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Does United Kingdom's Focus on Climate Technologies, Municipal Waste Treatment, and Economic Development Aligns With its 2030 Nationally Determined Contributions (NDCs)?

[1]Eric Tieku Agyemang, [2]Frank Yeboah Agyare, [3]Kwabena Ofori

[1]European university of lefke, Institute of Graduate Studies and Research, Department of Banking and Finance

[2]Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Department of Management

[3]University of Essex, Department of Government

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ABSTRACT

The study uses a Vector Error Correction Model (VECM) to examine the dynamic impacts of municipal waste recycling, climate technologies, and economic growth on greenhouse gas emissions in the United Kingdom using data collected in time series from 1995 to 2020. We ran tests for impulse response, variance decomposition, stationarity, cointegration, and residuals. Greenhouse gas emissions in the United Kingdom, economic growth, climate technology, and municipal waste recycling, are all found to be cointegrated. The previous year's deviation from long run equilibrium is corrected in the current period at an adjustment speed of 80%. Consequently, it takes around 1 year and 5 months to reach a stable condition. Municipal waste recycling and climate technologies has been found to promote reduction of greenhouse gas emissions in the United Kingdom in both short-run and long-run. However, climate technology is more effective at lowering emissions of greenhouse gases. Greenhouse gas emissions do go down in the long run, even though they go up at initial stages due to economic growth. Majority of the fluctuation in greenhouse gas emissions over both the short and long durations is explained by greenhouse gas emissions own shocks or innovations, rather than any external factors. Among the predictor variables, greenhouse gas variations in the short and long run are mostly attributable to changes in gross domestic product, with climate technology and municipal waste recycling following closely behind. The empirical analysis supports policy recommendations that the government and other stakeholders should improve their governing policies and methods on these variables to further succeed in regulating environmental pollution. Greenhouse gas emissions tend to rise in tandem with expanding economies, leading to substantial long-term volatility. Therefore, the economic management team of the United Kingdom government should establish legislation to limit economic activity that contributes to greenhouse gas emissions and instead provide support and funding for projects that are green and low-carbon. They want to cut emissions by 68% by 2030 as part of their National Determined Contribution (NDC), and this will get them there.

Keywords: Emissions, climate technologies, greenhouse gas, economic growth, variations, nationally determined contribution.

INTRODUCTION

Given that climate change constitutes among the greatest ecological dangers of our time, all attempts must be made to create a strong global policy based on the Kyoto Protocol's clauses, which all Parties are adhering to, in order to respond to this danger. Prior to the 21st Conference of Parties (COP21), which took place in Paris in December 2015, countries to the United Nations Framework Convention on Climate Change (UNFCCC) presented their plans for reducing global warming. The breadth of targets and strategies for lowering greenhouse gas emissions included in their Intended Nationally Determined Contributions (INDCs) have now been transformed into Nationally Determined Contributions (NDCs) for the Parties that signed onto the Paris Agreement.

The Department for Business, Energy, and Industrial Strategy (BEIS) emphasized that the Agreement of Paris and the Framework Convention on Climate Change are both Parties to the United Kingdom of Great Britain and Northern Ireland (BEIS, 2022). An environmental goal for reducing emissions for England, Scotland, Wales, and Northern Ireland is represented by the UK's NDC. In order to facilitate emissions alleviation, the UK uses a variety of regulatory at the national, and local levels. Several strategies, initiatives and laws are also used to support these efforts.

The constitutionally binding Climate Change Act 2008 provides the UK with an arrangement for lowering greenhouse gas (GHG) emissions and strengthening resistance to climate hazards through capacity building and adaptation. The UK was initially required by the Act to reduce its emissions by at least 80% below the initial threshold set in 1990 by the year 2050. This goal was changed on June 27, 2019, making the UK constitutionally bound to achieve net zero emissions by 2050 (see table 1), estimated on economy basis (UK Climate Change Act, 2008).

