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THE ROLE OF FDI IN THE GREEN TRANSITION OF CENTRAL AND EASTERN EUROPE COUNTRIES: FROM EMPIRICAL EVIDENCE

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Abstract

This paper empirically examines the role of FDI in the green transition for CEE countries from the perspectives of greenhouse gas emissions and renewable energy production. For the analysis of the two perspectives, the PMG and MG estimators based on nonlinear EKC and the fixed effect model were applied to the sample of CEE countries from 2001 to 2021. The results demonstrate that FDI has an inverted U-shaped relationship with greenhouse gas emissions, indicating that FDI accelerates the transition to a greener economy by reducing emissions after the turning point. However, the effect is only significant in the long term, and the turning point threshold varies by income group. On the other hand, there was no evidence of a correlation between FDI and the growth of renewable energy production, but energy intensity would substantially reduce the growth of renewable energy production. To maximise FDI's positive impact on their green transition, empirical evidence suggests CEE nations should implement policies to encourage FDI inflow and direct more investment towards renewable production and sustainable development.

Keywords

Přímé zahraniční investice; zelený přechod; země střední a východní Evropy; EKC.

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Declaration of Authorship

1. The author hereby declares that he compiled this thesis independently, using only the listed resources and literature.

2. The author hereby declares that all the sources and literature used have been properly cited.

3. The author hereby declares that the thesis has not been used to obtain a different or the same degree.

Prague   Date: Aug 1st 2023   Shiyuan Huang   signature:

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Abstract

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Key words: FDI; Green transition; CEE countries; EKC

Abstrakt

Tento článek empiricky zkoumá roli přímých zahraničních investic v ekologickém přechodu v zemích střední a východní Evropy z hlediska emisí skleníkových plynů a výroby energie z obnovitelných zdrojů. Pro analýzu těchto dvou hledisek byly na vzorku zemí střední a východní Evropy v letech 2001-2021 použity odhady PMG a MG založené na nelineárním EKC a modelu fixního efektu. Výsledky ukazují, že přímé zahraniční investice mají s emisemi skleníkových plynů vztah ve tvaru obráceného U, což naznačuje, že přímé zahraniční investice urychlují přechod k ekologičtější ekonomice tím, že po bodu zvratu snižují emise. Tento účinek je však významný pouze v dlouhodobém horizontu a prahová hodnota bodu zvratu se liší podle příjmové skupiny. Na druhou stranu nebyla prokázána žádná závislost mezi přímými zahraničními investicemi a růstem výroby energie z obnovitelných zdrojů, ale energetická náročnost by růst výroby energie z obnovitelných zdrojů podstatně snížila. Aby země střední a východní Evropy maximalizovaly pozitivní dopad přímých zahraničních investic na svůj ekologický přechod, měly by podle empirických důkazů provádět politiky na podporu přílivu přímých zahraničních investic a směřovat více investic do výroby energie z obnovitelných zdrojů a udržitelného rozvoje.

Klíčová slova: Přímé zahraniční investice; zelený přechod; země střední a východní Evropy; EKC.

Chapter 1. Introduction

Environmental concerns and the transition towards sustainability have emerged as significant global issues due to the rapid development of human society over the past century, which has led to extensive environmental degradation. The escalating emissions of greenhouse gas and the contamination of soil and water pose a significant risk to human health and the long-term sustainability of mankind. In response to this challenge, countries have collectively adopted various strategies aimed at fostering sustainability and working towards achieving the objective of net-zero emissions (Terzi, 2020). The relationship between economic development and the environment has become complex. Extensive research has been conducted on the Environmental Kuznets Curve (EKC), which suggests that environmental quality improves after a certain threshold of economic growth. And this theory has been widely examined and substantiated across a diverse range of countries (Tenaw and Beyene, 2021; Dogan and Ingles-Lotz, 2020). Foreign direct investment (FDI), a significant economic activity that plays a crucial role in promoting economic development and flourishing in the era of globalisation, has also been observed to have an impact on the environment.

FDI contributes to economic growth and the subsequent technology spillover that increases productivity efficiency. It also enhances local innovation and creates a competitive market environment. Some researchers have discovered that FDI contributes to the reduction of greenhouse gas emissions because it increases energy efficiency, and multinational corporations from developed regions generally adhere to stringent environmental standards. However, in many instances, FDI has been found to have a negative impact on the environmental quality of host nations (Khuda et al., 2017). The pollution haven effect results from the host country's lax environmental regulations, the pollution transfer activities of the investors, and the host country's energy structure and industry structure (Baek, 2016). Particularly, countries that receive substantial FDI in heavy industry or fossil fuel production have the greatest environmental degradation.

The region of Central and Eastern Europe (CEE) has undergone a transition from communism to a liberal economy, accompanied by a shift in both social and economic order. During the period of transition, CEE nations attracted a substantial quantity of FDI, which stimulated their economic growth and industrial upgrading (Prochniak, 2011). In the first decade of the 21st century, the CEE's GDP development rate was even higher than that of Western European nations. Meanwhile, as a region with diverse economies and varying environmental regulations, the energy structure and environmental degradation of these nations vary greatly. However, they both face the challenge of the green transition, which aims to develop sustainability by reducing emissions and shifting to the renewable energy sector, as the majority of CEE countries have joined the Kyoto Protocol and have binding targets, as well as facing the EU's agenda to be climate-neutral by 2050. However, the CEE region has achieved limited success in reducing emissions, and their emissions per capita are generally higher than in Western Europe.

The empirical results regarding the economic development and environment of CEE countries have generally validated the EKC hypothesis in the CEE region, indicating that their economic growth will generally result in an enhancement of the environment after a certain threshold (Simionescu et al., 2021; Chen et al., 2019). However, empirical evidence regarding the impact of FDI, an essential element of the economies of Central and Eastern Europe, is rare and yields a mixed result. Others find no correlation between the two variables. Moreover, recent research has demonstrated the existence of a relationship between FDI and EKC in certain CEE nations (Christoforidis and Katrakilidis, 2021).

The purpose of this paper is to highlight the role of FDI in the green transition for CEE countries using two empirical models. The objective of the first model is to examine the relationship between FDI and greenhouse gas emissions based on the EKC. The PMG and MG estimators will be used to estimate both the short- and long-term effects. To ensure the result is unbiased, the unit root test, the cointegration test, and the cross-sectional dependence test will be performed. The second model examines the relationship between FDI and renewable energy production using a country fixed effects model. In the meantime, the impact of population, energy intensity, renewable energy consumption, and urbanisation are studied as control variables. This paper's data covers the period from 2001 to 2021 and incorporates 18 CEE nations.

The major contribution of this paper includes: 1. Provide empirical evidence for FDI's impact on the transition to a green economy from two specific perspectives using an innovative model. The empirical analysis included the most up-to-date data for a broad spectrum of CEE countries, thereby enriching the literature on a topic that is rarely investigated and is typically limited to a single country or a small group. 2. Summarise the prior literature on FDI and the environment, and provide insight into the development of FDI and the green transition process for transition economies. 3. Provide CEE nations with policy recommendations to maximise the potential positive impact of FDI on their green transition.

And this paper's structure is as follows: The second section would consist of a literature review on FDI, the environment, and economic growth. The third and fourth sections discuss the green transition and FDI development in the context of CEE, respectively. The fifth section consists of the empirical model specification for EKC and a preliminary analysis of the variables. The following will be an empirical analysis and critical summary of the two models regarding the impact of FDI on the green transition. The final section would consist of policy recommendations and a conclusion.

Chapter 2. Literature Review

Concept of FDI and its impacts

FDI definition and development

Foreign direct investment, also known as FDI, is a type of foreign investment in which an investor from one country acquires a long-term stake in a company based in a different economy (Eurostat, 2021). And the concept of "long-term interest" denotes the existence of a long-term relationship between the direct investor and the direct investment business, as well as a high degree of management control over the latter (Duce and Espaa, 2003). The acquisition of shares or assets in a foreign company or the establishment of a wholly owned subsidiary in a foreign country are typical instances of this action and it is typically associated with multinational corporations that expand their business operations beyond their domestic market in order to tap into foreign markets (Marinova, Marinov, and Yaprak, 2004; Barretto and da Rocha, 2001). According to UNCTAD (2000), mergers and acquisitions activity is a significant driver of FDI flows, with cross-border M&A transactions accounting for approximately two-thirds of total FDI flows over the past few years. While the establishment of overseas subsidiaries is gaining popularity, greenfield investments that offer advantages such as improved operational control, the ability to tailor operations to local market conditions, and the possibility of long-term profitability are gaining traction.

The quantity of global FDI has increased significantly over the past several decades, as globalisation has led to a more interdependent global economy. According to the United Nations Conference on Trade and Development (2019), global FDI inflows reached $1.5 trillion in 2019, with more than half flowing to developing countries.

As a result of decreased trade barriers and improved communication technologies, corporations have been able to operate in international markets more easily and at a lower cost since the 1980s (Dunning & Lundan, 2008). This phenomenon was a major factor in the increase of FDI flows and the globalisation of the world economy (Dunning, 1993). Moreover, foreign direct investment initially flows from industrialised nations to other developed nations (Blonigen and Wang, 2005). Nonetheless, FDI inflows into developing nations have increased as emergent economies have become more attractive investment destinations. Throughout the 1990s, this trend was notably prevalent, as many developing nations experienced rapid economic growth and liberalised their investment regimes to attract foreign capital (Alfaro et al., 2004). Consequently, several emerging nations have become significant investors themselves, and FDI flows have begun to return to industrialised nations. This trend has been driven in part by the rise of multinational corporations in developing countries and the increased attractiveness of investing in mature markets (UNCTAD, 2019). As a result, the global FDI environment has become more complex, with a greater diversity of both incoming and outgoing countries.

FDI and economic development

Developed as a result of the expansion of globalisation and widely regarded as a factor influencing aggregate economic growth, a large number of publications have examined how FDI will influence economic expansion. Although the majority of studies have found that FDI has contributed to positive economic development, the result is complex and multifaceted as it depends on the study sample and a variety of other factors.

Recent studies have demonstrated that FDI is beneficial to economic growth in developed nations. Pegkas (2015) found that FDI has a positive impact on productivity growth and total factor productivity in developed countries, particularly in accordance with technology transfer and knowledge spillovers. In a separate study, Moudatsou

(2004) showed that FDI has a positive impact on economic development in European Union (EU) nations, particularly in nations with strong human capital and technological expertise. While in South Korea, FDI can stimulate economic growth through an increase in exports and international trade (Koojaroenprasit, 2012). Even outward foreign direct investment has a positive impact on economic development, and this effect is more robust over the long run, according to Lee's (2010) empirical study of Japan.

However, certain factors can limit or impede the economic stimulation effect of FDI in developed nations. Lim (2001) concluded that the positive influence of foreign direct investment on the economy is related to factors such as investment barriers, market size, and infrastructure quality. For instance, in certain industrialised nations, such as Scotland, FDI has a negative impact on economic development when they disregard the significance of human capital enhancement in favour of promoting new enterprises (Michie, 2001). Moreover, the empirical study by Sabir, Rafique, and Abbas (2019) indicates that the character of institutions and legal protection influence the quality of FDI.

The beneficial effect was also identified for developing countries. One of the earliest studies, conducted by Borensztein et al in 1998, discovered that FDI and economic growth in developing nations are positively correlated, which is consistent with the notion that FDI can bring in new technology, capital, and management skills from advanced investors, which can increase productivity and competitiveness. And as both the volume and quality of foreign direct investment increased, the positive impact persisted, as evidenced by an increasing quantity of literature focusing on various target nations. Quantitative research by Akinlo (2004) revealed that FDI had a consistent positive impact on Nigeria's economic growth, indicating that FDI was essential for African developing nations to attain sustainable economic growth. For China and Southeast Asia countries, which have attracted a substantial amount of FDI over the past decade, the inflow of investments had a positive and significant impact on economic growth, demonstrating FDI's essential role in driving economic growth in developing countries (Sjoholm, 2014; Zhang, 2006). Similar to the conclusion for developed nations, the positive impact of FDI on the economy also depends on the circumstances of the receiving countries; it is greater in countries with higher levels of institutional quality, openness, and human capital. (Kurul and Yalta, 2017; Sekkat, Veganzones and Varoudakis, 2007; Tran and Hoang, 2019)

However, FDI can also have negative economic effects on both developing and developed nations. According to Jude (2019), the crowding-out effect that occurs when FDI inflows replace local investment would be a factor that impedes development, particularly in developing nations such as those in Latin America and Africa (Agosin, and Machado, 2005). Yet, this occurrence is only temporary (Djokoto, 2021). In the meantime, when FDI continues to provide superior technology to the host country, it may contribute to technology dependence, limiting the ability of domestic firms to develop their own technical expertise (Costa and de Queiroz, 2002). Moreover, when the host country has developed an excessive reliance on FDI inflows from particular investors, their economic resilience to sudden changes in political upheaval is weakened, as is the case with Russia amid a war (Domnguez-Iménez and Poitiers, 2020). On the other hand, when FDI inflows are concentrated in extractive industries, such as mining and oil production, particularly in resource-rich nations, the energy-intensive expansion may have long-term negative effects on the environment, society, and economy (Moran, Graham, and Blomstrom, 2005). According to UNCTAD's 2020 Global Investment Report, FDI can even have a negative effect on the balance of payments and the currency exchange rate. This is especially true when FDI inflows are unpredictable and transient.

FDI’s other major impacts

Foreign direct investment has a substantial impact on the diverse perspectives of the entire society, in addition to its influence on the economy.

The impact of FDI on technology transfer and spillover is the most visible and well researched. Parallel to foreign investment, technology transfer can occur through a variety of channels, including the use of local suppliers, cooperation with local businesses, and the employment of local workers. This technology transfer provides the recipient nation with access to cutting-edge knowledge, which could improve the domestic sector's competitiveness (Ricken and Malcotsis, 2012). Moreover, it influences the investment decisions of multinational corporations (MNCs) in order to satisfy their diverse technological requirements (Duanmu, 2012).

And considering the channel of technology transfer, FDI substantially stimulated the transmission of knowledge via the spillover effect that implicitly moves knowledge to the host country (Yokota and Tomohara, 2010). Yang, Zeng, and Zhou (2023) discovered that FDI spillovers had a positive impact on the development of China's high-tech zone by increasing the R&D expenditure of local firms. However, the benefit was limited and was susceptible to local government policies (Zhang, 2021). Moreover, this positive impact is typically only substantial in the early stages, as the innovation process of the host country is characterised by imitation rather than the creation of novel products (Vujanović et al., 2022).

FDI's relationship to the employment rate and human resource development is also worth examining. The employment-creating function of foreign direct investment in host countries has been found to be widespread (Karlsson et al., 2007; Sakura and Kondo, 2014) and to be more pronounced in developing nations. Job creation is typically associated with the establishment of new organisations and the expansion of existing businesses in the host country (Golejewska, 2017), and is prevalent across Africa, Latin America, and Eastern Europe (Vacaflores, 2011). In developing regions, such as India and African nations, the majority of new employment opportunities are in the manufacturing and services industries (Chen, Geiger, and Fu, 2015; Mishra and Palit, 2020).

In addition to increasing the employment rate, FDI has a positive effect on the development of human resources and the competence level of the workforce in the host country (Zhuang, 2017). And the positive impact of FDI stems primarily from two channels: Emerging opportunities for investment encourage the development of the education level of the labour force in order to attract capital (UNCTAD, 2011); Increase in technological capabilities enhances the workforce's efficiency, creativity, and access to advanced knowledge, thereby enhancing their work skill set (Li, 2005). This development is currently extremely advantageous to the performance of domestic businesses (Apostolov, 2017), but a coordinated FDI and human resource development policy is required for optimal economic growth (Kheng, Sun, and Anwar, 2017). Moreover, in some regions, FDI has been shown to enhance the wages of educated employees in the host nation (Lipsey and Sjoholm, 2004).

FDI's effect could also be viewed from the perspective of the altering cultural and political environment. Foreign direct investment can introduce foreign products, services, and media content, which can disseminate ideologies, lifestyles, and consumer preferences (Pekarskiene and Susniene, 2015). Local societies can benefit from this cultural exchange, and expose individuals to new ideas and viewpoints. However, the dominance of global cultural trends may obliterate or erode local cultural identities, a phenomenon that is especially prevalent in emerging regions with low cultural confidence (ter Braak, 2010). These two additional effects are also observable from a political standpoint. On the one hand, FDI, particularly greenfield investment, could enhance the political environment and governance practices to establish a favourable and secure investment climate (Okara, 2023; Meyer and Habanabakize, 2018). However, host countries may become reliant on foreign investors, resulting in a loss of economic sovereignty and a heightened susceptibility to external influences, particularly for impoverished regions anxious to attract investment. When politicians are bribed by investors in exchange for special privileges, the political climate may even deteriorate, which could lead to market imbalances and monopolies. And this effect is demonstrated by the positive correlation between foreign direct investment and corruption in some nations (Kim, 2010).

In addition, FDI can influence the country's balance of payments (Nguku, 2013) and market power balance (Li et al., 2022).

FDI's relationship with the environment

The relationship between foreign direct investment and the environment remains complicated, despite that numerous academicians have conducted research concentrating on various target nations. Earlier studies have found that FDI tends to hasten environmental degradation, especially in large developing nations (Baek and Koo, 2009; Acharyya, 2009). However, some recent works have produced results contradicting FDI's environmental friendliness. For instance, the meta-analysis by Demena and Afesorgbor (2020) found that FDI has a significant effect on reducing emissions when heterogeneities in the study are taken into consideration. And the purpose of this section is to elucidate the two-sided effect from the channel's perspective.

FDI's positive influence on the environment

One of the primary channels through which FDI has a positive effect on the environment is through technology spillover. Typically, FDI introduces superior technology to the existing facilities in the host country, which increases working efficiency and reduces carbon emissions. Liu et al. (2016) used a panel model to investigate the environmental impact of FDI's technology spillover in China and discovered that the spillover had a positive influence on the Chinese energy industry and reduced total emissions. Rafique et al. (2020) discovered that the BRICS countries also experienced the environmental halo effect of FDI's technology diffusion. This effect is significant, however, only when FDI transfers from developed regions to emerging nations (Adxeel-Farooq, Riaz, and Ali, 2021). The findings of Wang and Luo (2020) indicate that FDI's environmental impacts through technological innovation have a threshold effect, such that only when the level of FDI exceeds the regional threshold can the positive effects of scientific and technological innovation capacity on environmental pollution become significant. Wang and Liu (2019) elaborated on the threshold effect and identified a double threshold, which indicates that FDI can only enhance the environment when regulations are neither too strict nor too lax.

Foreign direct investment and the environment also interact by influencing local environmental regulations. Environmental regulations restrict the behaviour and assert the environmental responsibility of organisations, and are generally considered to have a negative correlation with FDI inflow because they only permit investors to enter who comply with the regulations (Chung, 2014). Thus, a rise in FDI, which indicates a rise in companies that adhere to the regulation, would stimulate the implementation of such rules and improve environmental sustainability. For instance, in certain regions of China where pollution increased as a result of lax environmental regulations, the situation improved as more FDI poured in. However, the effect of FDI on enhancing environmental regulation also has a threshold effect that FDI can substantially improve green energy efficiency when environmental regulations are strict, but the relationship is insignificant when environmental regulations are lax (Gao et al., 2022).

FDI's effect on altering industrial structures also contributes to environmental improvement. Foreign direct investment is a key driver of economic growth and industrial upgrading; it promotes transitions to activities with a higher value-added, productivity, and energy efficiency. Wang et al. (2020) examined the relationship between foreign trade, FDI, and industrial structure upgrade and concluded that FDI is a significant factor in China's industrial upgrading. Pavlnek and Domask (2009), who focused on countries in Central and Eastern Europe, discovered that FDI has an effect on the upgrading of the automobile manufacturing industry. In addition, the policy of the host nation to attract FDI could encourage industrial upgrades to meet international requirements, thereby promoting long-term economic growth (Javorcik, Lo Turco, and Maggioni, 2019). When upgrading from a traditional resource-intensive industry or heavy industry to innovative technology or service industry, the overall level of eco-efficiency will increase substantially (Han et al., 2021).

FDI can also be a catalyst for advancing renewable energy development and altering domestic energy consumption. According to an empirical study conducted by Pan et al. (2020), foreign direct investment has a significant impact on improving Chinese energy utilisation efficiency via technical and structural channels, but this effect varies by region. Doytch and Narayan (2016) analysed a diverse sample of 74 countries and found that FDI altered the structure of energy consumption by encouraging renewable sources and discouraging non-renewable energy consumption. And specifically for the UAE, the positive impact of FDI on renewable consumption could be amplified by the development of green finance (Samour, Baskaya, and Tursoy, 2022).

