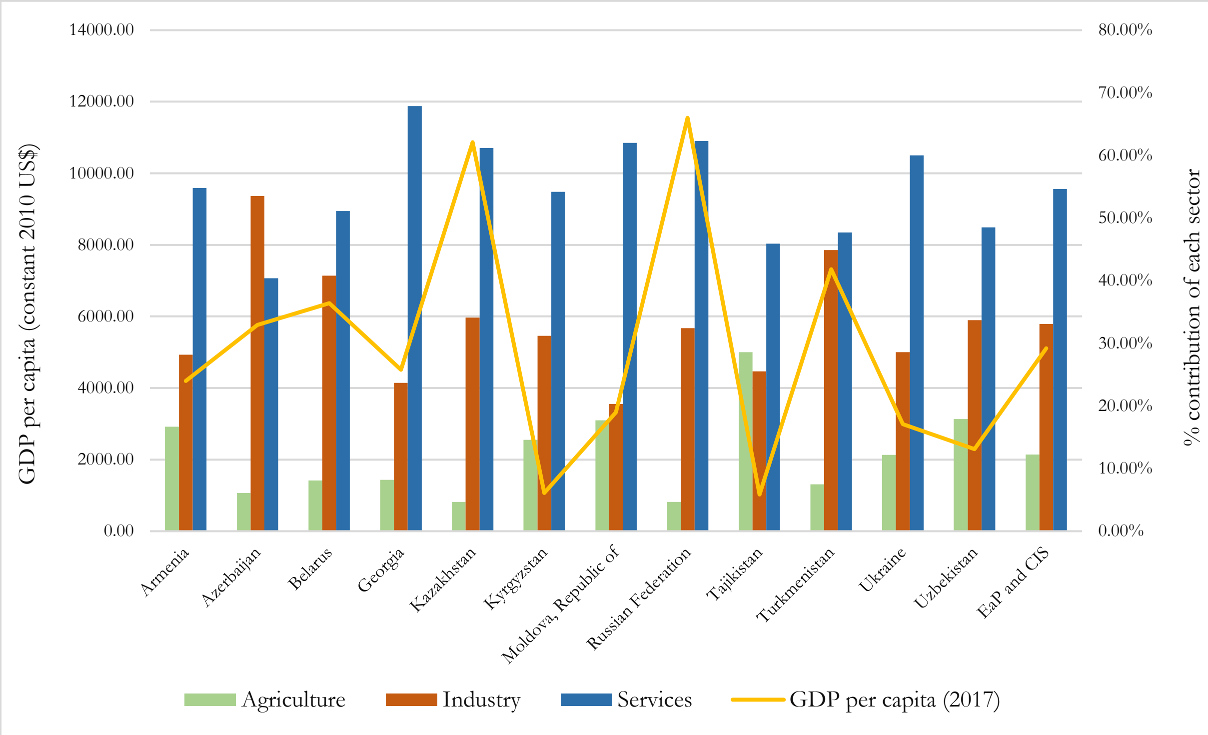
Source: Electrification data are collected from industry, national surveys and international sources. World Bank, Sustainable Energy for All (SE4ALL) database.

Appendix 2: Shifts in per capita CO2 emissions (metric tons of carbon) in EaP and CIS



Source: https://energy appstate/CDIAC

Appendix 3: GDP composition by sector (2017)



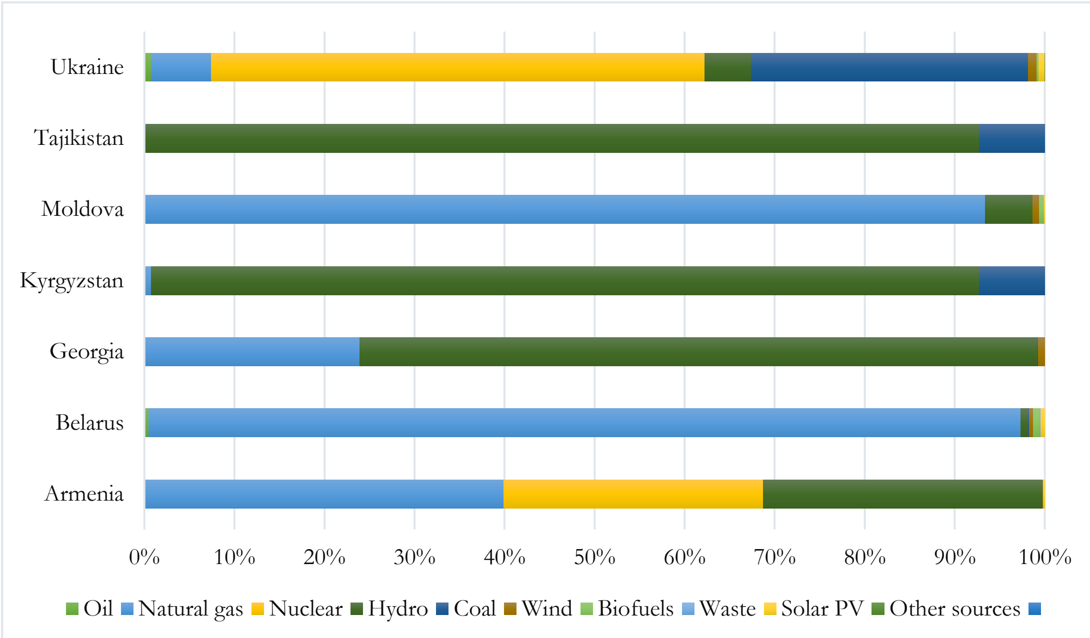
Source: GDP – composition, by sector of origin: CIA.gov