According to UNFCCC (2022), following Article 4 of the Paris Agreement, the United Kingdom of Great Britain and Northern Ireland notified the United Nations Framework Convention on Climate Change (UNFCCC) of its Nationally Determined Contribution (NDC) in December 2020. The United Kingdom has made pledges in its NDC to cut greenhouse gas emissions across the board by no less than 68% by 2030 when compared to 1990 levels. According to United Kingdom Climate Change Committee report in 2023, the UK Climate Change Act mandates the UK government to establish statutory 'Carbon Budgets' that serve as incremental milestones to reach the 2050 target. A Carbon Budget gives a limit on the quantity of greenhouse gases released in the United Kingdom. It is necessary to establish budgets with a minimum lead time of 12 years to provide sufficient preparation time for policy-makers, corporations, and citizens. The UK Climate Change Committee (CCC) provides guidance on the optimal magnitude of each carbon budget. After receiving approval from the Government, the corresponding budgets are officially enacted by Legislature. The proposed budgets outline the economically efficient approach to attaining the United Kingdom's long-term goals in addressing global warming. In addition, they consider many aspects such as scientific understanding, technological advances, economic conditions, and social context.

In table 1 below, United Kingdom has been able to achieve their first and second carbon budget as promised. The third budget will be assessed and its progress will be reported in 2024. The progress of the rest of the carbon budget will be reported in year as specified in the table above. The United Kingdom has gone under a process to review its NDC and ensuring it works in accordance with the Paris Agreement temperature target, while also looking into measures to improve it in compliance with standards of practice, in light of the Glasgow Climate Pact and the urgency conveyed by the most recent findings. The United Kingdom raised its overall International Climate Finance (ICF) to £11.6 billion between 2021/22 and 2025/26, as outlined in the UK's International Development Strategy (2022), providing an equitable balance between mitigation as well as adaptation finance. Promoting clean energy transition in nations that are developing will be a key component of ICF programming, with a minimum of £3 billion allocated to climate change and poverty reduction initiatives that preserve, replenish, and responsibly manage the environment between 2021–2022 and 2025–2026.

In figure 1, Carbon diovide has been shown to be United Kingdom major greenhouse gas while Nitrous oxide and Methane oxide follow closely.

Table 1: United Kingdom carbon budget towards 2050 Net Zero emissions

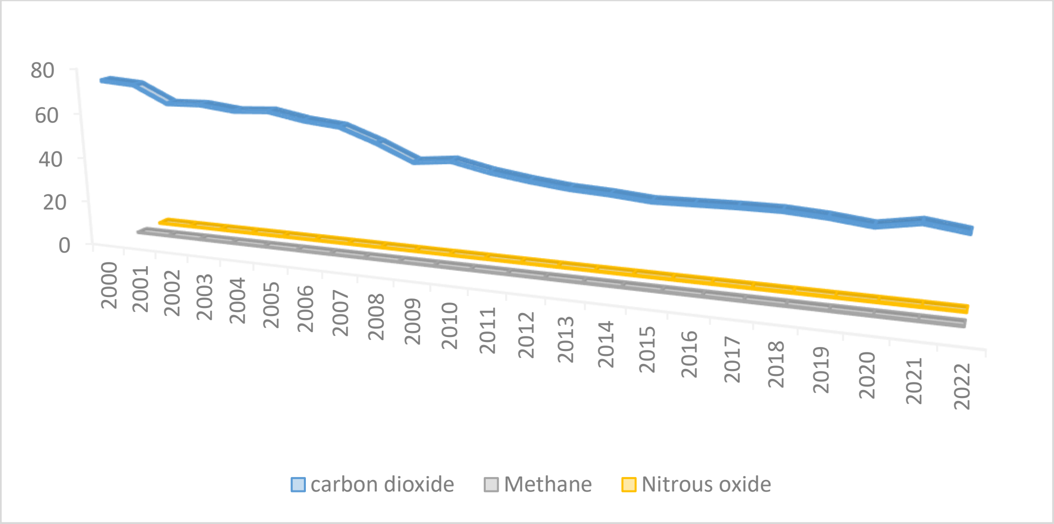
Budget	Carbon budget level	Reduction below 1990 levels	Met?
1st Carbon Budget (2008 to 2012)	3,018 $MtCO_2e$	26%	Yes