FDI’s negative impact on the environment

Some academicians viewed FDI as a negative factor for the environment, with its contribution to the environmental haven effect causing the most concern. In response to today's increasingly stringent carbon emission restrictions, a group of multinational corporations have shifted pollution overseas in order to maximise their profits. Apergis, Pinar, and Unlu (2023) examined the FDI flow from developed countries and confirmed the pollution heaven hypothesis as FDI from the United Kingdom and Denmark to BRICS countries increased carbon emissions. However, this effect is heterogeneous and varies between recipient and source nations. Zhang et al. (2021) studied a larger sample of Belt and Road countries, and their findings confirmed the positive relationship between FDI and carbon emissions, suggesting that host nations impose stricter environmental regulations in response to FDI and international trade.

On the other hand, FDI could exacerbate environmental issues by expanding domestic industries that pollute the environment. This is most typical for nations with a history of energy-intensive industry or abundant reserves of natural resources, as FDI naturally travels to nations with distinct competitive advantages (Pant, 2005). Since the 1990s, fast-developing China, with its inexpensive skilled labour force, industry infrastructure, and resources, has attracted a large quantity of FDI, but the majority of it has been invested in industries that emit pollution (Liu and Wang, 2017). And FDI has increased both short-term and long-term carbon emissions, resulting in significant environmental degradation and pollution problems that negatively impact resident health (Jun, 2018). Assa (2018) examined the case of sub-Saharan African nations, where FDI tended to aggregate in non-renewable resource mining industries, and discovered evidence that FDI had a significant negative impact on the forest area, resulting in forest degradation and water contamination. While in Latin America, the environmental impact of foreign direct investment in polluting industries decreases when local economic development exceeds a threshold (Sapkota and Bastola, 2017).

Although FDI could increase the stringency of environmental regulations in some nations, it can also contribute to the relaxation of such regulations in the host nation. Developing nations, especially those that are poor but possess labour or resource potential, continue to compete for FDI from developed regions in order to stimulate their economic growth. And the stringency of environmental regulations, such as emissions limits, pollution disposal, and resource exploitation limits, is regarded as one of the most significant factors for investors when selecting their investment target region (Yoon and Heshmati, 2021). Therefore, FDIs are more likely to migrate to regions with less stringent environmental regulations (Cheng, Li, and Liu, 2018). For instance, the pattern of UK outbound FDI was substantially influenced by host environmental regulations, and this influence was stronger than that of other endowment variables such as labour or development abundance (Mulatu, 2017). Cole, Elliott, and Fredriksson (2006) compiled panel data from 33 countries and demonstrated that FDI generally leads to less stringent environmental policy when the level of corruption is high, which is a common occurrence in poor regions where governors control everything.

Relationship between economics development and the environment

How to achieve a balance between economic development and environmental sustainability has become an issue of extensive debate in both developing and developed nations. The past pattern of economic development has resulted in severe damage to the environment as a whole (Le, Chang, and Park, 2016), resulting in resource depletion and environmental disasters that threaten human health. For instance, Chinese over-industry development has resulted in a severe emission problem that has led to haze and water pollution that is harming the health of residents (Li and Zhang, 2014).

Since Grossman and Krueger's (1991) publication, the relationship between economic development and the environment has received increased recognition. This important study presents a new economic model that emphasises the trade-off between environmental quality and economic development, demonstrating how growing pollution and environmental degradation can result from economic expansion fueled by international trade and foreign direct investment. Grossman and Krueger (1995) discussed the Environmental Kuznets Curve model, which suggested an inverted U-shaped relationship between economic development and the environment. It argues that there is a negative relationship between economic growth and environment quality in the initial phase, but that this relationship would turn positive as societies prioritise environmental concerns above an income threshold.

Currently, the environmental Kuznets curve (EKC) model has been extensively studied and acknowledged by numerous empirical studies as an instrument for examining the relationship between economic development and the environment for various country samples. Tenaw and Beyene (2021) developed an EKC model to estimate the relationship between environmental sustainability and economic development in sub-Saharan African nations and discovered the existence of an inverted U-shaped relationship, confirming the validity of the EKC model. In addition, they suggested the country's economic growth must conform to an appropriate economic policy. The EKC relationship has also been identified in European and East Asian nations (Dogan and Ingles-Lotz, 2020; Liu et al., 2018). However, this model is not verified in certain regions of the United States and China (Isik, Ongan, and Ozdemir, 2019; Liu et al.,2018). This could due to the policies that promote suitability and renewable energy being insufficiently robust or because the disparity between regional development and underdeveloped areas has not yet reached the EKC turning point.

However, the development of a sustainable environment is a complex process that involves the integration of sustainability, economic, and social factors (Slaper and Hall, 2011). Scholars have made modifications to the original Environmental Kuznets Curve model by incorporating additional variables to accommodate the investigation of different countries with unique situations. In order to enhance comprehension of the factors that contribute to environmental change, certain variables have been incorporated into the right-hand side of the EKC equation. The authors of the study (Isik, Ongan, & Özdemir, 2019) included several control variables in their equation, such as fossil fuel consumption, FDI flow amount, energy intensity level, population density, GINI index, globalisation, and financial development, based on their sample selection. Bello and Abimbola (2010) employed EKC model to examine the influence of economic growth on environmental quality in Nigeria made modifications to the model by incorporating supplementary control variables, including the manufacturing to GDP ratio, to account for Nigeria's national industry structure. And the findings indicate that the inverted U-shaped relationship does not exist in Nigeria. This can be attributed to the fact that Nigeria is still in the early stages of development. Similarly, when studying the EKC hypothesis for the Korean Republic, the author included the number of automobiles as a primary explanatory variable, as the Ministry of the Environment announced that automobiles are a significant contributor to national air pollution (Park and Lee, 2011). In addition, their findings indicate that the Republic of Korea has surpassed the EKC threshold and that its economic development is enhancing environmental quality overall. In some cases, the validation of EKC can also be related to natural resource reserves, institutional quality, technological advancement, trade liberalisation, and corruption level (Zafar et al., 2013; Dogan and Ingles-Lotz, 2020). And these variables could be used to determine the shape and threshold level of the Environmental Kuznets Curve in order to account for the variation between samples (Horii and Ikefuji, 2015).

On the other side of the EKC model, estimating the environmental variable is a crucial issue. In most cases, the quantity of CO_2 emissions is regarded as a suitable proxy for environmental issues and was included in the initial EKC model. Because CO_2 is regarded as the main driver of global warming, accounting for 76.7% of all greenhouse gas emissions (Miah, Masum, and Koike, 2010). While it has recently been demonstrated that other petrol emissions caused by the development of modern industry are responsible for environmental degradation, scholars have begun to estimate a new environmental proxy for EKC. To test the EKC hypothesis for China's coastal cities, Shen (2020) substituted CO_2 with SO_2, another important greenhouse gas that contributed to the formation of acid rain. The result verifies the inverted U-shaped relationship between SO_2 emissions and economic growth and reveals that the relationship between industrial water waste and industrial electricity consumption also follows the EKC model. In addition, nitrogen dioxide, a greenhouse gas that contributes to haze weather and causes severe damage to the surrounding atmosphere, is widely considered in EKC studies. Sinha and Bhattacharya (2016) investigated EKC estimation for 139 Indian cities by separating the cities into high-, middle-, and low-income groups. The results indicate that the EKC model is validated for the high-income regions, while the NO_2 emission and income level exhibit a linear relationship, overall indicating the existence of an inverted U-shaped relationship, but India has not yet reached the turning point.

However, it is also important to note that some studies fail to identify the EKC in their study population. Zambrano-Monserrate et al. (2018) and Ahmed and Long (2012) examine the relationship between economic growth and environment for Peru and Pakistan, respectively, and the empirical results do not support the validity of the EKC hypothesis. de Bruyn et al. (1998) also questioned the validity of EKC and stated an N-shaped relationship between economic development and the environment, indicating that income growth will contribute to an increase in pollution after a certain threshold is reached. And empirical investigations by Bekun et al. (2021) on sub-African nations and Allard et al. (2018) on all income categories have also discovered evidence supporting the existence of the N-shaped relationship.

Chapter 3. Green Transition of CEE Countries

The energy consumption structure of CEE countries

Central and East European nations were the primary frontline during the Cold War, and the majority of them have undergone significant change since the fall of the Soviet Union. They transitioned from communism to democracy through a complete political, economic, and institutional transformation. And their energy regulation and consumption, which were fundamental to the economic growth, political stability, and way of life in CEE nations, underwent a significant shift towards a more sustainable and highly efficient pattern. Nonetheless, some nations with profound communist roots or an abundance of fossil fuel reserves continue to struggle to establish a greener energy consumption structure.

During the years of communism, the CEE countries were ruled by a highly centralised government, with their industrial production serving the aim of attaining rapid economic development without much regard for the environmental cost. Russia, the primary body of the former Soviet Union, has heavily invested in resource-intensive heavy industries such as the military, automobile manufacturing, and steel production (Davis, 2014). With its chemical and ferrous industries, the Czech Republic has also been characterised as an energy-intensive society (Koenda and Čábelka, 1998). In order to meet the needs of the planned economy's development, the CEE nations have tightly regulated energy production, consumption, and trade.

Possessing an abundance of natural resource reserves, CEE nations consistently produce energy, particularly fossil fuels. In the 1980s, the former Soviet Union held approximately 55 percent of the world's discovered fossil fuel reserves, while Poland and Romania held significant coal and oil and gas reserves, respectively. And these nations have become the leading exporters of energy to support the development of the more developed nations in the CEE region. Thus, their economic structure and energy reserve together have influenced their energy consumption pattern to be dominated by fossil fuels.

The table below depicts the proportion of fossil fuels to total energy consumption in 1990, when data were complete and still reflected the communist era pattern. All of the countries were highly dependent on the consumption of fossil fuels, with half of them exceeding 90% and Poland ranking highest at approximately 98%. This value is considerably greater than the average of other developed European nations (France, Norway, Iceland, Spain, Italy, Portugal, and Germany) in 1990, which was approximately 60%. Also, the energy efficiency of CEE nations, as measured by energy consumption per million dollars of GNP, was not optimal. According to Korda and Moravcik (1976), in 1972, CEE countries consumed nearly twice as much energy as Western Europe (1548 tce) and the Common Market (1548 tce) to generate $1 million in GDP. And inefficient energy consumption has caused regional energy supply issues for the majority of the USSR's alliances, despite the fact that the USSR had abundant energy reserves. Although some countries in Central and Eastern Europe have begun utilising renewable energy sources such as nuclear, hydro, and thermal, their production remains low in comparison to that of fossil fuels (Sinyak, 1991).

Table 1. Fossil fuel consumption percentage 1990 (unit: %)

Country	Fossil fuel consumption -1990 (% to total energy)
Albania	76.59
Bulgaria	84.12
Bosnia and Herzegovina	93.92
Belarus	95.61
Czechia	91.62
Estonia	43.73
Croatia	81.05
Hungary	81.60
Lithuania	75.75
Latvia	81.77
Poland	97.81
Romania	96.15
Russian Federation	93.40
Serbia	90.82
Slovak Republic	81.62
Slovenia	71.28
Ukraine	91.83

Source: World Bank database

After the fall of communism, the countries in CEE have acquired control over their economic development and energy policies. Their energy reform reduced their reliance on Russian exports by securing new suppliers, promoted the development of renewable energy to prevent environmental degradation, and promoted energy efficiency. And since joining the European Union and the Kyoto Protocol, CEE nations have increased their efforts to improve their energy infrastructure. The second table depicts the proportion of fossil fuel in total energy consumption in 2014, and it is evident that the values for all of the countries in the table have decreased since 1990, with Estonia experiencing the greatest decline. Although some nations continue to rely extensively on fossil fuels, the majority have reached the level of Western European nations. Alongside the development of technology and the upgrading of industry towards knowledge-intensive lines, the energy efficiency of CEE nations has improved to a certain degree. Figure 1 contrasts the energy intensity index for CEE countries, and it is evident that every country in the sample was able to generate the same unit of GDP in 2019 at a reduced energy cost than in 2000. Particularly Romania, which had the highest percentage of fossil fuel consumption in 1990, has increased its energy efficiency by 57%, demonstrating a significant accomplishment in its energy transition.

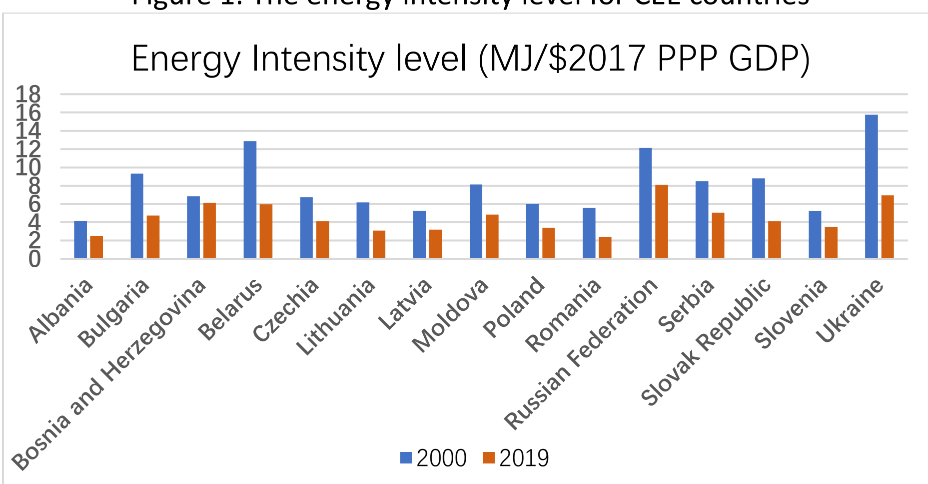
Table 2. Fossil fuel consumption percentage 2014 (unit: %)

Country	Fossil fuel consumption -2014 (% to total energy)
Albania	61.42
Bulgaria	71.05
Bosnia and Herzegovina	77.52
Belarus	92.44
Czechia	75.28
Estonia	14.49
Croatia	70.70
Hungary	68.19

Lithuania	67.99
Latvia	56.72
Moldova	88.69
Montenegro	64.66
Poland	90.09
Romania	72.52
Russian Federation	92.14
Serbia	83.87
Slovak Republic	63.95
Slovenia	59.66
Ukraine	75.35

Source: World Bank database

Figure 1. The energy intensity level for CEE countries



Source: World Bank database

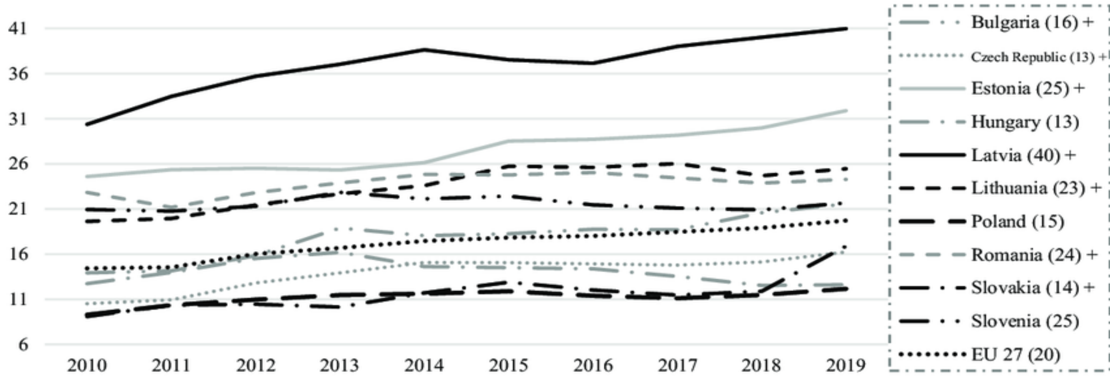
Along with the energy reform, the production and consumption of renewable energy have increased, with renewable energy now accounting for 25% of the total eclectic in the CEE region (E3G, 2023). Table 3 displays the renewable energy production of CEE nations in 2020. Poland is the leading producer of renewable energy, but it is also a big consumer of fossil fuels. Romania and the Czech Republic also generated a notable quantity of renewable energy, whereas some Balkan nations have not seen a significant increase in their clean energy industries.

Table 3. Renewable energy produced by CEE countries (in billion kilowatt-hours)

Country	Renewable energy production 2020 (Billion kilowatt-hours)
Poland	18.87
Romania	8.28
Czechia	8.07
Bulgaria	5.66
Hungary	4.68
Russia	4.23
Ukraine	3.46
Croatia	2.77
Estonia	2.67
Lithuania	2.46
Slovakia	2.38
Latvia	1.24
Belarus	0.64
Slovenia	0.53
Serbia	0.36
Montenegro	0.19
North Macedonia	0.19
Bosnia and Herzegovina	0.18
Moldova	0.07

Source: CountryWatch Data

Figure 2. Renewable energy to total consumption for CEE countries (%)



Source: Eurostat (2021)

Moreover, based on Figure 2, which depicts the proportion of renewable energy to total energy consumption, the majority of CEE nations have experienced a rise in the proportion of clean energy, albeit at a relatively sluggish rate.

In spite of the fact that some CEE nations have effectively accelerated their renewable production and performed above EU expectations, the general renewable utilisation rate still requires development. To maximise their renewable potential, countries in Central and Eastern Europe must exert more effort.

The greenhouse gases emission of CEE countries

During the communist era, the CEE nations were heavily invested in resource-intensive industries, such as heavy industry and manufacturing, which contribute significantly to greenhouse gas emissions. Even though some developed nations in this region have undergone industrial upgrades following the transition to labour- and technology-intensive industries, while some countries have had limited success in transitioning due to their economic or social stability and continue to be significant greenhouse gas emitters. Table 4 displays the CEE countries' per capita greenhouse gas emissions in 2000 and 2021, as well as the percentage change in emissions during this period. In 2021, Russia was the leading emitter of greenhouse gases in Central and Eastern Europe at 16.6t equivalent CO_2 per capita, followed by Estonia, Belarus, and Poland. While the change in greenhouse gas emissions indicates more countries on the list achieved a reduction in petrol emissions, the remaining countries experienced a significant increase. Latvia's emission levels have increased by more than threefold, while those of Lithuania, Montenegro, and Bosnia and Herzegovina have increased by more than fifty percent.

This situation is even more astounding when compared to Western European nations that have successfully reduced greenhouse gas emissions. Table 5 illustrates the change in greenhouse gas emissions for a group of developed European nations over the same period. In the CEE region, only one country (North Macedonia) has achieved a 32% reduction in emissions, whereas the United Kingdom has reduced its emissions by approximately fifty percent.

The inability to effectively reduce carbon emissions has impeded the development of some CEE nations. For the countries that have already joined the European Union, the pressure to satisfy the EU's pollution reduction requirements is increasing, delaying the general progress towards carbon-free development. While for countries outside the EU that wish to join, this might impede their efforts to join the EU or be considered an ideal applicant. And for all CEE nations, pollution has always been a source of environmental degradation, health risks, and widespread complaints. For instance, in Romania, the emission of Sulphur oxides and Nitrogen oxides has resulted in acid rain, which has caused soil and potable water contamination (Draşovean et al., 2015). Due to its reliance on coal combustion, Serbia, which ranked fifth among the most polluted nations in Europe, also experienced haze and resident health problems.