Appendix 4: Shifts in the GDP composition between 2010-2019

	GDP per capita		Agriculture		Industry		Manufacturing		Services	
	$ billions		% of GDP		% of GDP		% of GDP		% of GDP	
	2010	2019	2010	2019	2010	2019	2010	2019	2010	2019
Armenia	3218.37	4732.07	18	12 ↓	28	24 ↓	9	12 ↑	45.7	54.2 ↑
Azerbaijan	5842.81	5879.99	6	6	60	49 ↓	5	5	28.2	37.4 ↑
Belarus	6029.40	6678.51	9	7 ↓	35	31 ↓	23	21 ↓	43.5	48.8 ↑
Georgia	3233.30	4978.50	8	7 ↓	17	20 ↑	9	9 ↓	63.1	60.8 ↓
Kazakhstan	9070.49	11518.36	5	4 ↓	41	33 ↓	11	11	51.7	55.5 ↑
Kyrgyz Republic	880.04	1116.36	17	12 ↓	26	28 ↑	17	14 ↓	49.3	50.2 ↑
Moldova	2437.53	3720.23	11	10 ↓	20	23 ↑	10	11 ↑	54.5	54.1 ↓
Russian Federation	10675.00	12011.53	3	3	30	32 ↑	13	13	53.1	54 ↑
Tajikistan	749.55	1121.13	20	19 ↓	25	27 ↑	10	11 ↑	45.1	42.1 ↓
Turkmenistan	4439.20	7647.94	11	..	59	..	..	..	28.1	..
Ukraine	2965.14	3224.94	7	9 ↑	26	23 ↓	13	11 ↓	55.1	54.4 ↓
Uzbekistan	1634.31	2458.99	29	26 ↓	23	33 ↑	11	20 ↑	35.9	32.2 ↓

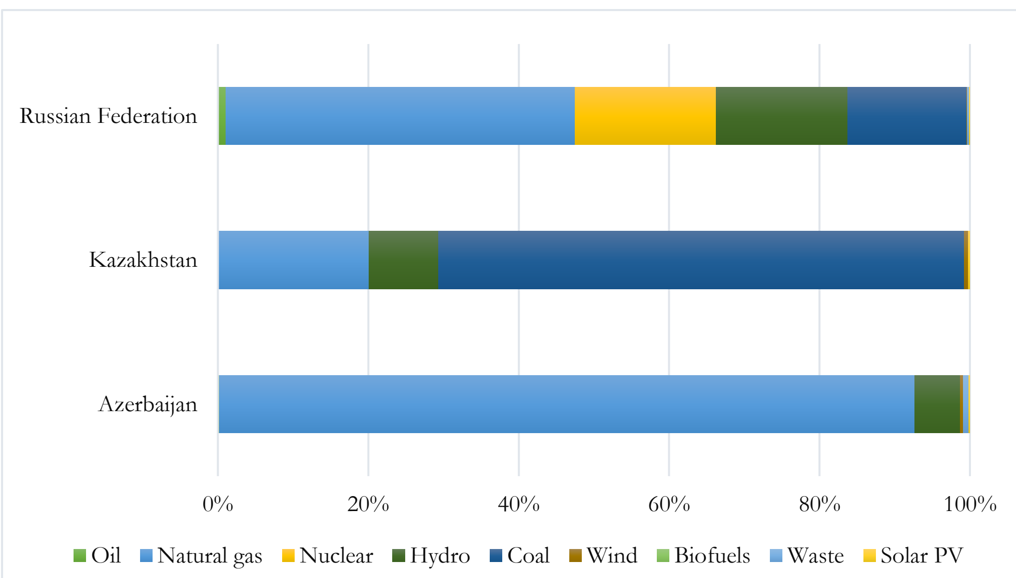
Source: World Bank national accounts data, and OECD National Accounts data files.