2nd Carbon Budget (2013 to 2017)	2,782 MtCO$_2$e	32%	Yes
3rd Carbon Budget (2018 to 2022)	2,544 MtCO$_2$e	38%	To be assessed in our 2024 Progress Report
4th Carbon Budget (2023 to 2027)	1,950 MtCO$_2$e	52%	To be assessed in our 2029 Progress Report
Nationally Determined Contribution (2030)	–	68%	To be assessed in our 2032 Progress Report
5th Carbon Budget (2028 to 2032)	1,725 MtCO$_2$e	58%	To be assessed in our 2034 Progress Report
6th Carbon Budget (2033 to 2037)*	965 MtCO$_2$e	77%	To be assessed in our 2039 Progress Report
7th Carbon Budget (2038 to 2042)*	To be set in 2025	–	–
Net Zero Target		At least 100% by 2050	
Note: The 6th Carbon Budget, and subsequent budgets, include international aviation and shipping.			

Source: UK Climate Change Committee (CCC) report, (2023)

Due to insufficient solid waste management systems, local governments and urban inhabitants frequently engage in inappropriate solid waste management practices, as the pace of solid waste output is outpacing that of urbanization. Some examples of these methods comprise storing and processing hazardous waste with regular home and business trash, using outdated or poorly managed facilities to store garbage, using inefficient transportation tactics, burning trash outdoors, dumping waste in uncontrolled areas, and using landfills that have not been designed to handle such materials (Abubakar et al.,2022).

Figure 1: United Kingdom’s national mitigation target in Manufacturing and Construction sector



Source: Authors construction based on UNFCCC 2023 data.

Air and water pollution, land degradation, climate change, emissions of methane and hazardous wastewater, and other consequences are all results of these practices. Residents, especially members of already-vulnerable social groups, would bear the brunt of the high expenses associated with environmental damage and public health concerns caused by these impacts. Among the main issues influencing environmental quality and the sustainable development of cities is inadequate waste management, which is linked to poor public health. Fostering optimistic public sentiment is essential for successful community engagement in the waste management. To get people to stop littering and start using the right waste cans, there needs to be an education campaign in the media. Water contamination and poor air in cities were other outcomes of improper waste management (Abubakar et al.,2022).

In metropolitan areas beset by rapid population expansion and waste production, solid waste management (SWM) remains a paramount social and administrative concern. As the global populace is projected to reach 8 billion by 2025 and 9.3 billion by 2050, with approximately 70% of that number residing in metropolitan areas, humanity will face the formidable task of solid waste management due to economic expansion, improved lifestyles, and consumerism (OECD, 2021). While 80-95% of developing-world towns' finances go toward garbage collection and transportation, only 50-80% of waste is actually collected (Guerrero et al., 2013). Public health and environmental hazards are exacerbated because only a small fraction of the waste in low-income countries actually gets collected. This is especially true for children who live in close proximity to garbage dumps, as they are more likely to contract acute respiratory infections and diarrhea (UN-Habitat, 2010). Inadequate knowledge, tools, funding, and leadership all work against efficient municipal SWM (Hettiarachchi et al., 2018).

Simultaneously achieving economic development and environmental sustainability is difficult task for most nations especially economies that depend greatly on non-renewable energy. At the heart of the ideas behind "green growth" and "the green economy" is the notion that civilizations can separate economic development from ecological constraints. After falling out of favor in the 1980s, these concepts gained steam again in the wake of the economic recession of 2008 and 2009, partly due to publications like UNEP's green economy report and the OECD's green growth plan (OECD, 2011; UNEP, 2011). The underlying assumption of these strategies is that both technology and innovations breakthroughs will enhance productivity, leading to endless GDP growth. The deep internal conflict between reducing carbon emissions and increasing growth in the economy is widely recognized as a problem that can only be solved by technical advancement (Li et al., 2017; Xie et al., 2021). Technological advancements, symbolizing the end of the Third Industrial Revolution, are hastening shifts in the basic pattern of economic prosperity on a worldwide scale and causing new ways of thinking about production and distribution. Technology is a crucial tool in the scientific and industrial transformation. It plays a major role in fighting global warming and offers considerable prospects for sustainable development (Haseeb et al., 2019; Zhang and Li, 2022).