Table 4. Greenhouse gases emission per capital for CEE countries CO_2 equivalent (Unit: t)

Country	2000	2021	Absolute change	Change in percentage
Albania	2.14	2.92	0.79	37%
Belarus	7.80	11.16	3.36	43%
Bosnia and Herzegovina	4.22	6.63	2.41	57%

Bulgaria	6.84	7.45	0.61	9%
Croatia	4.00	5.35	1.35	34%
Czechia	13.51	9.60	-3.91	-29%
Estonia	11.06	11.85	0.79	7%
Hungary	6.92	5.80	-1.11	-16%
Latvia	1.84	7.88	6.03	327%
Lithuania	4.92	8.85	3.93	80%
Moldova	1.70	2.27	0.57	34%
Montenegro	2.93	4.74	1.82	62%
North Macedonia	6.64	3.83	-2.80	-42%
Poland	10.35	10.04	-0.31	-3%
Romania	5.62	5.31	-0.31	-5%
Russia	12.13	16.62	4.49	37%
Serbia	6.59	5.28	-1.31	-20%
Slovakia	9.09	7.73	-1.37	-15%
Slovenia	9.80	8.38	-1.42	-15%
Ukraine	7.90	6.53	-1.36	-17%

Source: Global Carbon Project

Table 5. Greenhouse emission per capital for developed European countries (Unit: t)

Country	2000	2021	Absolute change	Change in percentage
Austria	9.48	8.23	-1.26	-13%
Belgium	15.36	10.91	-4.45	-29%
France	8.87	6.06	-2.81	-32%
Germany	12.31	8.94	-3.37	-27%
Italy	9.45	6.28	-3.17	-34%
Luxembourg	22.29	14.54	-7.75	-35%
Netherlands	13.91	10.16	-3.75	-27%

Portugal	8.15	5.01	-3.14	-39%
Spain	9.03	5.99	-3.03	-34%
Switzerland	7.17	4.74	-2.43	-34%
United Kingdom	12.00	6.26	-5.74	-48%

Source: Global Carbon Project

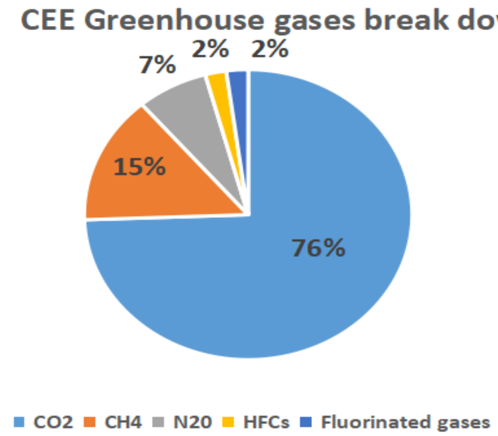
To further analyse greenhouse gas emissions in the CEE region, the next section will examine the categories of greenhouse gases and their sources. According to the European Environment Agency, carbon dioxide constitutes 76% of the eleven CEE countries' total greenhouse gas emissions. Methane is the second most important emission gas, accounting for 14.6% of CEE countries' greenhouse gas emissions, while N_2O, HFCs, and fluorinated gases are also notable pollution contributors.

Table 6. Greenhouse gas emissions breakdown for CEE countries 2021 (kt CO_2 eq)

Country	Total	CO_2	CH_4	N_20	HFCs	Fluorinated gases
Bulgaria	45,336	33,248	6,703	4,622	739	763
Croatia	18,945	11,785	3,894	1,557	1,699	1,709
Czechia	127,771	106,036	13,233	4,694	3,711	3,808
Estonia	15,628	13,084	1,228	1,122	190	193
Hungary	57,398	41,698	9,220	4,519	1,862	1,961
Latvia	13,373	8,448	2,758	1,905	250	262
Lithuania	14,388	7,817	3,301	2,744	513	525
Poland	382,296	311,492	43,393	22,372	4,937	5,040
Romania	66,394	28,107	25,789	10,536	1,908	1,962
Slovakia	33,678	27,566	3,721	1,696	672	695
Slovenia	13,027	9,944	2,085	707	267	291

Source: European Environment Agency

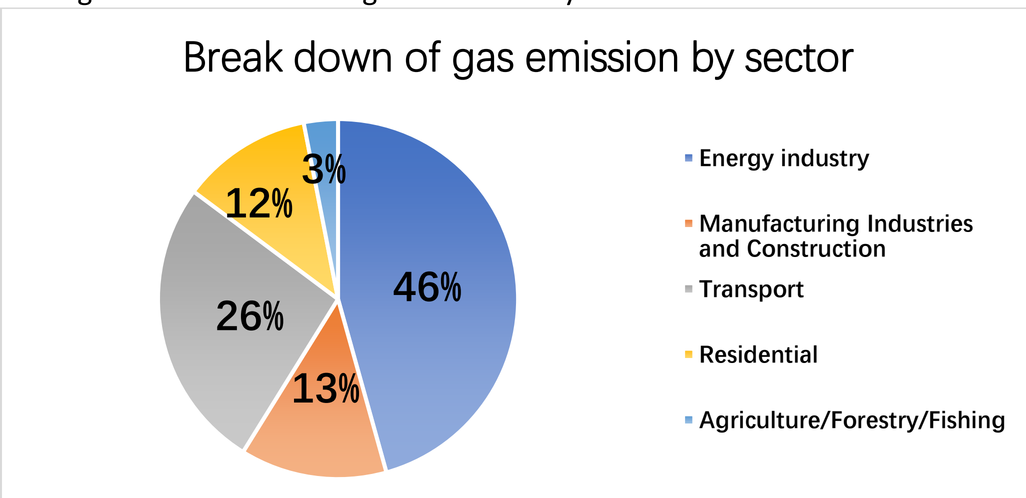
Figure 3. Breakdown of total greenhouse gas emissions for CEE countries - 2021



Source: European Environment Agency

The graph below breaks down the origin of greenhouse gases in greater detail. The energy industry, which provides public electricity and heating, petroleum refinement, etc., is responsible for 46% of total greenhouse gas emissions. The second-largest proportion, 26%, belongs to the transportation sector, followed by the manufacturing and residential sectors, each of which accounted for approximately 12%, and agriculture, with 3%. And the energy sector is also the leading producer of carbon dioxide, while the residential sector produces the most. Transportation and methane are the main sources of N_20.

Figure 4. Breakdown of gas emissions by sector for CEE countries - 2021



Source: European Environment

Table 7. Greenhouse emissions by sector for CEE countries 2021 (unit: 10^3kt CO_2 eq)

Emissions	Energy	Manufacturing	Transport	Residential	Agriculture
Total	279925.23	80819.27	161456.19	71995.17	18790.91
CO_2	278446.91	80091.99	159561.87	63521.15	17183.14
CH_4	251.81	296.41	250.43	7653.83	490.54
N_20	1226.52	430.87	1643.89	820.19	1117.24

Source: European Environment Agency

The obligation and future of CEE's green transition

The green transition refers to the comprehensive transformation of societies, economies, and industries towards the adoption of sustainable practices and the utilisation of low-carbon alternatives. The primary aim of this initiative is to mitigate the adverse impacts of human activities on the natural environment, while simultaneously fostering economic development and societal welfare. This is to be accomplished through the execution of a comprehensive range of measures and strategies toward achieving environmental sustainability and facilitating the transition towards a circular economy.

Typically, the green transition comprises two primary components. One primary objective is the mitigation of greenhouse gas emissions, encompassing the shift from fossil fuels, the advancement of energy efficiency, the advocacy for sustainable transportation systems, and the adoption of comprehensive measures across various sectors to reduce pollution and emissions. The advocacy for the utilisation of renewable energy sources is a further pivotal aspect to contemplate. The primary objective is to enhance the share of energy generated by renewable sources such as solar, wind, hydro, and geothermal energy. In addition to diminishing dependence on fossil fuels, this practice serves to reduce the impacts of climate change and enhance the quality of air and water resources. Along with addressing energy and emissions, the green transition encompasses a wider range of sustainability considerations including the adoption of sustainable agricultural practices, the reduction of waste and promotion of recycling, and the preservation of biodiversity and ecosystems.

According to the World Population Review (2023), Latvia is the leading consumer of renewable energy in the CEE region. It has reached its national target of generating more than 40 percent of its energy from renewable sources by 2020 and will rise to 41.5 percent by 2023. From 2010 to 2021, the amount of electricity and heat generated by biofuels and refuse has multiplied tenfold and fourfold, respectively. Its wind energy production increased from 4 GWh in 2000 to 141 GWh in 2021, and it has recently developed a solar PV infrastructure that will generate 7 GWh in 2021 (IEA, 2021). Alongside the development of renewable energy, the nation has increased its energy security by decreasing its net energy imports by 75% between 1990 and 2021. However, Latvia's energy intensity is still higher than the EU average, and more effort must be devoted to the green transition. And the government and EU are committed to investing 38% of the €1.8 billion grant to support the government's climate objective through 2026 and to enhance the sustainability of the Riga district.

Other developed CEE nations within the EU have also begun to cultivate sustainability. The Czech Republic has invested in renewable energy infrastructure, promoted the development of electric vehicles, and aims to eliminate coal by 2033. Hungary has also set a goal to eliminate the consumption of fossil fuels and coal and increase the production of solar PV, wind, and thermal energy. In addition, it has cooperated with FDI from Korea in the development of batteries for electric vehicles.

However, some countries in CEE have encountered obstacles in their transition to a green economy, particularly those whose economies were heavily dependent on energy industries. For example, Poland, the leading coal producer and consumer in Central and Eastern Europe, which accounted for 13% of the world's coal consumption in 2016, has implemented policies to close coal mines to comply with the EU's plan to reduce Methane emissions. However, this initiative has been extensively opposed by Polish coal workers and unions, as the immediate closure would result in the loss of employment for tens of thousands of miners, the majority of whom are from low-income groups. The controversy surrounding Polish coal mines has also resulted in sanctions from the EU court, protests against environmental degradation at the Czech border, and a threat to Polish energy security. In contrast to countries outside the EU, Russia has also struggled to make progress in the green transition, as its economy continues to rely heavily on the export of fossil fuels, which has exacerbated the emission problem and the regional environment.

Table 8 displays the total greenhouse gas emissions for CEE countries that have joined the EU in 1990 and 2021. All nations produced fewer greenhouse gases in 2021 compared to 1990, validating their efforts to transition to a greener economy. However, only three of the eleven countries on the list have met the EU's requirement to reduce greenhouse gas emissions by at least 55 percent by 2030: Estonia, Lithuania, and Romania. Poland, Slovenia, and Croatia have yet to accomplish even half of this target.

Table 8. Greenhouse gases total emissions change for CEE countries (unit: 10^3kt CO_2 eq)

Country	1990	2021	Percentage of reduction
Bulgaria	98999.56	53985.34	45%
Croatia	31454.18	24446.42	22%
Czechia	200727.48	119035.64	41%
Estonia	40276.36	12615.17	69%
Hungary	94985.02	64217.84	32%
Latvia	26063.11	10738.12	45%
Lithuania	48168.89	20291.78	58%
Poland	474838.25	399937.61	16%

Romania	257137.18	115403.15	55%
Slovakia	73826.44	41270.16	44%
Slovenia	18797.65	16106.48	14%

Source: European Environment Agency

Overall, CEE nations have recognised the need to develop sustainability and have taken the initiative to join the green transition by developing renewable energy sources and reducing emissions. As a result of historical, resource, and social issues, however, progress varies between nations and is generally slower than in developed regions of Western Europe. Thus, it is anticipated that these nations will invest more in green transition to enhance environmental and energy security in the current complex environment, given that energy is essential for living, economic growth, and political stability.

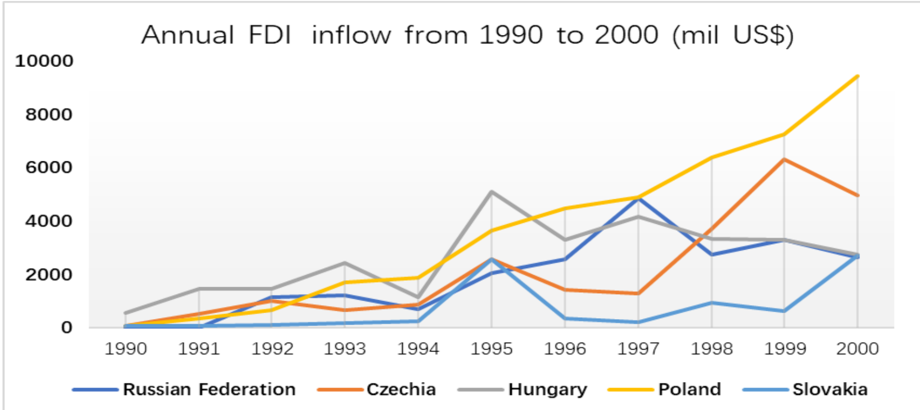
Chapter 4. FDI in CCE Countries

FDI development in CEE countries

During the period of communism, the growth of FDI was subject to strict limitations, with centralised control over both the identity of investors and the industries eligible for investment. Cross-border investments primarily originate from the economic collaboration between CEE countries and other members of the Council for Mutual Economic Assistance (COMECON). These investments are facilitated through bilateral trade agreements and joint ventures, which are established within the framework of their cooperation agreements. The sectors that were permitted the inflow of foreign direct investment are those that do not significantly impact domestic political stability and economic fundamentals. As an illustration, the 1986 legislation concerning joint ventures in Poland, which represents an expanded iteration of the nation's initial FDI law from 1976, continued to prohibit the involvement of foreign investors in sectors such as the defence industry, railway and air transportation, communications, banking, insurance, foreign trade, telecommunications, and international trade (Hany, 1995).

Following the end of Communism, countries in CEE embarked on a process of transitioning to market-based economies and expanding their domestic markets to encompass a broader international market. A series of policies were implemented, including economic liberalization, the enhancement of investment regulations, the privatization of state-owned enterprises, and the improvement of infrastructure, all aimed at fostering a friendly investment environment. In addition, they enacted policies that allowed for complete foreign ownership, established legal protections for foreign property, and offered tax incentives in order to attract foreign investors (Hunya, 1992). The figure presented below illustrates the fluctuations in FDI received by the CEE countries that have attracted the highest levels of FDI between the years 1990 and 2000. The countries undergoing transition following the period of communism have experienced a notable rise in FDI. Hungary, which initiated the adoption of FDI in the late 1970s has experienced a substantial increase of 52 times in FDI inflows over the course of this period. Notably, Poland and the Czech Republic have exhibited the most significant growth, positioning them as the primary destinations for FDI investments. Nevertheless, the Russian Federation, possessing substantial natural resources and well-developed industrial infrastructure in the post-1989 period, experienced only modest growth in FDI by the year 2000, reaching a level comparable to that of Slovakia. The existence of an oligarchy, corruption, and restrictions on privatization in Russia has led to this significant disparity, posing a threat to the property and income security of foreign investors (Jones, Fallon, & Golov, 2000).

Figure 5. FDI flow to CEE countries 1990 to 2000 (units: Million US dollar)



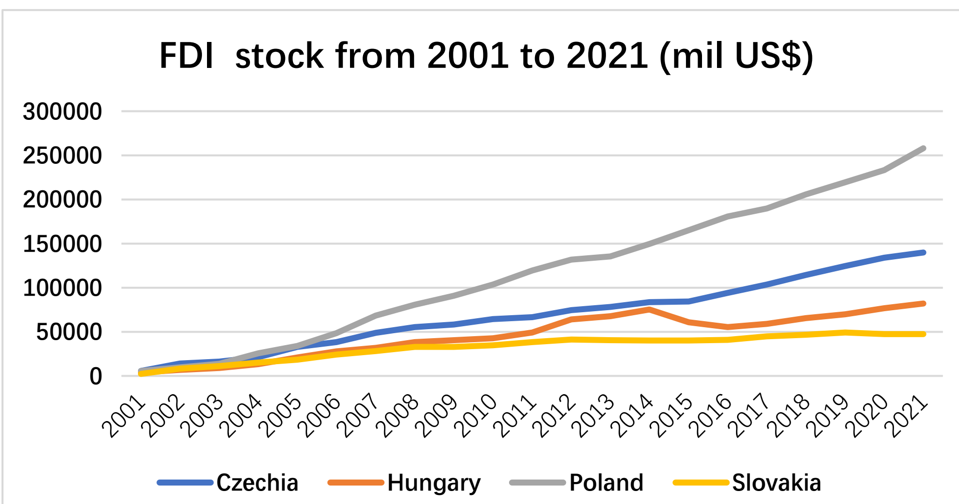
Source: UNCTAD - World Investment Report 2022

Furthermore, in this particular timeframe, Central and Eastern European countries with comparatively inexpensive labour, proficient workforces, and well-developed industrial infrastructure have successfully enticed FDI through the relocation of Western European nations. Initially, the majority of FDI has been concentrated in the manufacturing sectors, specifically the automobile and electronics industries. The increasing FDI had a positive impact on the economic development of CEE countries, and resulted in the establishment of significant manufacturing facilities, thereby positioning these countries as key participants in the global supply chain. In addition, it is worth noting that FDI played a significant role in the privatisation and economic reconstruction of CEE countries during the later stages of their transition period (Kornecki and Rhoades, 2007). In this particular scenario, countries in CEE have continued to undertake additional measures to enhance their attractiveness to FDI, which serves as a catalyst for their economic advancement.

Consider the Visegrad 4 countries, which are recognized as the primary recipients of FDI in CEE, the ensuing graph presents their FDI stock spanning the years 2001 to 2021. To accurately depict the change during this period, the FDI stock of 2000 was represented as zero. It is evident that Poland continues to be the primary recipient of FDI, displaying consistent growth even amidst the epidemic period. Additionally, the remaining three countries have also experienced a substantial twenty-fold increase in

FDI stock from 2001 to 2021. The increase in FDI within the Visegrad group is strongly linked to their investment promotion policies, which aim to maintain their attractiveness to foreign investors. For example, as CEE countries have progressed and joined the high-income category, the attraction of FDI based on inexpensive and readily available labour has diminished. Consequently, significant FDI flows have shifted towards more cost-effective destinations such as China and Southeast Asia (Sass and Hunya, 2014). In response, the Visegrad Group countries have implemented measures to maintain their competitiveness. Governments have enhanced their involvement in FDI by augmenting the presence of highly skilled workers, transitioning production towards higher value-added goods, and redirecting FDI's emphasis from manufacturing to support service sectors (Szent-Iványi, 2017). Nevertheless, in the dynamic and evolving global landscape, the annual inflow of FDI for the aforementioned country has displayed a greater degree of volatility. Consequently, it is imperative for the country to prioritize endeavours such as industrial upgrading, innovation, enhancement of workforce education, and investor care. These measures are essential for sustaining an upward trend in FDI development over the long term (Szent-Iványi, 2017).

Figure 6. Change of FDI stock to Visegrad 4 2001 to 2021 (units: Million US dollar)



Source: UNCTAD - World Investment Report 2022

Based on the data provided by the World Bank in 2022, it can be observed that

FDI inflows have emerged as a crucial component in the economic picture of most CEE nations. According to the data presented in Table 9, Montenegro has experienced a FDI inflow that accounts for 14.31% of its total GDP in 2022. This percentage is the highest among countries in the CEE region and has demonstrated consistent growth over the past five years. However, Hungary has experienced notable fluctuations in the ratio of FDI to GDP as a result of its varying GDP levels.

Table 9. The annual FDI flow as percentage of GDP of CEE countries 2018-2022 (unit: %)

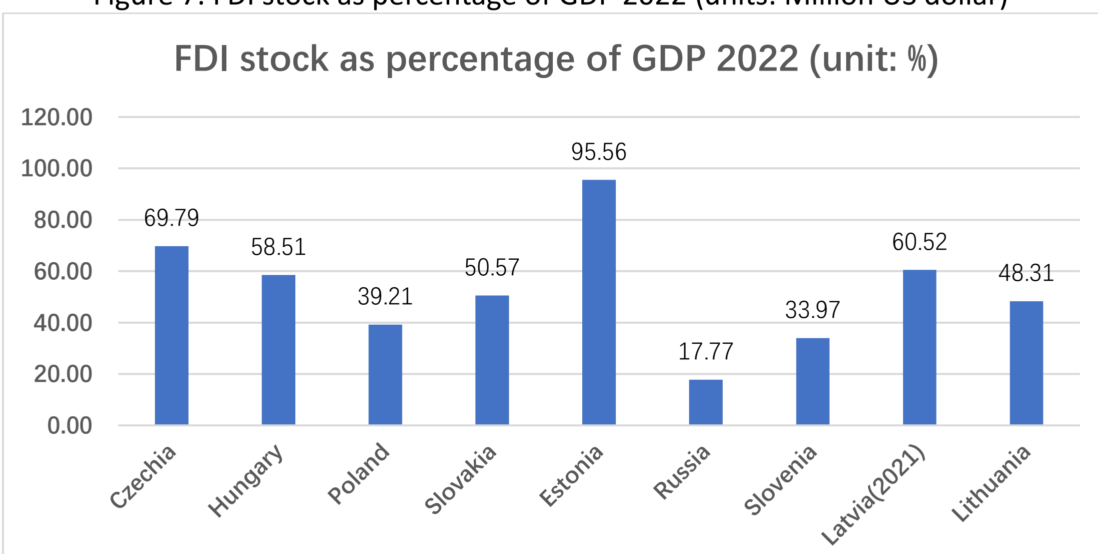
Country	2018	2019	2020	2021	2022
Albania	7.95	7.80	7.06	6.80	7.63
Bulgaria	2.73	3.22	5.11	2.97	3.61
Bosnia and Herzegovina	2.94	2.19	2.14	2.70	2.63
Belarus	2.38	1.98	2.27	1.77	2.22
Czechia	3.34	4.26	3.46	4.57	3.62
Estonia	4.02	9.82	11.53	19.79	3.84
Croatia	2.14	6.43	2.17	6.77	5.17
Hungary	-40.09	60.04	106.59	16.37	-7.35
Lithuania	2.42	6.27	7.92	4.47	0.97
Latvia	1.23	3.25	2.71	9.37	2.96
Moldova	2.61	4.32	1.37	2.86	4.11
North Macedonia	5.11	4.36	0.06	5.04	6.42
Montenegro	8.82	7.53	11.13	11.84	14.31
Poland	3.26	2.96	3.19	5.46	5.09
Romania	3.02	2.93	1.43	4.11	3.94
Russian Federation	0.53	1.89	0.63	2.20	-1.93
Serbia	8.04	8.29	6.53	7.29	7.23
Slovak Republic	2.12	2.16	-1.07	0.82	3.51

Slovenia	2.84	3.96	0.94	3.48	2.83
Ukraine	3.80	3.77	0.19	3.98	0.34

Source: UNCTAD - World Investment Report 2022

And from the most recent data obtained from the OECD database, it can be observed that the cluster of CEE countries exhibited a considerable FDI stock relative to their annual GDP. Estonia emerged as the frontrunner in this regard, while Russia occupied the lowest position within the ranking. However, it is worth noting that the stock of FDI in CEE regions has shown a general upward trend following the transition period and even during the recent epidemic. The entry of these regions into the European Union has further facilitated their FDI development by enabling market expansion, reducing trade barriers, and creating a favourable investment environment. Furthermore, an increasing number of smaller nations are attracting an increasing number of FDI, thereby altering the prevailing trend of concentration in developed regions.