Appendix 5: Electricity Generation by Source in Energy Importing Countries in 2019



Source: International Energy Agency (iea) Country Datasets

Appendix 6: Electricity Generation by Source in Energy Exporting Countries in 2019



Source: International Energy Agency (iea) Country Datasets

Appendix 7: Descriptive statistics for EaP and CIS panel (Without Russian Federation)

Variable		Mean	Std. dev.	Min	Max	Observations
GDP per capita	overall	2867.8	2188.2	366.9	10646.0	N = 220
(GDPpc)	between		1882.2	618.5	7244.9	n = 11
	within		1246.2	-562.60	6268.9	T = 20
Share of RE consumption	overall	14.3	19.1	0.002	64.6	N = 220
In total final EC	between		19.6	0.1	58.6	n = 11
	within		3.6	0.4	29.4	T = 20
Renewable energy	overall	3.2	3.2	0.002	13.0	N = 220
Consumption per	between		3.2	0.1	10.8	n = 11
Capita (RECpc)	within		0.8	0.5	5.9	T = 20
Non-renewable energy	overall	43.9	32.4	4.1	136.5	N = 220
Consumption per	between		32.6	4.9	107.6	n = 11
Capita (NRECpc)	within		9.0	14.2	72.8	T = 20
FDI share of GDP	overall	6.3	7.0	-0.4	55.1	N = 220
(FDI/GDP)	between		4.5	1.4	18.1	n = 11
	within		5.5	-9.4	43.2	T = 20
Domestic Investments	overall	26.5	8.2	9.1	57.9	N = 217
Share of GDP (DI/GDP)	between		4.4	19.5	35.7	n = 12
	within		7.2	9.4	55.3	T = 19.73

Appendix 8: Descriptive statistics for Russian Federation

Variable	Observation	Mean	Std. dev.	Min	Max
GDP per capita	20	8904.6	2307.9	5505.7	11731.4
Renewable energy consumption per capita (RECpc)	20	3.8	0.1	3.6	4.1
Non-renewable energy consumption per capita (NRECpc)	20	105.3	3.2	98.8	111.1
REC share of TFEC	20	3.5	0.2	3.2	3.8
FDI share of GDP	20	2.1	1.2	0.5	4.5
DI share of GDP	20	21.3	2.9	14.8	25.5

Appendix 9: Descriptive statistics for energy exporting and energy importing countries

Variable	Observation	Mean	Std. dev.	Min	Max
Energy Exporting Countries: (Azerbaijan, Russian Federation, Kazakhstan, Turkmenistan, Uzbekistan)					
GDP per capita	100	4955.8	3310.8	874.4	11731.4
Renewable energy consumption per capita (RECpc)	100	1.4	1.3	0.001	4.1
Non-renewable energy consumption per capita (NRECpc)	100	75.6	32.7	28.0	136.5
REC share of TFEC	100	1.9	1.3	0.002	4.5
FDI share of GDP	100	7.4	9.5	0.5	55.1
DI share of GDP	100	26.9	9.0	14.8	57.99
Energy Importing Countries (Armenia, Belarus, Georgia, Kyrgyz Republic, Moldova, Tajikistan, Ukraine)					
Variable	Observation	Mean	Std. dev.	Min	Max
GDP per capita	140	2238.8	1474.5	366.9	6649.65
Renewable energy consumption per capita (RECpc)	140	4.7	3.2	0.6	13.01
Non-renewable energy consumption per capita (NRECpc)	140	30.1	22.9	4.1	72.5
REC share of TFEC	140	21.5	20.7	0.9	64.6
FDI share of GDP	140	4.8	3.6	-0.4	18.6
DI share of GDP	140	25.5	7.3	9.1	47.94

Appendix 10: Results for cross-sectional lag selection for panel ARDL

	Optimal lag structure	GDP per capita	REC per capita	NREC per capita	FDI/GDP	DI/GDP	Log likelihood
Armenia	ARDL (2, 1, 2, 2, 0)	2	3	2	2	0	49.610
Azerbaijan	ARDL (1, 2, 0, 2, 2)	1	2	0	2	2	44.509
Belarus	ARDL (1, 0, 1, 2, 0)	1	0	1	2	0	54.393
Georgia	ARDL (2, 2, 2, 2, 2)	2	2	2	2	2	69.909
Kazakhstan	ARDL (1, 2, 0, 1, 0)	1	2	0	1	0	47.308
Kyrgyz Republic	ARDL (2, 1, 2, 2, 2)	2	1	2	2	2	112.803
Moldova	ARDL (1, 0, 2, 2, 0)	1	0	2	2	0	49.230
Russia	ARDL (2, 2, 1, 1, 2)	2	2	1	1	2	67.493
Tajikistan	ARDL (2, 0, 0, 2, 0)	2	0	0	2	0	58.284
Turkmenistan	ARDL (2, 2, 1, 2, 2)	2	2	1	2	2	79.060
Ukraine	ARDL (2, 2, 2, 2, 1)	2	2	2	2	1	64.757
Uzbekistan	ARDL (2, 1, 2, 1, 2)	2	1	2	1	2	77.977
Panel	ARDL (2, 2, 2, 2, 2)	2	2	2	2	2	448.89