Nevertheless, technology relies on electricity for its foundation, the advancement and functioning of high in energy facilities like cloud computing, and blockchain technology will result in increased carbon emissions (Yi et al., 2022). The advancement of technology leads to continuous enhancements in the computational power, processing speed, and network capacity of computers and servers. This would facilitate the comprehensive digitalization of society and expedite the expansion of carbon emissions in the digital sector. The advancement of digital technology necessitates the creation, transmission, and processing of vast amounts of data, resulting in increased energy consumption within the digital economy. Consequently, the overall carbon emissions also experience a steady rise (Jones, 2018; Park et al., 2018; Zhou et al., 2019).

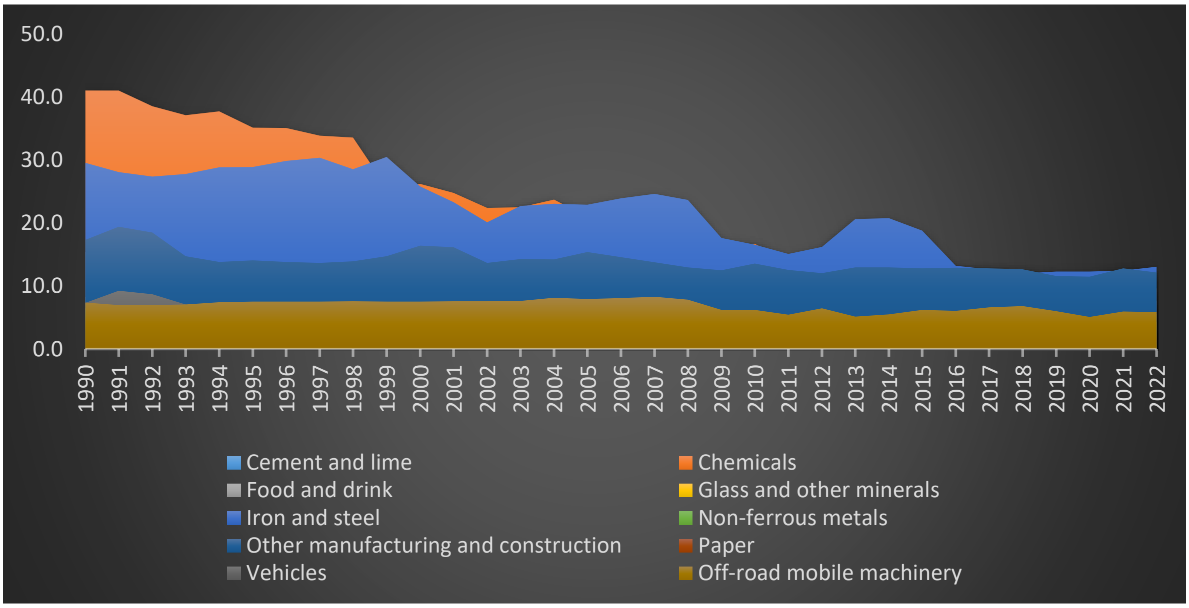
According to a production-based vantage point, it appears evident that European nations have successfully separated their gross domestic product (GDP) from its ecological effects and resource consumption (EEA, 2019b). This suggests that gross domestic product (GDP) is growing whereas these two variables are decreasing. The environmental implications of a considerable amount of European consumerism are neglected when these estimates are derived from domestic sources only and do not account for foreign business activities (Parrique et al., 2019; Wiedmann et al., 2020).

There is mounting demand for the UK to become net zero, and the country has made a legal promise to do so, however it appears that they are unlikely to be able to meet this objective. The rising price crisis and the economic fallout from the conflict in Ukraine have lately impeded progress. By the year 2035, consumption of power is expected to rise by 40-60% (Edie, 2023).

Because of the aforementioned, the UK is only expected to reduce its emissions by 92% of what it assured in its Nationally Determined Contribution (NDC) by 2030, and the effectiveness of its present strategies is under scrutiny in relation to the Climate Change Committee's Sixth Carbon Budget. As a result, efforts are being made to ensure that the biggest emitters suffer the highest fines while ensuring the most disadvantaged people receive extra assistance (Friends of The Earth, 2023). Figure 2 below display United Kingdom’s emissions by various sectors.

However, the literature contributions in the UK frequently fail to address the tangible effects of climate technology, economic growth, and municipal waste recycling on greenhouse gas emissions. This study fills the gap by applying an empirical test to the dynamic relationship between greenhouse gases and economic growth, municipal waste recycling, and climate technologies, all of which have received less consideration in prior research.