Figure 7. FDI stock as percentage of GDP 2022 (units: Million US dollar)



Source: OECD database

The source and structure of FDI in CCE countries

FDI in CEE nations primarily originated from other member countries of the Council for Mutual Economic Assistance (COMECON). However, with their attainment of economic independence and subsequent market liberalisation, these countries began to draw significant FDI from global sources. The nations situated in Western Europe or within the European continent were the initial pioneers in investing in CEE countries. This strategic move was driven by the desire to take advantage of the region's low labour costs and highly skilled workforce, and these Western European countries continue to maintain a significant portion of FDI in CEE countries currently, spanning various industries. The subsequent tables shown below illustrate the origin of inbound FDI stock for the Visegrad 4 nations, Russia, and Romania, the primary recipients of FDI stock within the CEE regions.

Table 10. FDI sources of Czech Republic - 2020

Czech Republic	Percentage to total FDI Stock	FDI stock (US$ million)
Netherlands	17.48%	33007.76
Luxembourg	16.12%	30435.39
Germany	16.03%	30254.52
Austria	10.59%	19985.04
France	6.39%	12056.63
Switzerland	4.20%	7926.58
Cyprus	3.47%	6542.9
Slovakia	3.24%	6107.65
Italy	2.85%	5379.12
United Kingdom	2.78%	5253.71

Source: International Trade Centre Investment map

Table 11. FDI sources of Poland - 2020

Poland	Percentage to total FDI Stock	FDI stock (US$ million)
Netherlands	22.14%	56061.66
Germany	17.28%	43757.65

Luxembourg	13.08%	33115.87
France	8.50%	21524.19
Cyprus	4.33%	10963.77
Austria	4.20%	10642.02
Belgium	3.60%	9114.41
Switzerland	3.58%	9075.14
United Kingdom	3.51%	8886.54
Spain	3.15%	7974.19

Source: International Trade Centre Investment map

Table 12. FDI sources of Hungary - 2020

Hungary	Percentage to total FDI Stock	FDI stock (US$ million)
Luxembourg	30.03%	103373.7
Switzerland	17.39%	59877.69
Canada	11.64%	40067.51
United Arab Emirates	7.67%	26415.54
Netherlands	5.94%	20447.9
Germany	5.19%	17865.59
Cayman Islands	5.14%	17695.03
United Kingdom	3.91%	13462.02
British Virgin Islands	3.78%	13027.38
Ireland	3.78%	13019.65

Source: International Trade Centre Investment map

Table 13. FDI sources of Slovakia - 2020

Slovakia	Percentage to total FDI Stock	FDI stock (US$ million)
Netherlands	24.88%	14272.03

Austria	16.54%	9488.8
Czech Republic	15.90%	9122.26
Germany	8.21%	4707.89
Korea, Republic of	7.01%	4023.66
Luxembourg	6.66%	3818.61
Italy	6.63%	3802.54
Belgium	5.94%	3408.39
Hungary	4.67%	2679.62
Cyprus	2.52%	1447.36

Source: International Trade Centre Investment map

Table 14. FDI sources of Romania - 2020

Romania	Percentage to total FDI Stock	FDI stock (US$ million)
Netherlands	22.03%	24539.79
Germany	12.2%	13586.94
Austria	11.96%	13326.67
Italy	8.43%	9391.73
France	6.22%	6924.53
Cyprus	6.00%	6683.16
Switzerland	5.13%	5714.73
Luxembourg	4.30%	4794.16
United Kingdom	3.03%	3381.15
Hungary	2.45%	2726.25

Source: International Trade Centre Investment map

Table 15. FDI sources of Russia- 2020

Russia	Percentage to total FDI Stock	FDI stock (US$ million)
Cyprus	28.78%	155352.19

Bermuda	8.90%	48033.05
Netherlands	8.73%	47100.87
United Kingdom	7.78%	42008.87
Area not specified	6.87%	37059.92
Luxembourg	5.95%	32105.15
Ireland	5.55%	29937.62
Bahamas	4.38%	23617.68
France	3.64%	19622.67
Germany	3.50%	18889.07

Source: International Trade Centre Investment map

In each country, FDI originating from industrialised countries in Western Europe constituted a significant majority. FDI originating from the Netherlands has been identified as the leading source of FDI in the Czech Republic, Poland, Romania, and Slovakia. Additionally, investments originating from Germany and Luxembourg have also emerged as significant contributors, ranking top 2 in four countries. Italy, the United Kingdom, France, and Austria are also recognized as prominent players in FDI, ranking in the top 10 investors across various nations. It is also apparent that some nations in CEE have emerged as significant sources of FDI. For instance, the Czech Republic and Slovakia are in the top 10 sources of FDI for each other, while Hungary also has considerable importance as an FDI investor for Romania and Slovakia. The case of Russia is unusual for the inclusion of Cyprus, Bermuda, and the Bahamas, which are tax havens, in its top 10 FDI investors. These countries are functioning as financial intermediaries for investment in Russia as a means of ensuring security and evading regulatory constraints. For example, Russian authorities cannot expropriate assets in Cyprus (Aris, 2019). And based on the statistics provided by UNCTAD in 2017, it is evident that the United States, China, and Russia itself have emerged as significant providers of FDI for Russia, after adjusting for the ultimate investors.

This issue is also evident in other CEE nations, such as the Netherlands, Ireland, and Luxembourg, which are among the leading investors in these regions. Nevertheless, it is worth noting that several nations have not disclosed their FDI data in terms of ultimate investors, hence posing challenges in accurately determining the actual source of these investments. In order to enhance comprehension of FDI, the following tables provide a detailed breakdown of the final investors of FDI in Poland, Estonia, Hungary, the Czech Republic, Slovenia, and Lithuania, in which trustworthy data is available in the OECD database.

According to tables 16 to 21, the nations located in western Europe continue to play a considerable role as contributors of FDI to the countries in CEE, even after accounting for the ultimate source of investment. Notably, Germany, the United Kingdom, and Austria have consistently ranked high in terms of their FDI contributions to several nations in the CEE region. However, the most significant finding is that the United States has emerged as the leading source of FDI in CEE nations and became the top investor in Hungary and Lithuania, after the necessary adjustments. This suggests the substantial inflow of FDI from the US to the CEE countries was flowing through tax havens. Several Asian countries, like Japan and South Korea, have also made their way onto the list, indicating a shift in investment patterns and an increase in investment from Asian nations in this area. Moreover, it is worth noting that a significant number of the nations listed below serve as leading FDI contributors of their own. This observation further supports the assertion made by Aris (2019) about the practice of local corporations transferring funds abroad and then reinvesting them back to mitigate tax liabilities.

Table 16. FDI sources by ultimate investing country Poland - 2020

Country name	FDI amount (million US$)
Germany	54,261
France	27727.89

Netherlands	26706.39
United States	24901.09
United Kingdom	15,425
Spain	13,752
Poland	13,370
Austria	9,171
Switzerland	7,527
Japan	7453.26

Source: OECD statistics BMD4

Table 17. FDI sources by ultimate investing country Estonia - 2020

Country name	FDI amount (million US$)
Finland	7,491
Sweden	6,487
Germany	2,613
Italy	2,532
Estonia	1,585
Luxembourg	1,528
Lithuania	1,439
Jersey	1,222
Russian Federation	992
United Kingdom	959

Source: OECD statistics BMD4

Table 18. FDI sources by ultimate investing country Hungary - 2020

Country name	FDI amount (million US$)
United States	175,457
Canada	21,965
Germany	21,549
Switzerland	18,971

Ireland	11,730
Austria	9,894
Malta	9,580
Korea, Republic of	6,773
France	5,987
United Kingdom	5,529

Source: OECD statistics BMD4

Table 19. FDI sources by ultimate investing country Czech Republic - 2020

Country name	FDI amount (million US$)
Germany	42,639
Czech Republic	31,115
Austria	17,147
United States	13,379
France	13,101
Netherlands	8,096
Italy	7,913
Switzerland	6,919
Belgium	6,900
United Kingdom	6,257

Source: OECD statistics BMD4

Table 20. FDI sources by ultimate investing country Slovenia - 2020

Country name	FDI amount (million US$)
Austria	3,213
Germany	2,942
United States	1,883
Italy	1,807
Switzerland	1,625

Netherlands	1,119
Croatia	980
Hungary	605
Slovenia	600
United Kingdom	564

Source: OECD statistics BMD4

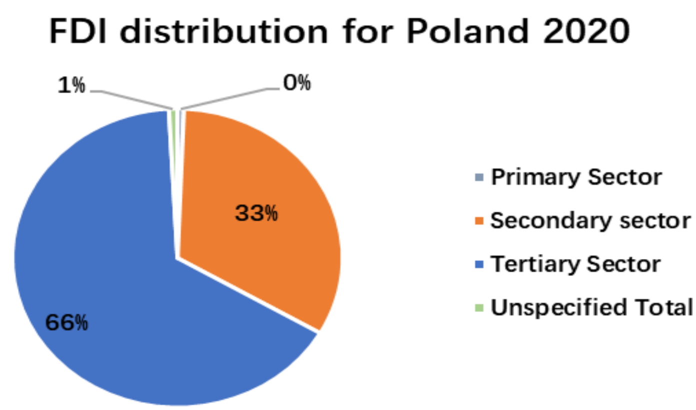
Table 21. FDI sources by ultimate investing country Lithuania - 2020

Country name	FDI amount (million US$)
United States	5,850
Sweden	4,614
United Kingdom	2,398
Germany	1,960
Lithuania	1,504
Estonia	1,216
Netherlands	1,174
Denmark	1,089
Jersey	1,027
Poland	964

Source: OECD statistics BMD4

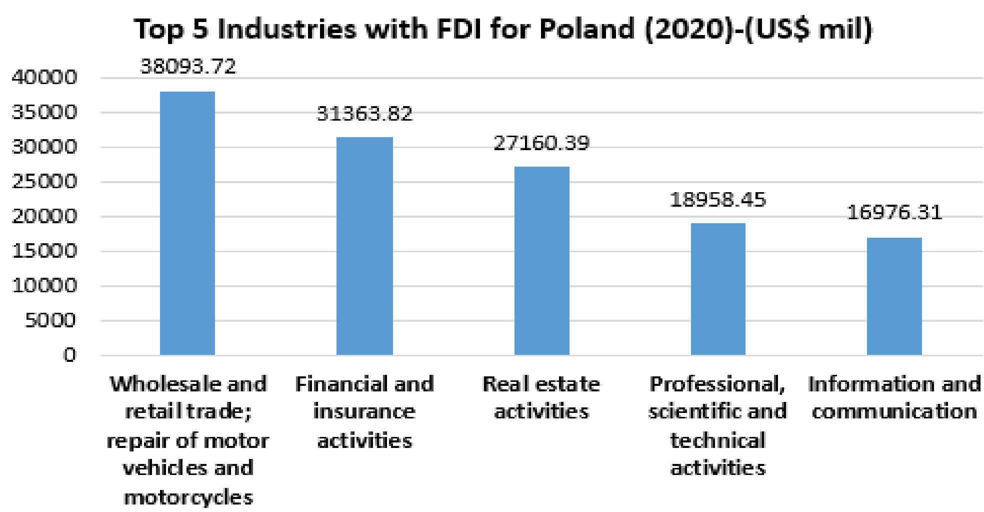
On the other hand, the structure of FDI in CEE countries has also evolved alongside the change of investment partners. The following pie chart breaks down the distribution of FDI funds by industry for the big FDI recipients in CEE.

Figure 8. FDI distribution for Poland 2020 (%)



Source: International Trade Centre

Figure 9. Top 5 industries for FDI (Poland)



Source: International Trade Centre

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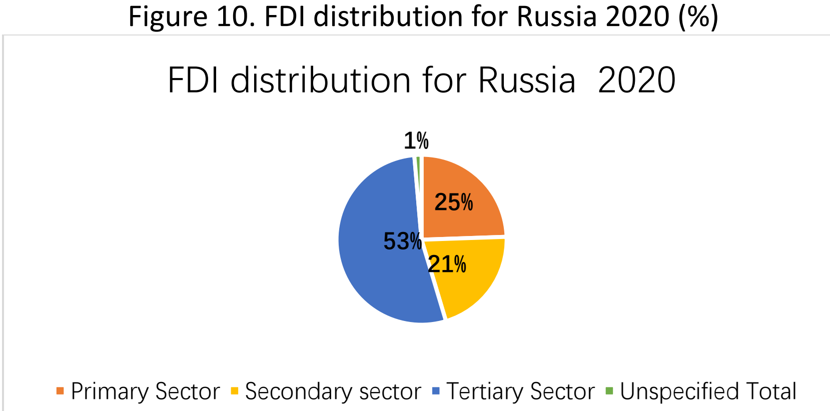
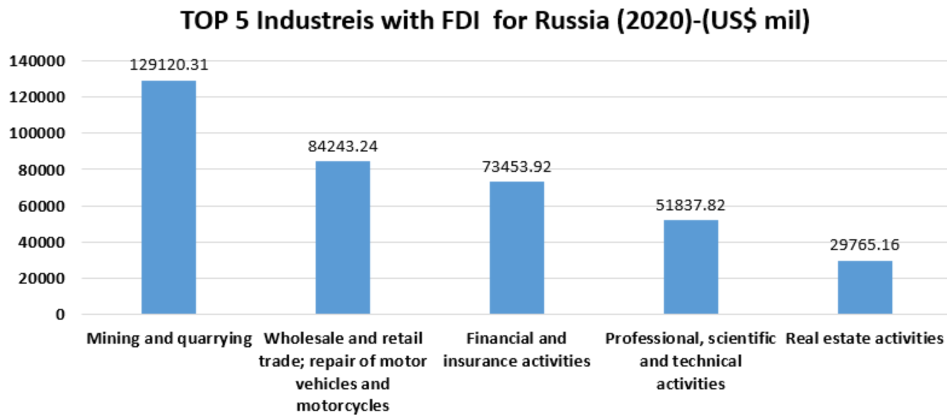
Figure 10. FDI distribution for Russia 2020 (%)



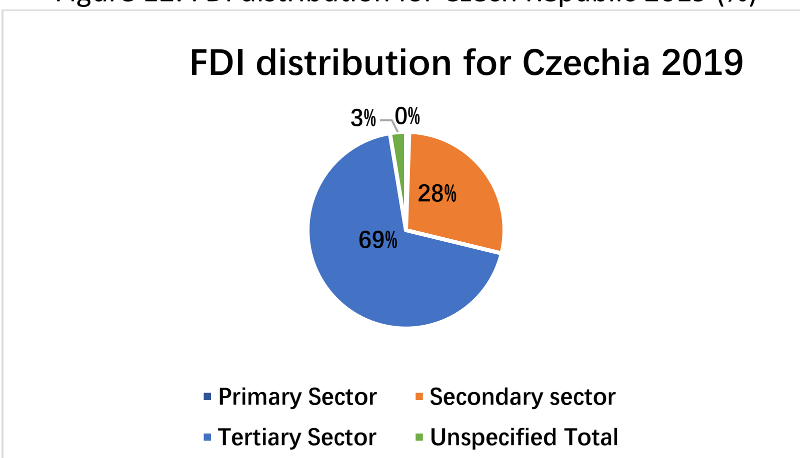
Source: International Trade Centre

Figure 11. Top 5 industries for FDI (Russia)



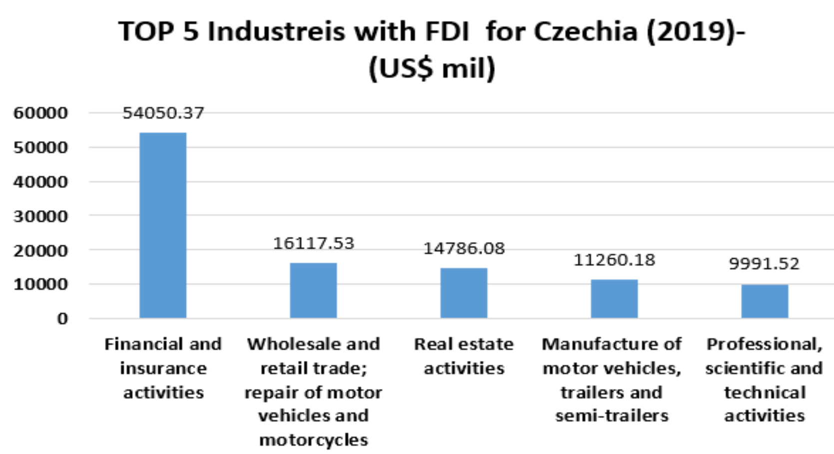
Source: International Trade Centre

Figure 12. FDI distribution for Czech Republic 2019 (%)



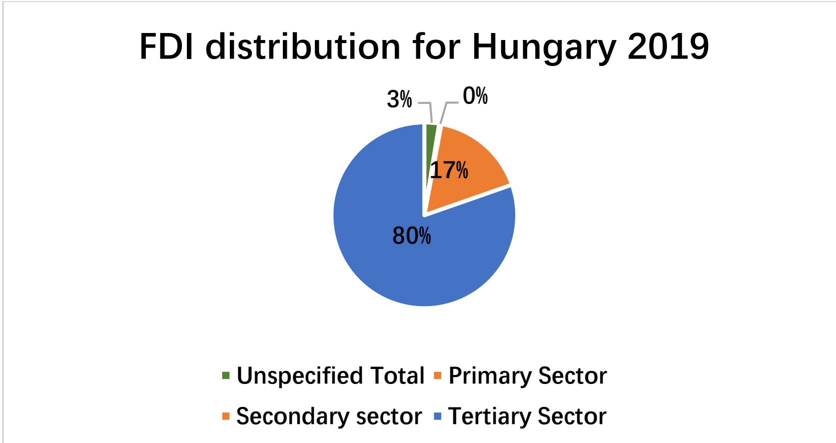
Source: International Trade Centre

Figure 13. Top 5 industries for FDI (Czech Republic)



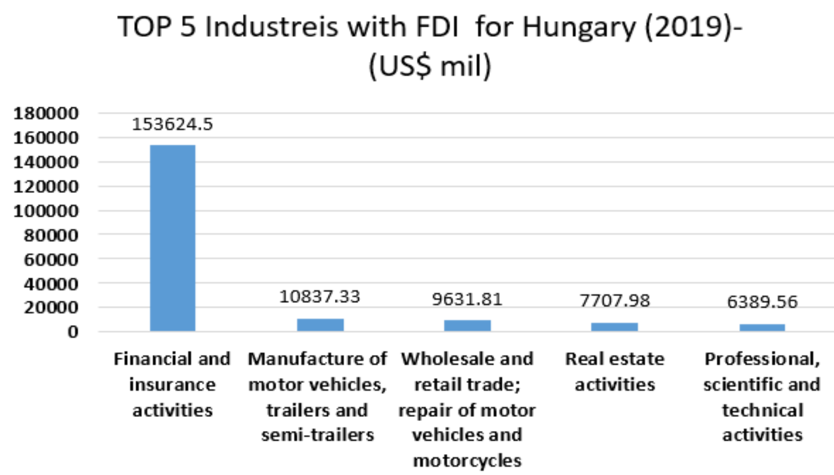
Source: International Trade Centre

Figure 14. FDI distribution for Hungary 2019 (%)



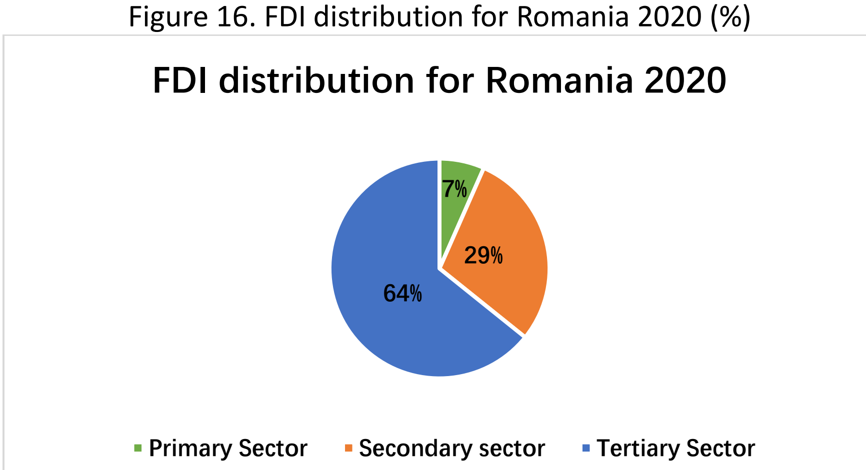
Source: International Trade Centre

Figure 15. Top 5 industries for FDI (Hungary)



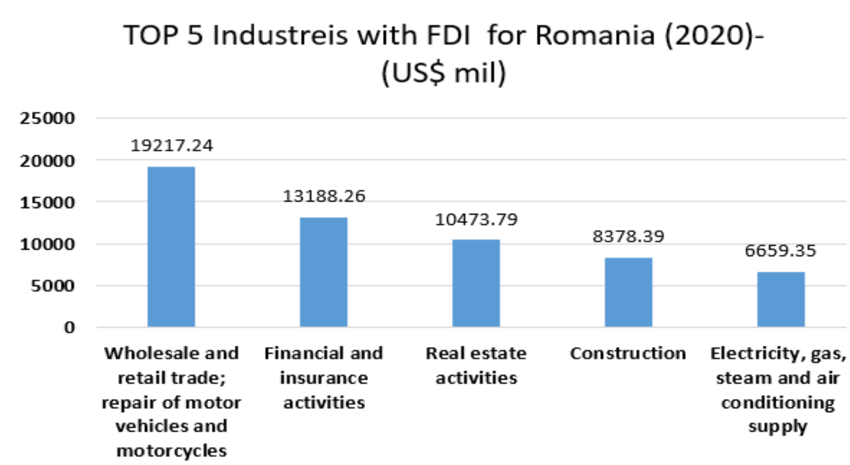
Source: International Trade Centre

Figure 16. FDI distribution for Romania 2020 (%)



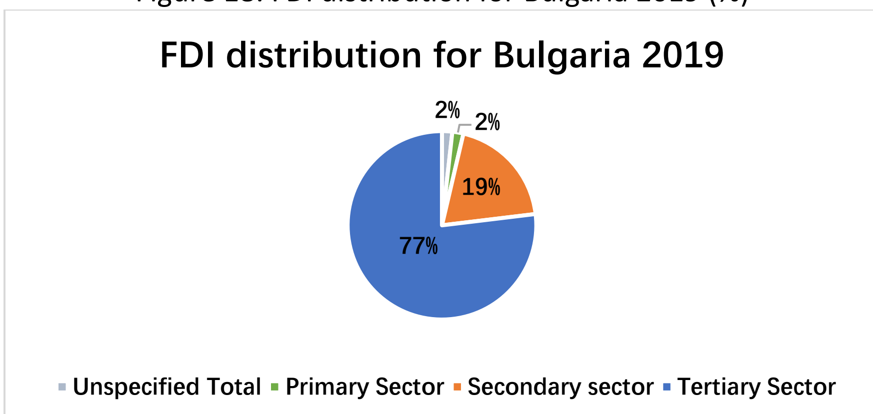
Source: International Trade Centre

Figure 17. Top 5 industries for FDI (Romania)



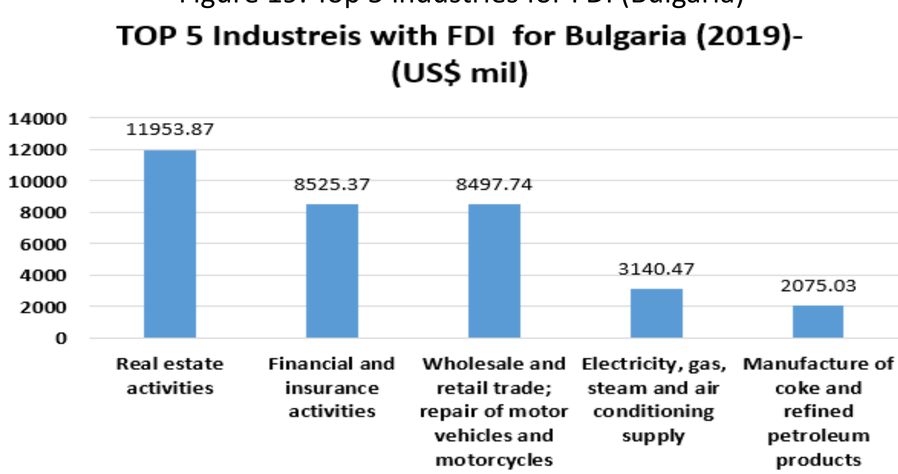
Source: International Trade Centre

Figure 18. FDI distribution for Bulgaria 2019 (%)



Source: International Trade Centre

Figure 19. Top 5 industries for FDI (Bulgaria)



Source: International Trade Centre

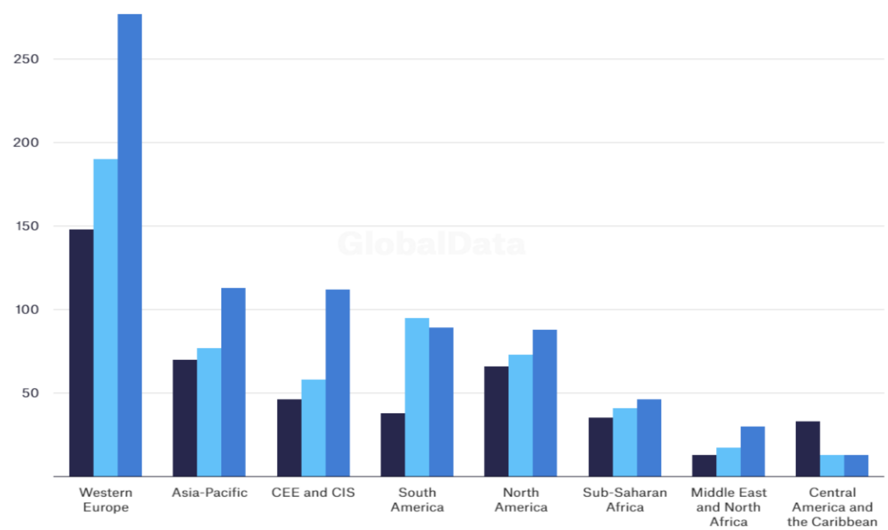
Based on Statista (2020), it can be seen that Poland, Russia, Czechia, Hungary, Romania, and Bulgaria together constituted over 60% of the total FDI stock in the CEE area. Consequently, these countries may be considered suitable representatives for understanding the distribution of FDI over the whole CEE region. The figures demonstrate that, in their most recent observations, all nations possess the biggest proportion in the tertiary sector. This suggests a change in investment concentration from conventional manufacturing to service sectors, aligning with the industrial advancements seen in the majority of CEE countries. However, the secondary industry continues to hold a significant portion of the CEE economy, with the greatest segment being the manufacturing of motor cars, trailers, and semi-trailers, as well as the manufacturing of food goods that have historically been favourable in the Central and Eastern European region. Financial and insurance services have also emerged as a significant area of interest for FDI in CEE, especially evident in the case of Hungary, where FDI in financial and insurance activities constitutes a substantial portion, amounting to 64% of the whole national FDI stock. In addition, the wholesaling, automobile repair, and real estate sectors are significant areas of investment focus, representing the primary sources of economic opportunity in Bulgaria. Moreover, it is interesting that among the countries included in the sample, Russia stands out as the only nation exhibiting a greater proportion of FDI in the primary sector compared to the secondary industry. The FDI in the mining and quarrying industry in Russia accounted for around 20% of the overall FDI stock. This allocation is in line with the economic structure of the nation, which is oriented towards energy exports.

FDI in sustainable development

FDI has emerged as a significant catalyst for promoting sustainable development in the present day. This primarily occurs via the transfer of energy-efficient technologies and the facilitation of renewable energy production. Both channels exist in CEE countries, as FDI is expected to have a significant impact on facilitating the green transition in this area. From 2019 to 2021, there has been a notable growth in

FDI projects focused on renewable and alternative development in the CEE area, rising from 70 to 113 and making the CEE region the third most active region globally in terms of FDI in the renewable energy sector. However, the value of the renewable industry in CEE nations is still only half that of Western European countries. This suggests that there is still significant untapped potential for renewable sector growth in the CEE region, presenting ample opportunities for new investments.

Figure 20. Number of greenfield FDI in renewable energy from 2019 to 2021



Source: GlobalData's FDI Projects Database

In the past decade, there has been a growing trend for countries to invest in renewable energy in CEE. Western European countries have engaged in the development of solar and wind energy infrastructure in the Czech Republic, Romania, and Poland. Since the implementation of the 'Belt and Road' initiative, China has also increased its FDI in the CEE region, particularly in the Balkans and Russia, and established ever-stronger energy cooperation with Russia and Serbia.

The table shown below illustrates the trajectory of FDI in renewable projects across 20 countries in CEE for the period from 2003 to 2023. In this analysis, the CEE region has attracted a total of 796 FDI projects, with a cumulative value of $1,113,070 million. Renewable FDI in CEE had its first surge in about 2011, followed by a subsequent wave starting in 2018 that has persisted to the present. The total FDI reached its highest point in 2011, amounting to around $14,000 million. Subsequently, there has been a consistent upward trend in FDI from 2018 to May 2023. In recent times, a notable increase in the average number of renewable investment projects has seen, leading to a consequential rise in job prospects for the nations hosting such initiatives.

Table 22. Renewables FDI for 20 CEE countries 2003 to 2023 by year (May)
(Currency unit $US mil)

Year	Projects	Capex	Avg capex	Jobs created
2023	25	6,408.0	256.3	2,450
2022	58	7,763.3	133.8	3,430
2021	49	6,000.8	122.5	3,342
2020	60	4,545.5	75.8	3,024
2019	57	4,174.4	73.2	2,431
2018	42	3,905.2	93.0	2,218
2017	23	1,527.0	66.4	938
2016	13	1,489.9	114.6	625
2015	11	905.1	82.3	445
2014	21	2,840.8	135.3	1,072
2013	53	6,878.6	129.8	2,686
2012	60	9,155.5	152.6	3,565
2011	76	13,917.1	183.1	6,545
2010	51	7,083.4	138.9	3,018
2009	48	11,705.2	243.9	3,870
2008	59	11,956.5	202.7	4,196
2007	42	6,280.9	149.5	3,416
2006	31	3,942.3	127.2	2,143
2005	11	1,335.2	121.4	917
2004	1	524.0	524.0	128

2003	5	732.1	146.4	228
Total	796	113,070.8	142.0	50,687

Source: fDi Markets by Financial Times

From the perspective of the recipients, Poland received 156 FDI projects in the renewable energy industry over the past two decades and ranked first on the list. Romania ranked first with the most FDI stock and the most employment generated, despite having 122 FDI ventures. Serbia, Bulgaria, and Hungary are also among the primary recipients of renewable FDI, superseding traditional FDI titans such as Russia and the Czech Republic. And according to figure 21, 40% of renewable FDI was invested in wind farms, 29% in solar electricity, and 19% in biomass energy. Investing in hydroelectric and geothermal energy accounted for only 7% of the total. This could be a result of the distribution of FDI and the geographical advantages of host nations.

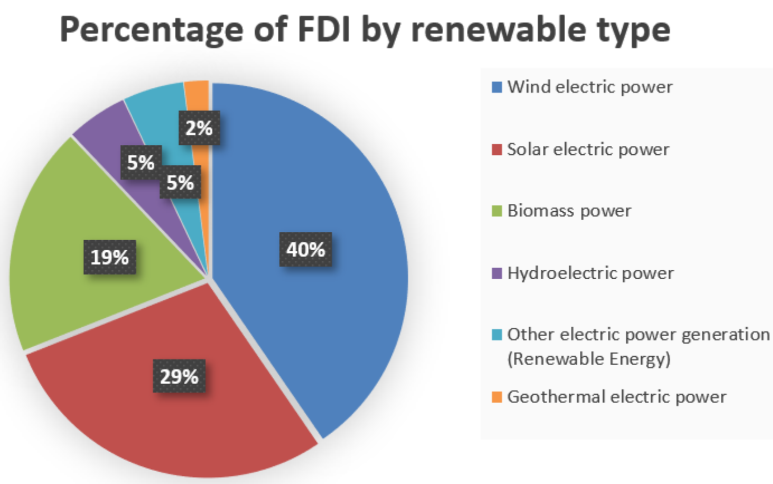
Table 23. Renewables FDI for 20 CEE countries 2003 to 2023 (May) by country (Currency unit $US mil)

Destination Country	Projects	Capex	Avg capex	Jobs created
Poland	156	11,761.2	75.4	8,229
Romania	122	31,722.4	260.0	9,731
Bulgaria	93	15,632.1	168.1	5,950
Serbia	72	10,746.4	149.3	4,704
Hungary	53	4,418.2	83.4	3,188
Russia	49	5,377.1	109.7	2,992
Ukraine	48	5,966.6	124.3	2,512
Bosnia-Herzegovina	35	5,427.2	155.1	2,661
Croatia	29	3,218.8	111.0	2,176
Czech Republic	24	3,354.5	139.8	1,489
Lithuania	20	2,613.1	130.7	1,112
Estonia	19	1,006.5	53.0	988

Latvia	16	3,111.0	194.4	1,336
Slovakia	16	1,246.6	77.9	1,061
North Macedonia	12	2,271.0	189.3	719
Albania	10	2,478.4	247.8	672
Belarus	10	1,102.7	110.3	475
Montenegro	8	1,492.2	186.5	546
Moldova	2	44.5	22.3	110
Slovenia	2	80.5	40.3	36
Total	796	113,070.8	142.0	50,687

Source: fDi Markets by Financial Times

Figure 21. Distribution of renewable FDI in CEE by sector



Source: fDi Markets by Financial Times

Table 24. Renewable FDI in CEE amount by sector (Currency unit $US mil)

Wind electric power	Solar electric power	Biomass power	Hydroelectric power	Other electric power	Geothermal electric
53,908.3	30,141.4	15,284.2	7,632.9	3,837.4	2,266.6

Source: fDi Markets by Financial Times

Regarding the source of renewable FDI in CEE countries, the EU's developed nations continue to be the most significant investors. Germany topped the investment list in terms of both the number of projects and the total investment sum. Italy, Spain, Austria, and France ranked second through fifth and contributed 33 percent of total investment. While China and the United States were also significant investors in renewable energy in Central and Eastern Europe, the Czech Republic and Lithuania were also investing in renewable energy in neighbouring countries. In addition, the vast majority of foreign FDI concentrated on electricity generation to improve sustainability, while a portion of the funds went directly to industries such as sales, manufacturing, and transportation, where they would likely improve energy efficiency.

Table 25. Top 20 Renewables FDI investors for 20 CEE countries 2003 to 2023 (May) (Currency unit $US mil)

Destination Country	Projects	Capex	Avg capex	Jobs created
Germany	132	16,954.1	128.4	7,994
Italy	71	10,493.2	147.8	4,318
Spain	66	10,590.0	160.5	4,284
Austria	55	7,417.5	134.9	2,795
France	51	8,634.2	169.3	3,388
China	40	5,297.2	132.4	2,385
United States	29	6,315.0	217.8	3,426
Denmark	26	3,360.3	129.2	1,363
Netherlands	25	3,708.6	148.3	1,748
Norway	24	2,602.3	108.4	1,182
Czech Republic	23	4,030.7	175.2	1,521
Finland	22	2,155.0	98.0	1,178
Lithuania	22	1,881.0	85.5	873
Portugal	22	2,226.8	101.2	1,469
Belgium	18	1,793.2	99.6	750
Sweden	18	2,731.7	151.8	1,473
Israel	13	2,211.6	170.1	894
United Kingdom	13	2,000.7	153.9	993

Estonia	12	1,159.9	96.7	643
Japan	12	2,709.1	225.8	963

Source: fDi Markets by Financial Times

Table 26. Renewable energy FDI by business activity for CEE countries 2003 to 2023 (May) (Currency unit $US mil)

Industry Business activity	Projects	Capex
Electricity	648	99564
Sales, Marketing & Support	71	6349.7
Manufacturing	67	6736.7
Logistics, Distribution & Transportation	3	371.1
Customer Contact Centre	2	0.5
Recycling	2	12.1
Business Services	1	9.2
Headquarters	1	9.7
Research & Development	1	17.8

Source: fDi Markets by Financial Times

Chapter 5. Methodology and Data

The source of data

In order to ascertain the impact of FDI on the green transition of CEE countries, conducting the empirical analysis necessitates the utilization of data encompassing the emissions of various types of major greenhouse gases, the flow and stock of FDI, production and consumption of renewable energy, as well as other relevant demographic and economic variables including annual data of gross domestic product (GDP), population, trade volume, and so forth.

The primary data source used in this study is the World Bank database, which has reliable greenhouse gas emission statistics. Additionally, the database offers a comprehensive range of economic and societal data that could be chosen as control variables for the research. In addition, I would consider using the database provided by the European Energy Agency and EU statistics to access comprehensive information pertaining to the development, production, and consumption of renewable energy in CEE nations.

I would also consult the Chinese Belt and Road database and the national statistics of CEE countries, as well as perform my own calculations if I was unable to locate the necessary data in a large public database. In order to assure the validity and readability of the data, the source and calculation procedure will be presented in context.

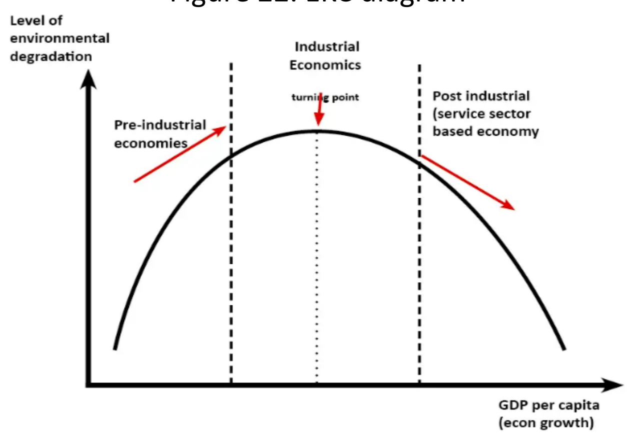
The construction of the model and variables

Environmental Kuznets Curve model

The Kuznets Curve was first proposed by Simon Kuznets in the 1950s and 1960s as a means to articulate his idea of the U-shaped correlation between economic progress and economic inequality (Kuznets, 1955). During the 1990s, a number of researchers initiated the introduction of the notion that economic growth is the foremost determinant of the environment and established the basis for the Environmental Kuznets Curve. It was suggested that the environment would initially deteriorate in the early stages of economic growth, but would tend to improve as nations became wealthier (Kaika and Zervas, 2013). The threshold at which economic growth begins to have a beneficial influence on environmental deterioration is regarded as the turning point. This threshold varies across various samples depending on their industrial and demographic circumstances (Tenaw & Beyene, 2021)

In recent years, this model has gained significant recognition and is used as a tool for analysing the correlation between economic elements and environmental factors across various samples. In several regions, including the United States, sub-Saharan Africa, China, Japan, and some Southeast Asian nations, scholars have identified the presence of inverted U-shaped interactions (Pata, 2021; Liu et al., 2018; Tenaw and Beyene, 2021). In addition to addressing the conventional carbon emission problem, the model was discovered to be applicable to a diverse array of environmental issues. Paudel, Zapata, and Susanto (2005) established a validated EKC association between water pollution and income level in Louisiana. Similarly, Murshed (2022) discovered a comparable outcome for deforestation and economic growth in Bangladesh.

Figure 22. EKC diagram



While the EKC has also been studied for the sample of CEE nations. Piatowska and Wodarczyk (2017) have demonstrated the EKC for a sample of 10 CEE nations and discovered that an extended EKC model with asymmetric better explains the economic-environment pattern for the sample nations. Majewska and Gieratowska (2022) stated further that the Human Development Index as the primary explanatory variable produced a superior model suiting the EKC for CEE and that energy consumption per capita has a substantial effect on greenhouse gas emissions.

Overall, the EKC model has been demonstrated to be a suitable instrument for examining the relationship between economic and environmental factors over a broad range, and it permits modification and extension based on the sample to produce accurate results. Consequently, empirical models based on EKC will be constructed in this paper.

Model modification

The formula of original EKC equation is as below (Agras and Chapman, 1999):

$$CO_{2\,i,t} = a_0 + a_1 GDP_{i,t} + a_2 GDP_{i,t}^2 + \varepsilon_{i,t} \quad (1)$$

The dependent variable CO_2 is the carbon dioxide emission per capita. G The primary independent variable is the GDP (per capita), which indicates the income level or economic growth. The parameters a_1 and a_2 together measures the relationship between income level and carbon emissions, the change in carbon emissions when income increases. a_0 is the constant estimated parameter and ε_{it} denotes the random error correlated in the analysis.

When the parameters a_1 and a_2 are statistically significantly under desired significance level, the relationship between the dependent and independent variables is nonlinear and U-shaped. But we can only conclude that the EKC model is validated in the cases that a_2 < 0 and a_1 > 0; therefore, the inverted U-shaped relationship exists, with the turning point arriving at a reasonable income level. If a_2 > 0 and a_1 < 0, the quadratic function connection remains valid. However, the outcome indicates that pollution would initially decrease with economic progress but subsequently rise, which contradicts the EKC hypothesis.

If the EKC hypothesis is validated or there exist a U-shaped relationship, the turning point should also be identified. Following the equation (1) and equation (2) of Stern (2004), the turning point is:

$$\textit{Turning Point } CO_2 \max \rightarrow GDP_{tp} = -\left(\frac{a_1}{2a_2}\right),\ a_2 \neq 0 \quad (2)$$

While overall considering the methods of papers investigated EKC in CEE, the selected sample countries, and the data availability. I would modify the equation of original EKC to the modified equation that is shown below:

$$Ln\_GHG_{i,t} = a_0 + a_1FDI_{i,t} + a_2FDI_{i,t}^2 + a_3Ln\_GDP\_per\_capita + a_4X_{i,t} + \varepsilon_{i,t} \quad (3)$$

The dependent variable in equation 3 is Ln_GHG, which represents the logarithm of total greenhouse gas emissions, including Carbon dioxide, Methane, and Dinitrogen oxide. The primary independent variable for FDI and squared FDI would be the sample countries' FDI stock as a percentage of GDP. Ln_GDP_per_capita, the logarithm of annual GDP per capita, is another explanatory variable that approximates national income and was identified as a major contributor to greenhouse gas emissions. X is an array of control variables that includes energy consumption ratio and energy intensity level. a_1 and a_2 are the coefficients of interest for this study, expressing the relationship between FDI and the greenhouse gas emissions. These coefficients are necessary for evaluating the validity of EKC and calculating the turning point. The correlation coefficients a_3 and a_4 express correlation between the control variables and greenhouse gas emissions. a_0 is the constant unit and $\varepsilon_{i,t}$ is the random error.

Chapter 6. Empirical Analysis

Data preliminary analysis

The data compiled for this analysis encompass 18 CEE countries and the years 2001-2021, during which the data I comprehensive and the panels are well-balanced. Serbia and Montenegro are excluded from the sample because their data was absent for a long time during the observation period as a result of their historical circumstances. And in this section, the preliminary analysis of the variables in the subsequent empirical models would reveal their distribution, historical trend, and how CEE countries behave in each sector. The variables for the regression analysis are listed in the table below.

Table 27. The variable list

Variable name	Description
GHG	Greenhouse gases emission quantity
FDI^2	The square form of the percentage of FDI stock to GDP
FDI	The percentage of FDI Stock to GDP
GDP_per_capita	GDP per capita
Energy Intensity	The amount of energy used to generate 1 unit of GDP (2015$ GDP PPP)
Energy consumption per capita	Energy consumption per capita
Population	Population by country
Renewable Production	The electricity generated by renewable source
Renewable Consumption	renewable energy consumption to total energy consumption
Urbanisation	Urban population to total population

Greenhouse gases emission

The overall amount of greenhouse gas emissions, which acts as a proxy for environmental deterioration, the main problem that the green transition attempts to address, is the dependent variable for the FDI-EKC analysis in this research. This paper uses the cumulative emission number of carbon dioxide, methane, and nitrous oxide, which are the main greenhouse gases for CEE countries, as the dependent variable, in contrast to traditional publications exploring only the CO_2 emission. The data pertaining to this variable were obtained from the Climate Data Explorer provided by CAIT. The emissions of all greenhouse gases have been transformed into their respective quantities of carbon dioxide equivalents.

The distribution of greenhouse gas emissions across the sample countries is presented in Table 28. The data clearly indicates that the Russian Federation is the predominant source of greenhouse gas emissions in the CEE region, displaying the highest average value. In the year 2021, the greenhouse gas emissions of Russia reached a record high of 241 million kt of CO_2 equivalent, representing the highest value among all the countries included in the sample during the period of observation. Ukraine and Poland were significant contributors to greenhouse gas production, occupying the second and third positions, respectively, within the sample. Nevertheless, their average emission values were only approximately 20% of that of Russia. Moreover, Moldova and Albania were positioned at the lower end of greenhouse gas production in the CEE region, with an average emission level of less than 10 million t CO_2 equivalent. This accounts for less than 1% of the average gas production in Russia. Furthermore, it is noteworthy to mention that among the 18 countries analysed, 15 countries exhibited an average emission level that was lower than the overall group mean. This observation indicates a notable disparity in the total emissions across the countries within the CEE region. The graph presented below illustrates the trend of greenhouse gas emissions in the selected countries. Over the course of a 20-year period, it has been observed that the majority of countries in the CEE region have exhibited a stable tendency. This suggests that these countries have actively endeavoured to regulate and mitigate greenhouse gas emissions while simultaneously experiencing economic growth.

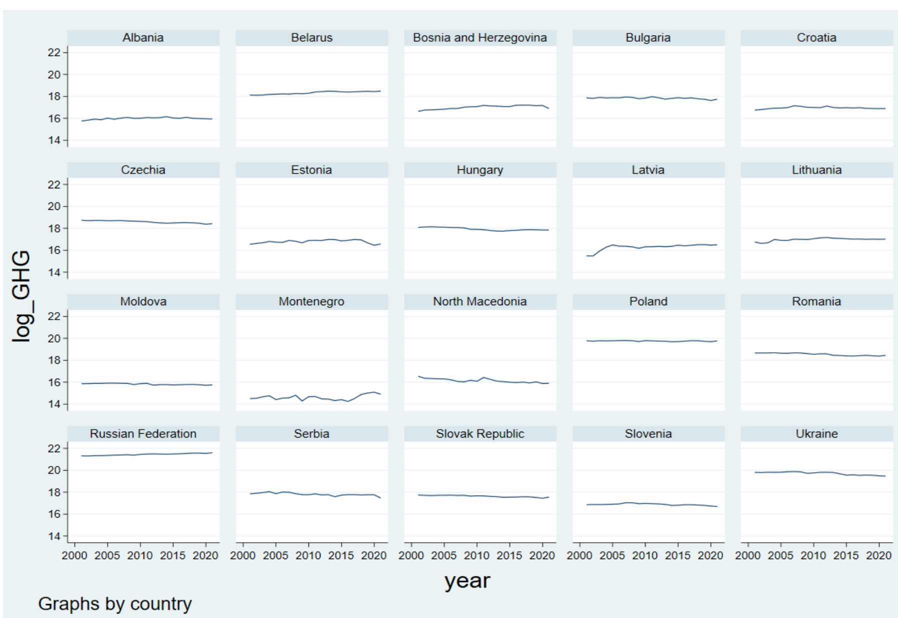
In the meantime, the absolute value of greenhouse emission is excessively high, resulting in a coefficient that is notably small; consequently, this variable will be transformed into its natural logarithmic form for further analysis.

Table 28. Summary for greenhouse gases emission (unit: 10^3 t CO_2 equivalent)

Country	Max	Min	Mean	p50
Albania	10300	7000.947	8835.526	8939.39
Belarus	107000	73300	91800	98200
Bosnia and Herzegovina	29700	16800	24700	25900
Bulgaria	64200	45300	56100	57300

Croatia	28000	18800	23200	23000
Czechia	138000	95600	119000	121000
Estonia	23800	14100	19800	20100
Hungary	75700	50800	62300	58200
Latvia	14800	**5287.171**	12200	12700
Lithuania	28600	16700	23800	24400
Moldova	8168.688	6681.227	7479.892	7267.979
North Macedonia	15300	7892.263	10400	9697.051
Poland	400000	358000	381000	386000
Romania	131000	96400	114000	118000
Russian Federation	**2410000**	1790000	**2070000**	**2100000**
Slovak	50900	37800	45600	46000
Slovenia	25200	17800	21500	21400
Ukraine	431000	284000	368000	394000
Total	2410000	5287.171	192000	33800

Figure 23. Trend of logarithm of greenhouse emissions by country



FDI

FDI is the central focus of this paper and serves as the primary independent variable in this study. The modified EKC model in this analysis incorporates both the original and squared forms of the variable under consideration. This is conducted to assess the correlation between the variable and the FDI index, as well as to identify the turning point for the inverted U-shape correlation if such a relationship is confirmed. The FDI data has been sourced from the OECD statistics. In order to address the significant discrepancy in FDI stock resulting from economic circumstances identified in previous analyses, I have opted to use the ratio of FDI stock as a percentage of GDP as a suitable proxy for this variable.

A summary of the distribution of FDI figures in CEE nations is shown in table 29 that is shown below. In terms of FDI stock, Estonia emerged as the leader, with the greatest value equal to 112% of its GDP and an average value that hovered around 80%, placing it at the top of the list. The Czech Republic, Hungary, and the Slovak Republic are all among the top nations, with a value exceeding 56% on average. It is also noteworthy to see that Bulgaria outperformed the developed nations and came in second, while Poland only had an average value of roughly 36%, below the group norm. The average ratio of FDI stock was similarly lowest in Belarus, with Slovenia and Russia following closely after. This pattern suggests that the magnitude of this variable is far less changeable than greenhouse gas emissions, with a total of eight countries exceeding the average value of the group. Additionally, industrialised regions' values are not always higher than those of less developed nations.

Table 29. Summary for FDI stock as percentage of GDP (%)

Country	Max	Min	Mean	p50
Albania	64.43%	8.27%	31.29%	30.77%
Belarus	39.02%	**7.16%**	18.19%	21.04%
Bosnia and Herzegovina	47.83%	9.37%	34.95%	39.38%

Bulgaria	94.62%	20.77%	70.40%	79.60%
Croatia	69.60%	15.23%	46.76%	51.91%
Czechia	79.58%	39.95%	58.25%	60.66%
Estonia	**112.59%**	50.34%	**79.11%**	**80.65%**
Hungary	81.03%	50.99%	63.78%	64.29%
Latvia	61.11%	22.27%	43.16%	45.35%
Lithuania	51.95%	21.78%	36.79%	38.51%
Moldova	41.72%	30.90%	37.22%	37.15%
North Macedonia	58.55%	24.69%	43.90%	46.00%
Poland	45.66%	21.16%	35.66%	38.92%
Romania	44.79%	17.03%	35.41%	38.47%
Russian Federation	37.20%	12.69%	23.99%	23.15%
Slovak Republic	67.45%	37.95%	56.53%	57.56%
Slovenia	37.93%	12.08%	25.32%	22.79%
Ukraine	51.10%	12.21%	31.28%	35.82%
Total	112.59%	7.16%	42.89%	39.80%

GDP per capita

The GDP is the most frequently examined variable in environmental analyses and the primary explanatory variable in the original EKC formula. The expansion of GDP will result in a rise in production and consumption across every sector of the economy. Consequently, the GDP is considered a significant contributor to greenhouse gas emissions. Nevertheless, the U-shaped relationship between economic development and carbon quantity has also been demonstrated in certain regions. Consequently, it is essential to include the impact of GDP in this analysis, as it would function as a control variable in the equation. The data for GDP was obtained from the World Bank database and represent the annual GDP per capita in US dollars for each nation.

The distribution of GDP per capita in the CEE nations is displayed in Table 30 below. The developed nations have, on average, the highest per capita Gross Domestic Product values, with Slovenia having the highest at $21,925. The Czech Republic, Estonia, Lithuania, Latvia, and Slovakia are also prominent nations in the CEE regions, with their highest value exceeding $20,000 USD. However, Moldova, Ukraine, and Albania are considered to be the least developed countries in the sample, with a median value of less than $4000. Despite the fact that half of the sample has an average GDP level that is higher than the group average, the disparity in GDP in the CEE region is significant, with the wealthiest country having a level that is ten times that of the weakest. In addition, as the absolute value of GDP per capita is substantial, it would be converted to its natural logarithm for subsequent analysis.

Table 30. Summary for GDP per capita (unit: US$)

Country	Max	Min	Mean	p50
Albania	6377.20	1281.66	3877.88	4124.06
Belarus	8341.29	1244.37	5249.42	5967.07
Bosnia and Herzegovina	7230.20	1382.77	4354.656	4688.35
Bulgaria	12222.24	1770.91	6716.31	7271.31
Croatia	17747.79	5364.01	12632.65	13664.21
Czechia	26822.51	6637.18	18179.23	19870.8
Estonia	27943.7	4505.86	16276.86	17403.21
Hungary	18772.14	5276.03	13007.35	13217.5
Latvia	21080.18	3578.00	12749.42	13847.34
Lithuania	23712.54	3525.79	13239.79	14367.71
Moldova	5235.64	**507.40**	2508.32	2749.91
North Macedonia	6694.64	1823.02	4496.73	4841.25
Poland	17999.83	4991.24	11772.46	12560.05
Romania	14927.12	1825.19	8418.67	8976.96

Russian Federation	15974.62	2100.35	9425.00	10194.44
Slovak Republic	21782.86	5722.16	15651.57	16908.85
Slovenia	**29291.4**	10479.76	**21925.16**	**23514.03**
Ukraine	4827.85	807.80	2799.17	3078.43
Total	29291.4	507.40	10182.26	8823.02

Energy intensity

The measurement of energy intensity refers to the quantity of energy used in the generation of a fixed unit of GDP. A higher energy intensity value would suggest the country is less efficient in utilising its energy resources to generate economic outputs, which in turn has the potential to contribute to an increase in greenhouse gas emissions. The statistics on energy intensity are derived from the U.S. Energy Information Administration, and the value is expressed by the energy consumed to generate a fixed unit of GDP at 2015 US$ PPP.

According to the data shown in table 31, it can be seen that Ukraine exhibits the highest energy intensity index on average. Similarly, Russia and Belarus have considerable energy intensity, suggesting a relatively lower level of energy efficiency in these regions. This could be due to their high dependence on fossil fuel consumption. While the countries situated around the Baltic coast, which are considered developed nations, as well as the less developed areas such as Albania and North Macedonia, had a comparatively greater rate of energy efficiency, Estonia, a specific country with a great share of renewable energy use, has the lowest average energy intensity. And the disparity for energy intensity was small, with 10 countries having an average value under the group mean.

Table 31. Summary for Energy Intensity (unit: 1000 Btu/2015$ GDP PPP)

Country	Max	Min	Mean	p50
Albania	5.36	2.95	3.97	3.83
Belarus	12.21	5.21	7.48	6.80
Bosnia and Herzegovina	7.90	4.67	5.91	5.81
Bulgaria	9.22	4.69	6.38	5.90
Croatia	4.82	3.16	3.82	3.76
Czechia	6.97	4.13	5.40	5.32
Estonia	3.82	**2.19**	2.54	2.48
Hungary	5.20	3.39	4.15	4.17
Latvia	5.36	2.76	3.75	3.53
Lithuania	6.60	2.71	4.14	3.76
Moldova	8.32	4.60	6.02	5.77
North Macedonia	5.38	3.48	4.35	4.30
Poland	6.14	3.36	4.61	4.44
Romania	6.58	2.57	3.99	3.64
Russian Federation	12.61	8.48	9.55	8.92
Slovak Republic	9.23	3.87	5.65	5.09
Slovenia	5.67	3.43	4.57	4.58
Ukraine	**16.64**	7.27	**10.74**	**10.01**
Total	16.64	2.19	5.39	4.79

Energy consumption per capita

The energy consumption per capita is commonly included in papers focusing on environmental issues, and several papers that examined CEE countries found it to be substantially related to carbon emission and other environmental concerns. From the perspective of greenhouse gas emissions, a higher value of energy consumption per capita is indicative of a nation's greater energy demand and higher level of greenhouse gas emissions. And the data of this variable is the primary energy consumption per capita of each country that recorded by the World Bank.

Table 32 provides a summary of energy consumption data, revealing that the Russian Federation is the largest consumer of energy, achieving the maximum value in the sample and ranking first in terms of average value. Additionally, other industrialised nations such as Estonia, Czech Republic, and Slovenia are noticeable positioned on the list with per capita consumption levels exceeding 40000 kilowatt-hours. Countries with the lowest per capita gross domestic product, such as Moldova, Albania, and North Macedonia, also had the lowest average energy consumption.

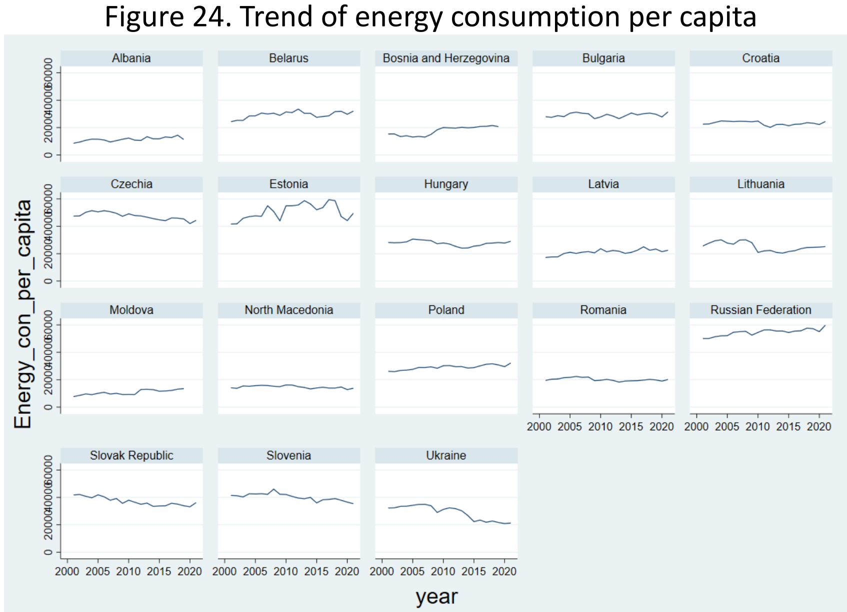
The below figure 24 depicts the evolving pattern of energy consumption value across CEE nations during the observation period. Energy consumption has decreased in The Czech Republic, Ukraine, the Slovak Republic, and Slovenia, while it has increased in Russia, Belarus, Poland, and Bosnia and Herzegovina. Other nations are generally comparatively stable, whereas Estonia has experienced the greatest fluctuations. In addition, because the absolute value of this variable is typically large, it will be transformed into its natural logarithmic form during regression analysis.

Table 32. Summary for Energy consumption per capita (unit: KWH/ person)

Country	Max	Min	Mean	p50
Albania	14483.85	8635.532	11428.2	11524.43
Belarus	33557.43	24306.93	29459.62	29999.41
Bosnia and Herzegovina	21542.25	13117.11	17652.09	19624.72
Bulgaria	31603.25	26533.45	29155.77	29289.73
Croatia	24878.12	20222.33	23233.91	23200.73
Czechia	51398.59	41980.63	47390.74	47432.22
Estonia	59397.73	41647.34	50764.18	50750.43

Hungary	30652.67	24061.92	27648.39	27804.6
Latvia	25046.83	17236.14	21186.84	21348.52
Lithuania	30115.12	20413.02	25180.09	24812.76
Moldova	13488.84	**7673.85**	10740.55	10069.24
North Macedonia	16186.00	12811.62	14691.22	14689.19
Poland	32210.06	25864.03	29125.96	29419.19
Romania	22364.22	18270.23	20151.36	19839.05
Russian Federation	**59913.56**	50112.77	**54639.78**	**55091.67**
Slovak Republic	42124.31	33144.22	37133.95	36195.94
Slovenia	46037.57	35382.96	40216.32	40319.9
Ukraine	34933.59	20908.51	28818.45	31235.10
Total	59913.56	7673.85	29062.7	27755.26

Figure 24. Trend of energy consumption per capita



Renewable production

In addition to investigating the relationship between FDI and the green transition from the perspective of reducing carbon emissions, renewable energy production is also essential. The development of renewable energy production could assist in the reduction of greenhouse gas emissions, but it would also have a greater impact on enhancing energy security and resiliency to climate impacts. On top of that, this variable acts as the dependent variable in the second empirical analysis carried out in this paper. The quantity of electricity generated from renewable sources, as recorded in the World Bank database, serves as a proxy for renewable energy production.

The table below demonstrates that the Russian Federation, the largest energy consumer and fossil fuel producer in the CEE region, is also the leader in the production of renewable energy. Countries with larger territories, such as Ukraine, Romania, and Poland, are also significant renewable energy producers, indicating that the natural advantage may be a significant factor influencing the production of renewable energy. Moldova, on the other hand, has the lowest average value of renewable energy production, which is 0.1% of that of Russia, confirming the enormous disparity in CEE for this variable. In addition, the logarithmic form of this variable's absolute value will be used to enhance the coefficient values in the subsequent regression analysis.

Table 33. Summary for Renewable Energy production (unit: KWH)

Country	Max	Min	Mean	p50
Albania	2414.56	1453.10	1718.21	1508.56
Belarus	490.50	11.03	134.92	35.13
Bosnia and Herzegovina	2032.48	1508.00	1688.13	1700.56
Bulgaria	4451.67	893.00	3064.87	2950.00
Croatia	3453.60	2057.00	2467.59	2273.80
Czechia	4415.46	1094.59	2918.01	3680.50
Estonia	988.70	**7.00**	359.70	334.20
Hungary	3022.26	67.00	988.67	766.00
Latvia	1856.61	1526.00	1677.89	1642.00

Lithuania	1165.00	105.00	454.25	351.30
Moldova	129.97	56.00	73.79	64.00
North Macedonia	963.37	443.00	622.81	558.00
Poland	16872.17	902.00	4771.46	3018.51
Romania	11212.05	6245.00	8508.03	7410.00
Russian Federation	**56101.53**	45113.13	**49532.88**	**48111.87**
Slovak Republic	2431.00	1592.00	2048.34	2300.50
Slovenia	1617.11	925.00	1239.83	1184.00
Ukraine	14921.00	4646.70	6499.69	4945.40
Total	56101.53	7.00	4931.62	1601.85

Renewable consumption

The ratio of renewable energy consumption will be included as a control variable in the examination of the relationship between FDI and renewable energy production. This variable has a significant effect on the environment performance of the targets, according to Majewska and Gieratowska (2022). They argued that an increase in the use of renewable energy can contribute to a reduction in emissions and an improvement in environmental conditions, while a higher renewable energy consumption ratio can also stimulate and expand the production of renewable energy from a demand and supply standpoint. The variable renewable consumption is calculated by dividing the proportion of renewable energy consumption by the total energy consumption. The data was retrieved from the World Bank's database.

According to table 34, Albania, Latvia, and Estonia had the greatest utilisation rates of renewable energy, surpassing 40%. And these figures are aligning with their comparatively lower energy intensity. The countries exhibiting the greatest energy intensity, namely the Russia Federation, Ukraine, and Belarus, were also found to have the lowest levels of renewable energy consumption, accounting for less than 10% of their overall energy consumption.

Table 34. Summary for Renewable Consumption (unit: %)

Country	Max	Min	Mean	p50
Albania	**44.58**	31.62	37.37	37.04
Belarus	8.39	6.25	7.05	7.14
Bosnia and Herzegovina	37.71	14.16	21.75	19.92
Bulgaria	21.08	7.24	13.80	13.75
Croatia	33.60	22.66	28.67	28.28
Czechia	16.97	6.29	11.34	11.56
Estonia	40	17.22	24.28	24.72
Hungary	17.18	4.63	11.52	13.53
Latvia	43.75	33.07	**37.49**	**37.20**
Lithuania	33.78	17.06	23.87	22.10
Moldova	26.07	4.27	15.193	20.19
North Macedonia	23.91	14.63	18.89	18.8
Poland	16.14	7.18	10.14	9.97
Romania	24.40	13.40	20.67	21.84
Russian Federation	3.72	3.18	3.41	3.35
Slovak Republic	17.64	5.35	10.12	10.32
Slovenia	22.91	16.31	19.60	19.64
Ukraine	8.72	**0.99**	3.51	2.87
Total	44.58	0.99	17.70	17.38

Population

Population, according to Nwokeji (2011), is an important factor that contributes to renewable production. The growth of the population generally leads to a rise in energy demand. Population increases in industrialised areas, would particularly result in higher energy consumption. And to meet the increasing energy demand while controlling the consumption of fossil fuels, the expansion of renewable energy production would be a generally optimal choice for the countries. The growing demand would even attract more investment and further enhance renewable production.

According to table 35, the most populous country in the sample is the Russian Federation, at a level about three times that of Ukraine, the second populous nation. And with Poland ranked third in average population, it is interesting to find that the top three producers of greenhouse gases in the CEE region are also the most populous countries. On the other hand, the disparity in population is demonstrated by the fact that only four nations had a population average greater than the group average. And Estonia, which had the highest ratio of FDI stock to GDP, has the smallest population among the sample.

The Table 36 compares the population between 2001 and 2021 for the sample countries on the list, and the most important information to note is that the sample countries have collectively experienced a 10% decline in population during this time frame. The Czech Republic, North Macedonia, the Slovak Republic, and Slovenia are the only countries to have experienced a population increase over the past two decades, but the increase is negligible in comparison to their total population size. And Ukraine has experienced the largest population decline in absolute terms, with a decrease of 4869550 people.

Table 35. Summary for Population (unit: 10^3)

Country	Max	Min	Mean	p50
Albania	3060.17	2811.67	2929.99	2905.20
Belarus	9928.55	9340.31	9544.56	9469.38

Bosnia and Herzegovina	4198.41	3270.94	3757.82	3743.14
Bulgaria	8009.14	6877.74	7372.10	7348.33
Croatia	4311.16	3899.00	4223.63	4280.62
Czechia	10700	10200	10400	10500
Estonia	1388.12	**1314.55**	1337.46	1330.93
Hungary	10200.00	9709.89	9950.54	9971.73
Latvia	2337.17	1884.49	2089.44	2059.71
Lithuania	3470.82	2794.14	3080.34	3028.12
Moldova	2918.14	2615.20	2824.95	2860.70
North Macedonia	2076.69	2020.16	2054.59	2058.54
Poland	38200	37700	38100	38100
Romania	22100	19100	20400	20100
Russian Federation	**146000**	143000	**144000**	**144000.**
Slovak Republic	5458.83	5372.28	5405.61	5398.38
Slovenia	2108.08	1992.06	2043.53	2052.84
Ukraine	48700	43800	45900	45700
Total	146000	1314.55	17500	4841.72

Table 36. Population foe CEE in 2001 and 2021 (unit: 10^3)

Country	2001	2021	Change
Albania	3060.17	2811.67	-248.51
Belarus	9928.55	9340.31	-588.24
Bosnia and Herzegovina	4194.93	3270.94	-923.99
Bulgaria	8009.14	6877.74	-1131.40
Croatia	4299.64	3899.00	-400.64
Czechia	10216.61	10505.77	289.17
Estonia	1388.12	1330.93	-57.18

Hungary	10187.58	9709.89	-477.68
Latvia	2337.17	1884.49	-452.68
Lithuania	3470.82	2800.84	-669.98
Moldova	2918.14	2615.20	-302.94
North Macedonia	2034.88	2065.09	30.21
Poland	38248.08	37747.12	-500.95
Romania	22131.97	19119.88	-3012.09
Russian Federation	146000.00	143000.00	-3000.00
Slovak Republic	5378.87	5447.25	68.38
Slovenia	1992.06	2108.08	116.02
Ukraine	48662.40	43792.86	-4869.55

Urbanisation

According to Wang, Zhang, and Zhang (2016), the rate of urbanisation is also a factor related to the consumption of renewable energy and therefore functions as a control variable. There are a number of ways in which the growth of urbanisation could impact the production of renewable energy. Urbanisation frequently leads to a greater concentration of population and economic activity in cities, resulting in a rise in energy demand. This increased energy demand may strain the existing energy infrastructure and encourage the adoption of renewable energy sources in order to sustainably meet the rising demand. However, from an infrastructure standpoint, despite the fact that urbanisation leads to an increase in rooftop solar photovoltaic installation, this land-consuming process may also challenge the possibility of constructing large-scale renewable energy infrastructures, such as wind farms and water power stations. Consequently, the effect of this variable is ambiguous and may be pertinent to the situation of the sample.

The percentage of urban population to total population is widely considered as a proper proxy for urbanisation by scholars and would be employed in this paper, and the data was obtained from the World Bank database. The summary table 37 below shows that Belarus achieved the highest urban population value in the sample and also has the highest average urban population rate, followed by Russia and the Czech Republic. While the average value in Moldova and Albania, where has the lowest GDP per capita in CEE, is relatively lower. On the other hand, half of the sample nations had an urban population ratio higher than the group average, showing a lesser discrepancy in this variable when compared to FDI or GDP.

Table 37. Summary for Urbanisation (unit: %)

Country	Max	Min	Mean	p50
Country	Max	Min	Mean	p50
Albania	63.0	**42.4**	53.1	53.2
Belarus	**79.9**	70.5	**75.2**	75.2
Bosnia and Herzegovina	49.4	42.7	45.9	45.9
Bulgaria	76.0	69.2	72.6	72.6
Croatia	57.9	53.6	55.5	55.3
Czechia	74.2	73.2	73.6	73.6
Estonia	69.4	68.0	68.6	68.6
Hungary	72.2	64.7	68.9	69.4
Latvia	68.4	67.8	68.0	68.0
Lithuania	68.2	66.6	67.1	66.9
Moldova	44.2	42.5	42.8	42.7
North Macedonia	58.8	57.1	57.6	57.5
Poland	61.8	60.0	60.8	60.8
Romania	54.3	52.8	53.7	53.9
Russian	74.9	73.3	73.9	73.7

Federation				
Slovak	56.2	53.7	54.7	54.4
Slovenia	55.4	50.8	52.9	52.9
Ukraine	69.8	67.2	68.6	68.7
Total	79.9	42.4	61.8	63.8

FDI's impact on greenhouse gas emission

Based on the studies conducted by Adeel-Farooq, Raji, and Adeleye (2021) as well as Christoforidis and Katrakilidis (2021), it has been suggested that the mean group (MG) estimator proposed by Pesaran and Smith (1995) and the pooled mean group (PMG) estimator introduced by Pesaran et al. (1999) serve as appropriate intermediate approaches for estimating the EKC in both the short run and long run. Estimating heterogeneous panels with a higher number of time periods than groups (T>N) and delivering effective results.

The PM estimator is a panel estimator that estimates long-run coefficients from parameters by autoregressive distributed delays (ARDL) and permits heterogeneous short-run and long-run intercepts, slopes, and error variances across groups. In addition, the PMG estimator takes into account the heterogeneity of short run coefficients, the pace of adjustment to long-run equilibrium, and error variances, as well as the homogeneity of long-run coefficients. The ARDL (p,q...q) model exhibits the following:

$$\Delta Ln\_GHG_{i,t} = \sum_{j=1}^{p} \lambda_{i,j}\, \Delta Ln\_GHG_{i,t-j} + \sum_{j=0}^{q} \beta_{i,j}\, \Delta X_{i,t-j} + \varepsilon_{i,t} + \mu_i \qquad (4)$$

In equation (4), Ln_GHG is the main dependent variable, $X_{i,j}$ denotes the vector of main explanatory variables and control variables for group i and μ_i represents the fixed effect. Based on this equation, the PMG model for analysis EKC is as below:

$$\Delta Ln\_GHG_{i,t} = \sum_{j=1}^{p-1} \lambda_{i,j}\, \Delta Ln\_GHG_{i,t-j} + \sum_{j=0}^{q-1} \beta_{i,j}\, \Delta X_{i,t-j} + \varphi_i EC_{i,t} + \varepsilon_{i,t} + \mu_i \qquad (5)$$

In equation (5), i and t denote year and country, respectively, $\lambda_{i,j}$ and $\beta_{i,j}$ are the vectors of the country-specified short-run coefficient. The EC is the error correction term equalling $Y_{i,t-1} - \theta X_{i,t-1}$ with θ being the long term equilibrium coefficient that is common across the panels. And the φ_i is the error correction parameter that denotes the speed of adjustment to the long-run equilibrium.

Both the PMG and MG estimators include lagged terms of both the dependent and explanatory variables, enabling them to address issues related to endogeneity and autocorrelation. The inclusion of time and country fixed effects is also essential to ensure the generation of unbiased results. The homogeneity of the long-run coefficient produced by the PMG method is expected to be useful for research that focuses on CEE countries that possess geographical closeness and share comparable historical and economic attributes. However, it is imperative to acknowledge that there are three crucial concerns pertaining to the estimate of PMG, and it is crucial to test variables prior to performing the regression analysis. And the table below shows the variables included in this equation.

Table 38. The variable list 2

Variable name	Description
Ln_GHG	The logarithm of greenhouse gases emission
FDI^2	The square form of the percentage of FDI stock to GDP
FDI	The percentage of FDI Stock to GDP
Ln_GDP_per_capita	The logarithm form of GDP per capita
Energy Intensity	The amount of energy used to generate 1 unit of GDP (2015$ GDP PPP)
Ln_Energy consumption_per_capita	The logarithm of energy consumption per capita

Test for stationary

The first is a test for the existence of unit roots in the panels. The PMG model could produce unbiased long-term results for a mixture of stationary and nonstationary variables, but the variables must be stationary at least at the first difference. The IPS unit root tests were performed to determine whether the variables are stationary or not, and the results are shown in Table 39. The dependent variable Ln_GHG, FDI and its squared form had a p-value less than 0.05, rejecting the null of nonstationary at the 5% significance level. The explanatory variables logarithm of GDP per capita and Energy intensity are also stationary at the 1% significance level, whereas the p-value for the logarithm of Energy consumption per capita is not significant and indicates the presence of a unit root. In addition, table 40 displays the IPS unit root test for the first difference of all variables, where the p-values all equal to zero, indicating that all variables have reached a stationary level.

Table 39. IPS unit root test

Im–Pesaran–Shin unit-root test		
	Statistic	**p-value**
Ln_GHG	-2.2295	0.0129
FDI^2	-1.6718	0.0473
FDI	-2.2197	0.0132
Ln_GDP_per_capita	-2.6815	0.0037
Energy Intensity	-4.4514	0.0000
Ln_Energy consumption_per_capita	0.6841	0.7530

Table 40. IPS unit root test for first difference variables

Im–Pesaran–Shin unit-root test		
	Statistic	**p-value**
D.Ln_GHG	-12.4801	0.0000
D.FDI^2	-17.2404	0.0000
D.FDI	-16.6573	0.0000
D.Ln_GDP_per_capita	-8.8497	0.0000
D.Energy Intensity	-12.2057	0.0000

D.Ln_Energy consumption_per_capita	-14.8868	0.0000

Test for cointegration

Cointegration indicates that the variables have a long-run relationship and is a necessary condition for PMG estimators that use the error correction term to confirm cointegration. The Kao test for cointegration is used to examine the long-term relationship between the variables. Four of the five p-values in the kao cointegration tests are significant below the 10% significance level, and three of them are equal to zero, thereby rejecting the null hypothesis of no cointegration and indicating a long-run relationship between the variables.

Table 41. Result for kao cointegrated test

Kao test or cointegrated		
	Statistic	**p-value**
Modified Dickey–Fuller t	-1.2075	0.1136
Dickey–Fuller t	-4.0966	0.0000
Augmented Dickey–Fuller t	-1.6337	0.0512
Unadjusted modified Dickey–Fuller t	-4.9878	0.0000
Unadjusted Dickey–Fuller t	-6.0545	0.0000

The results of the Pedroni test for cointegration are shown in the second table. All three p-values are found to be statistically significant at a 10% significance level and 2 under 5% significance level. This further confirms the robustness of the cointegration between the variables and establishes their suitability for PMG estimation.

Table 42. Result for Pedroni cointegrated test

Pedroni test or cointegrated		
	Statistic	**p-value**
Modified Phillips–Perron t	3.7456	0.0001

Phillips–Perron t	-1.3351	0.0990
Augmented Dickey–Fuller t	-1.6966	0.0449

Cross-sectional dependence test

To detect the presence of cross-sectional dependence, the Pesaran cross-sectional dependence test was used. The findings shown in Table 43 indicate that the p-value for all variables is 0. As a consequence, we cannot reject the null hypothesis of cross-sectional independence, suggesting the presence of cross-sectional dependency. In this instance, I implemented the CIPS unit root test, as outlined by Christoforidis and Katrakilidis (2021), which incorporates consideration for cross-sectional dependence among the panels.

Table 43. Result for Pesaran cross-sectional dependence test

Pesaran Cross-sectional dependence test		
	Statistic	**p-value**
Ln_GHG	7.247	0.0000
FDI^2	31.919	0.0000
FDI	34.914	0.0000
Ln_GDP_per_capita	54.77	0.0000
Energy Intensity	49.462	0.0000
Ln_Energy consumption_per_capita	6.179	0.0000

The findings shown in table 44 demonstrate that the variables included in the regression analysis exhibit stationarity at level first difference. This observation confirms that the assumptions required for the PMG estimator are satisfied.

Table 44. Result for CIPS unit root test

CIPS unit root test			
	CIPS		**CIPS**
Ln_GHG	-2.032	**D. Ln_GHG**	-4.459***

FDI²	-2.172*	**D.FDI²**	-4.312***
FDI	-2.229**	**D.FDI**	-4.207***
Ln_GDP_per_capita	-1.982	**D.Ln_GDP_per_capita**	-3.391***
Energy Intensity	-2.683***	**D.Energy Intensity**	-4.301***
Ln_Energy consumption_per_capita	-1.459	**D.Energy consumption_per_capita**	-4.253***

Original form: 10% Significance level -2.11; 5% Significance level -2.2; 1% Significance level -2.38
First difference: 10% Significance level -2.1; 5% Significance level -2.21; 1% Significance level -2.4

Determine of optimal lags

Further, to determine the optimal lags for ARDL, I conducted tests for each country to find out the most common lags for the variable. The results are shown below:

Table 45. Selection of optimal lags

Country	Ln_ GHG	FDI²	FDI	Ln_GDP_ per_capi ta	Energy Intensity	Ln_Energy consumpti on_per_ca pita
Albania	1	1	0	1	0	0
Belarus	1	0	0	1	0	0
Bosnia and Herzegovina	1	0	0	0	0	0
Bulgaria	1	0	1	0	0	0
Croatia	1	0	0	0	0	0
Czechia	1	0	0	0	1	0
Estonia	1	**0**	0	0	0	0
Hungary	1	0	0	1	1	0
Latvia	1	0	0	0	0	0
Lithuania	1	0	0	0	0	0
Moldova	1	0	1	1	0	0
North Macedonia	1	1	1	1	1	1

Poland	1	0	0	1	0	0
Romania	1	0	0	0	0	0
Russian Federation	1	0	0	1	0	1
Slovak Republic	1	0	0	0	0	0
Slovenia	1	0	0	0	0	0
Ukraine	1	0	1	0	0	0
Total	**1**	**0**	**0**	**0**	**0**	**0**

To select the optimal lags for the analysis, the most common lags for each variable is checked. And the combination of ARDL (1,0,0,0,0) is most common, thus this will be used in the PMG and MG estimation.

PMG and MG estimation

In tables 46 and 47, the results of the PMG and the MG are displayed. It is evident from the PMG estimator's output that, in the long run, all variables are significantly correlated with greenhouse gas emissions. With the coefficient of squared FDI being negative and the coefficient of FDI being positive, both of which are significant at the 1% significance level, the inverted U-shaped relationship between FDI and environment is shown to exist, indicating that the FDI-EKC hypothesis holds true for CEE countries. However, in the short run, the correlation is no longer significant, indicating that the EKC only exists over the long term. In the long run, the coefficient of the GDP variable is significantly negative, whereas it is significantly positive in the short run. This is consistent with the conclusion of the traditional EKC model in Central and Eastern Europe, which suggests that economic development will eventually contribute to an improvement in the environment, but in the interim, emissions may continue to rise until the tipping point. Both in the long and short term, the coefficient of energy intensity is negative, but only in the long term is significant. However, the logarithm of per capita energy consumption has a significant positive effect on greenhouse gas emissions in both the short and long term, but particularly in the long term. A one percent increase in energy consumption will increase greenhouse gas emissions by 1.42 percent in long run.

Table 46. Result for PMG estimator

	Long run	Short run
FDI^2	- 0.0001073 *** (0.000)	- 0.0000641 (0.519)
FDI	0.0158045 *** (0.000)	0.0043647 (0.572)
Ln_GDP_per_capita	- 0.1204983*** (0.000)	0.1128921*** (0.001)
Energy Intensity	- 0.0209532* (0.058)	- 0.0167191 (0.542)
Ln_Energy consumption_per_capita	1.418139 *** (0.000)	0.3375623** (0.015)
__ec		- 0.2115879*** (0.006)

Table 47. Result for MG estimator

	Long run	Short run
FDI^2	-0.0006596* (0.05)	0.0000901 (0.269)
FDI	0.053204 (0.104)	-0.006442 (0.392)
Ln_GDP_per_capita	- 0.1776034 (0.516)	0.1054277 (0.122)
Energy Intensity	- 0.0193339 (0.761)	0.0165763 (0.665)
Ln_Energy consumption_per_capita	0.5969356 ** (0.037)	0.016120 (0.898)
__ec		-0.659432 *** (0.000)

Also, based on the findings shown in table 47, it can be inferred that the MG estimator does not offers support for the presence of the FDI-EKC model in the CEE nations in both long and short term, as no evidence shows both FDI and its squared form are significant correlated to dependent variable. The correlation between GDP and energy intensity with greenhouse gas emissions is also insignificant. However, it is important to note that energy consumption has a considerable impact on emissions, particularly in the long term.

In addition, I utilized the Hausman test to compare the efficiency and consistency of the MG and PMG estimators. The p-value of 0.3716 in table 48 indicates that the null hypothesis cannot be rejected and that PMG is a more appropriate estimator for the analysis.

Table 48. Hausman test result

Hausman Test between MG and PMG	
chi2	**p-value**
5.38	0.3716

Summary and critical analysis of the result

The PMG estimator results confirm that the FDI-EKC hypothesis is supported for the sample of CEE countries. Indicating that an increase in the FDI stock to GDP ratio will initially increase total greenhouse gas emissions but will eventually reduce emissions and benefit the environment. And according to equation (2), the threshold of FDI to GDP stock for the entire group is 73.64%, indicating that after the national FDI stock has exceeded 73.64 percent of the national GDP, further increases in the national FDI stock will result in a decrease in national greenhouse gas emissions. And according to the data on FDI stock, it seems this threshold is so high that only Bulgaria, Estonia, Hungary, and the Czech Republic have exceeded it. Thus, in order to account for the heterogeneity of FDI and GDP between developed and developing nations, as CEE is a region with a considerable income disparity, I additionally estimated the PMG by income group to estimate more detailed result. According to World Bank data from 2023, the high-income group consists of Croatia, the Czech Republic, Estonia, Latvia, Lithuania, Hungary, Romania, Poland, the Slovak Republic, and Slovenia, while the middle-income group consists of Albania, Bulgaria, Bosnia and Herzegovina, Belarus, Moldova, North Macedonia, the Russian Federation, and Ukraine. And their results are displayed in tables 49 and 50, respectively.

Table 49. Result for PMG estimator (High-income group)

	Long run	Short run
FDI^2	- 0.0003816 *** (0.000)	- 0.0000726 (0.128)
FDI	0.0372452 *** (0.001)	0.0051112 (0.299)
Ln_GDP_per_capita	0.131484 (0.184)	0.1128921* (0.068)
Energy Intensity	0.0539547 (0.157)	- 0.0312206 (0.341)
Ln_Energy consumption_per_capita	-0.2287134 (0.305)	0.5053474*** (0.001)
__ec		- 0.2062324*** (0.005)

Table 50. Result for PMG estimator (Middle-income group)

	Long run	Short run
FDI2	- 0.0005405 *** (0.000)	- 0.0001061 (0.672)
FDI	0.0319025 *** (0.000)	0.009491 (0.615)
Ln_GDP_per_capita	- 0.0102847 (0.793)	0.1372889 ** (0.045)
Energy Intensity	- 0.0093508 (0.475)	0.004695 (0.938)
Ln_Energy consumption_per_capita	0.9889155 *** (0.000)	0.3109797 (0.224)
__ec		- 0.3248466 *** (0.001)

Table 51. Hausman test result for high-income group

Hausman Test between MG and PMG	
chi2	**p-value**
4.56	0.4719

Table 52. Hausman test result for middle-income group

Hausman Test between MG and PMG	
chi2	**p-value**
0.57	0.9658

The Hausman test result shows the PMG estimator is the better option when testing for different groups. In the long run, the inverted U-shaped relationship remains valid in high-income countries, and all variables are significant below the 1% level of significance, with the exception of energy intensity. While other explanatory variables were not significantly correlated to the gas emissions. By calculating the coefficients, the threshold for high-income countries is 48.8%. While in the short run, the result does not indicate the existence of EKC, but the increase of GDP per capita and energy consumption per capita will induce gas emission growth under 10% and 1% significance levels respectively.

While the PMG result for middle-income countries also indicates the existence of FDI-EKC over the long term. A 1% increase in their economic development per capita will result in a 0.137% increase in their short-term greenhouse gas emissions at a significance level of 5%, while a 1% increase in their energy consumption will result in a 0.989% increase in their long-term greenhouse gas emissions, a level lower than that of developed nations. And the turning point would be 29.51 % which is significantly lower than the value for developed nations. This value indicates that even though their FDI value is comparatively low, the impact on reducing emissions is still observed, showing their positive participation in the green transition.

FDI's impact on the renewable energy production

Quantitative model analysis

In addition to mitigating greenhouse gas emissions, FDI has the potential to facilitate the advancement of green transition by incentivizing the production of renewable energy sources. In this section, a country fixed effect model is used to examine the correlation between FDI stock and the output of renewable energy. The formula for estimation is as follows:

$$RP_{i,t} = a_0 + a_1 FDI_{i,t} + a_2 X_{i,t} + \mu_{i,t} + \varepsilon_{i,t} \qquad (6)$$

The dependent variable RP measures the amount of electricity generated from renewable energy sources of each country. FDI refers to the stock of FDI expressed as a percentage of GDP, and X is the vector of the control variable sets. $\mu_{i,t}$ is the entity fixed effect term, whereas $\varepsilon_{i,t}$ is the error term. The coefficient of interest is a_1 indicates the relationship between FDI and renewable energy production, while a_2 represents interaction between the control variables and the dependent variable. Last, a_0 is the constant parament term.

Based on the meta-analysis conducted by Wang et al. (2023) and the research conducted by Nwokeji (2011), it has been shown that there exists a significant connection between the development of renewable energy and numerous variables, including renewable energy consumption, population, energy intensity level and urbanisation, which would be considered as control variables in this study. And the analysis will consist of 16 CEE countries without Poland and Belarus, whose data is missing in some years.

Before the regression, unit root tests were performed to ensure that the variables are stationary, enabling an unbiased result. The tables 53 and 54 demonstrate that the logarithm of renewable energy production, Energy intensity and Urbanisation are stationary at level at 1% significance levels. While the other variables become stationary under the 1% significance level at their first difference. Thus, their transformed forms will be incorporated into the equation. Table 55 displays the final selected variables for the regression.

Table 53. IPS unit root test results 1

Im–Pesaran–Shin unit-root test		
	Statistic	**p-value**
Ln_Renewable_Production	-3.1827	0.0007
FDI	-1.3331	0.0913
Energy Intensity	-3.5251	0.0002
Ln_Population	4.6278	1.0000
Renewable Energy consumption	- 0.9372	0.1743
Urbanisation	- 10.2438	0.0000

Table 54. IPS unit root test results 2

Im–Pesaran–Shin unit-root test		
	Statistic	**p-value**
D_Ln_Renewable_Production	--6.0319	0.0000
D_FDI	--15.3732	0.0000
D_Energy Intensity	-12.2057	0.0000
D_Ln_Population	-4.8792	0.0000
D_Renewable Energy consumption	-12.1618	0.0000
D_ Urbanisation	1.1614	0.8773

Table 55. Variables description

Variable name	Description
Ln_Renewable_Production	The logarithm of total energy generated by renewable energy
D_FDI	The first difference of FDI stock as percentage of GDP
Energy Intensity	Energy used to generate 1 unit of GDP (2015$ GDP PPP)
D_Ln_Population	The first difference of the logarithm of population
D_Renewable energy consumption	The first difference of the renewable energy consumption to total energy consumption

Urbanisation	The percentage of urban population to total

The following table displays the regression result, with the model's P-value equal to zero, indicating that the model is statistically significant. The within R-square indicates that the model accounts for 23.97% of the variation within the entities. The FDI coefficient is negative but insignificant, indicating that FDI and renewable energy production do not have a robust relationship. And under 1% significance level, the energy intensity variable is significantly negatively correlated with the dependent variable, indicating an increase in energy intensity would reduce renewable production. However, the urbanisation rate and growth rates of population are both significantly positively correlated with the dependent variable, respectively, under 1% and 5% significance levels. The growth of renewable consumption, on the other hand, does not have a significant correlation with renewable production.

Table 56. Fixed effect regression result

Fixed effect	
	Ln_Renewable_Production
D_FDI	-0.0021 (-0.53)
Energy Intensity	-0.0174*** (-6.62)
D_Ln_Population	20.4899** (-2.60)
D_Renewable energy consumption	0.0078 (0.536)
Urbanisation	0.0453*** (-6.62)
_cons	5.5602*** (5.45)
N	304
R^2 within	0.2397
F-test	0.0000

The Hausman test for model specification was first performed to evaluate the result's trustworthiness. And the result had a significant p-value of 0.006, rejecting the null hypothesis that favoured a random effect model at a significance level of less than 1%, indicating that the fixed effects model is appropriate.

The Wald test was used to assess heteroskedasticity, yielding a p-value of 0.0172. This result indicates the presence of heteroskedasticity in the preceding estimate. Furthermore, the Wooldridge test for panel data yielded a statistically significant p-value, leading to the rejection of the null hypothesis and indicating the presence of autocorrelation in some panels. The Pesaran's test for cross-sectional dependency was also conducted, yielding a p-value of 0001. This p-value rejects the null hypothesis under 1% significance level, demonstrating the exisitence of cross-sectional dependence.

Table 57. Results for Hausman test

AR parameter: Panel-specific		**Asymptotics: T,N -> Infinity sequentially**
Panel means:	**Included**	
Time trend:	**Not included**	**Cross-sectional means removed**
	Statistic	**p-value**
W-t-bar	**19.46**	0.0006

Table 58. Modified Wald test for heteroskedasticity in panel data

Wald test for heteroskedasticity	
chi2	**p-value**
30.16	0.0172

Table 59. Wooldridge test for autocorrelation in panel data

Wooldridge test for autocorrelation	
H0: no first-order autocorrelation	
F Statistics	**p-value**
1613.996	0.0000

Table 60. Pesaran's test of cross-sectional independence

Pesaran's test of cross- sectional independence		
Test result	**p-value**	**Average absolute value of the off-diagonal elements**
3.799	0.0001	0.426

In order to address the aforementioned concerns, I conducted a regression analysis using the Driscoll and Kraay (1998) standard errors, which are known for its capacity to provide robust results in the presence of autocorrelation and heteroskedasticity (Hoechle, 2007). Additionally, I used the fixed effect regression model with the robust option.

Robustness check

The p-values for both models continue to demonstrate statistical significance, under 1% and 5% significance levels, respectively. The coefficient of interest for FDI remains statistically insignificant in both sets of results, providing additional evidence that FDI does not have a significant connection with renewable production in CEE. In the regression with the Driscoll and Kraay (1998) standard errors, the coefficients of these variables maintain their original signs. Nevertheless, the coefficient related to the growth of population demonstrated statistical significance at a significance level of 10% rather than the 5% in the previous estimation. While in the fixed effect regression with robust option, the correlation for population growth, urbanisation become insignificant. But the correlation for energy intensity still being significant under 5% significance level, suggesting the robust correlation between energy intensity and renewable production.

Table 61. Driscoll and Kraay standard errors regression and robust fixed effect result

	Regression with Driscoll and Kraay standard errors	Fixed effect with robust option
	Ln_Renewable_Production	**Ln_Renewable_Production**
D_FDI	- 0.0021	- 0.0021

	(0.736)	(0.229)
Energy Intensity	- 0.1735*** (0.000)	- 0.1735** (0.014)
D_Ln_Population	20.4899* (0.051)	20.4899 (0.331)
D_Renewable energy consumption	0.0078 (0.559)	0.0078 (0.588)
Urbanisation	0.0453*** (0.000)	0.0453 (0.302)
_cons	5.5603*** (0.000)	5.5603* (0.057)
N	304	304
R^2 within	0.2397	0.2397
F-test	0.0000	0.0144

In light of the findings obtained from both the fixed effects model and the Driscoll and Kraay standard errors regressions, it can be concluded that there is no significant evidence to suggest that the growth of FDI stock leads to an increase in renewable energy production in CEE regions. This implies that FDI does not effectively facilitate the green transition in CEE countries through the acceleration of renewable energy production. The escalation in energy intensity would have an adverse effect on the growth of development in renewable energy output, and the impact stemming from consumption of renewable energy is not evidenced.

The insufficiency of the beneficial impact of FDI may be attributed to the small proportion of FDI flows directed into the renewable energy sector in relation to the entire FDI flow, despite the overall increase in FDI stock, consistent with the trend of FDI distribution in the CEE area. Conversely, the lack of a substantial correlation between the growth rate of renewable consumption and the growth rate of renewable energy production could suggest that the previous increase in renewable consumption in CEE may largely reliant on imports rather than domestic production.

Chapter 7. Appraisal of FDI's Effect and Policy Suggestions

The two models that analysed the impact of FDI on greenhouse gas emissions and renewable energy production have provided an overview of how foreign investments have contributed to the green transition of CEE nations. The most important finding is the existence of a validated EKC relationship between FDI and greenhouse gas emissions in the long run, indicating that FDI would initially induce greenhouse gas emissions but lead to environmental improvement after a threshold, demonstrating that the development of FDI would promote the green transition via the greenhouse gas emission reduction channel. However, the fixed effect model found no evidence of a relationship between FDI and renewable energy production, indicating that FDI does not promote the green transition by increasing renewable energy production.

And based on an evaluation of the results as a whole, it appears that FDI is possible to exert a positive impact on the environment quality and could play a positive role in accelerating the green transition in CEE countries. However, the result also indicates the positive effects of FDI have not yet realised their full potential, and there are vast areas for development. To maximise the positive impact of FDI, it is recommended that the government and legislative organisations implement certain policies and measures.

Some countries have attained the FDI turning point by the EKC and appear to be reducing emissions, while other remain below the turning point and continue to increase carbon production. Consequently, in light of the positive impact of FDI and the EKC partnership, CEE nations should continue to open their markets and attempt to attract more FDI. Policymakers could implement incentives such as investment subsidies, tax reductions or exemptions, and import and export duty schemes. In addition to implementing regulations to create a stable and hospitable business environment that protects the profit and property of investors, it is also essential to concentrate on enhancing infrastructure and labour force skills. Additionally, broadening cooperation with diverse investor sources and removing investment barriers, such as joining the EU or other organisations, could meanwhile increase FDI inflow. Continuously increasing FDI would promote economic development and enable CEE nations to attain the FDI-EKC turning point. Moreover, CEE countries could conduct their own in-depth research on FDI and greenhouse gas emissions and identify individual tipping points to determine the progress ahead and the optimal FDI level for their economies.

In the meantime, the government should direct the increasing FDI towards sustainable industries and capitalise on the technology spillover that introduces cutting-edge, energy-efficient technology. The policies should encourage offering specific incentives to investors who introduce innovative technologies and reduce carbon emissions. For instance, the Czech Republic, which has achieved a visible reduction in greenhouse gas emissions, has enacted legislation encouraging foreign investment in high-value added and R&D while eliminating incentives for investors seeking low-skilled labour. In addition to attracting more FDI, however, the operating and emission regulations governing FDI should be strengthened. Regular inspections could be conducted to ensure that companies are operating in accordance with the environmental regulations of the host nation. The government can reserve the right to reclaim or revoke the benefits granted to foreign-invested companies that did not operate sustainably as pledged at the initial, or it can use an instrument such as carbon pricing to penalise those who exceed the environmental regulation emission standard.

On the other hand, it is necessary and innovative to highlight the positive impact of renewable production in CEE nations. Although investments in renewable infrastructure have increased in CEE regions, the insignificant result suggests that these investments may not be effective in generating renewable energies, or that the total quantity is still insufficient. Therefore, the CEE countries should also implement policies and incentives to increase FDI flows to the renewable energy producing industry. In addition to tax reductions and subsidies, investors would be encouraged by technology and expert assistance from the host country that would aid them in rapidly identifying and exploiting the renewable energy reserve in their investment region, thereby allowing them to generate profits more quickly. Also, on the consumer side, the government could promote renewable energy consumption by subsidising renewable energy consumers or facilitating cooperation between industrial energy producers and industrial energy consumers, thereby reducing emissions. The government could also implement programmes that establish cooperation companies with FDI investors, thereby attracting more FDI with government credit. In addition, the development of green finance and the reform of the energy market, which eliminate barriers to entry and permit a greater flow of FDI in the renewables industry, are also crucial channels. To ensure the efficacy of renewable energy production, however, a production target plan with rewards and penalties should be established for investors who have benefited from renewable energy investment incentives. And research and development for renewable energy production should be developed proactively to ensure the productivity and efficiency of renewable energy companies, thereby ensuring that renewable FDI can continue to play a positive role in the green transition.

However, from a broader perspective, the green transition of CEE nations is a process that requires extensive efforts from businesses, governments, and every household. The positive impact of FDI on accelerating the transition to a greener economy can be maximised when all participants collaborate in order to enhance the environment. Thus, the nations should adopt the net-zero agenda of the EU, or establish their own green transition goals, and increase the recognition of green transition via public education. With an aggregated and broadly supported domestic green industry environment, FDI from various origins will naturally migrate inward and further accelerate the green transition for CEE nations.

Chapter 8. Conclusion

The effect of FDI on the environment has been the subject of extensive discussion; however, the results of studies focusing on various sample sizes and time periods have been inconsistent. The countries of Central and Eastern Europe have undergone a rapid transition from a communist society to a liberal economic and democratic society. During the transition and post-transition periods, they have attracted a growing amount of FDI in a variety of sectors, while their energy consumption structure and trend of greenhouse gas emissions have changed. CEE countries also have initiated their green transition in response to environmental degradation and the EU's net-zero agenda.

This paper aims to analyse the role of FDI in CEE countries transition by finding out FDI’s relationship with greenhouse gas emissions and renewable energy production, which are the two major goals of green transition. The development of FDI in CEE countries was first analysed, and it’s clear that CEE countries have become a hot spot for global investors that accommodates investment in various industries, but the percentage of investment in renewable production remains relatively low. T The status of greenhouse gas emissions was also examined, and the findings suggest the CEE region has achieved a reduction in gas emissions but is still behind the status of the Western Europe region.

For the empirical context of this paper, the data spans 18 CEE nations from 2001 to 2021, and two model analyses were conducted. The first model is based on the

Environmental Kuznets Curve, and the PMG estimator and MG estimator were used to examine the long-term and short-term correlation between FDI and greenhouse gas emissions. The unit root and cointegration tests were also conducted to assure the validity of the results. The second model utilised a country fixed effects model to determine the impact of FDI on renewable energy production, with population, energy intensity, renewable consumption and urbanisation serving as control variables.

The result for the first model indicates that the FDI-EKC relationship is validated, indicating that the development of FDI will increase greenhouse gas emissions during the initial period but decrease emissions after a turning point. However, the inverted U-shaped relationship is significant under a significance level of 1% in the long run, but is insignificant in the short run. And the turning point varies according to income level; the PMG estimator reveals that the turning point for high-income countries is 48.8%, and for middle-income countries it is 29.51%, which is consistent with the disparity of FDI stocks and economic development in the CEE region. In the short term, high- and middle-income nations' economic development would substantially increase their greenhouse gas emissions. Furthermore, the growth of energy consumption causes a rise in greenhouse gas emissions in the short term for high-income countries and in the long term for middle-income countries.

The result of the second model indicates that there is no significant correlation between the development of FDI and the growth rate of renewable energy production, indicating that FDI does not inherently increase renewable energy production in the CEE region. However, the increase in energy intensity would reduce renewable production, while the increase in renewable consumption has little effect on the increase in renewable production.

Combining the two findings, we can conclude that FDI promotes the green transition in CEE countries through emission-reduction channels but not through channels that encourage renewable energy production. Therefore, in order to maximise the positive impact of FDI on the green transition of CEE countries, the government should implement more incentives and strengthen investment laws in order to attract more FDI inflow and encourage FDI flows into sustainable and renewable industries. However, regulations should also be implemented to ensure that investors who receive benefits adhere to environmental regulations and effectively advance the green transition. Lastly, by increasing domestic recognition of the green transition, CEE nations could establish a green economy that attracts global green FDI.

However, due to insufficient data, this paper did not consider the situation in some CEE countries and was unable to provide detailed analysis of the situation in each country. Future research could fill this gap by investigating the distinct circumstances of each CEE nation and contributing to the design of the most effective policies for their green transition.

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