Figure 2: UK industrial emissions by sectors.



Source: Authors constructions based on BEIS (2022) national statistics data on UK GHG emissions.

The study’s objective is to investigate the effects of economic growth, municipal waste recycling, and climate technologies on greenhouse gases in the United Kingdom. The contribution of this study is comprised of three main sections. To start, the study takes a look at how climate technologies, municipal waste recycling, and economic expansion all influence emissions of greenhouse gases. When it comes to sustainable development studies in the United Kingdom, this study is at the forefront of research. Previously, studies have looked at the effects of economic growth, municipal waste recycling, and climate technology separately; however, this study examines all three factors simultaneously with regard to greenhouse gases emissions. Secondly, United Kingdom will be able to use the study's findings to inform the development of more realistic policies that will help it achieve its Nationally Determined Contributions. Lastly, this study examines the research findings and presents associated policy recommendations that will be highly valuable to researchers and policymakers. It uses Vector Error Correction Model (VECM) to investigate the impacts of economic expansion, municipal waste treatment, and climate technologies on greenhouse gas emissions. This study is divided into five sections: Section 2 reviews relevant literature; Section 3 provides a brief overview of the empirical methodology, variables, and data used in this study; Section 4 gives the statistical evaluation; and Section 5 provides a conclusion.

LITERATURE REVIEW

The impact of economic expansion, municipal waste treatment, and climate technologies on greenhouse gas emissions was taken into account in this study. We split the pertinent literature into the following groups for review to enable us to assess the advancements made in current research.

Municipal waste treatment and greenhouse gases emissions

Having a comprehensive understanding of what constitutes municipal waste is essential for comprehending the subject matter topic of this study. The term "municipal waste" is used by the OECD (2011) to describe waste that has been gathered and processed by local governments. Lawn and garden waste, street sweepings, the contents of dustbins, marketplace waste, and waste from commercial and trade establishments are all part of municipal waste. Not included are materials from municipal sewage systems and treatment, as well as debris from building and demolition projects. According to Eionet (2009), human activities can result in waste in various stages, including collecting raw materials, being processed, final product manufacturing, usage, and other act that humans perform.

The study conducted by Bogner et al. (2007) concluded that the waste sector accounts for less than 5% of global greenhouse gas (GHG) emissions. Methane, the primary greenhouse gas (GHG) emitted from the waste sector, is released during landfill operations, transportation of wastewater, sewage treatment processes, and from leaks during the anaerobic digestion of waste or wastewater sludge. Based on the scenarios outlined in the study "Projections of Municipal Waste Management and Greenhouse Gases" Bakas et al. (2011), the lowest possible reduction in greenhouse gas emissions from municipal waste management is estimated to be 49 Tg the equivalent of CO2 in the baseline scenario. This quantity represents 1.16% of the emissions from the 1990s. Although municipal solid waste accounts for only 8-9% of the total garbage in the EU, the estimate of 1.16% represents a noteworthy and positive outcome. In developing countries, the rates of methane emissions from landfills are predicted to rise as the amount of waste in landfills increases. Nevertheless, the implementation of incentives like the Clean Development Mechanism can expedite the process of recovering and utilizing Methane emissions from landfills, while simultaneously enhancing waste management techniques.

(Bogner et al., 2007) stated that the landfill is not merely an important driver of Methane emission, but additionally acts as a prolonged reservoir for carbon. Due to the resistant nature of lignin and the gradual disintegration of cellulosic parts, at least 50% of the organic carbon present throughout the landfill cycle failed to be transformed into biogas carbon, but instead retained in the landfill (Bogner et al., 2007). Furthermore, the integration of energy consumption with landfill highlights the increasingly significant function of energy in the carbon cycle of landfill. Furthermore, the proportion of carbon in landfills is subject to variation based on the initial composition of the garbage and the conditions within the dump. Weitz et al. (2002) reported that municipal solid waste management initiatives in the United States had successfully reduced greenhouse gas (GHG) emissions, despite a nearly twofold rise in garbage creation. This case study proved that the technological progress in managing municipal solid waste had a beneficial effect on reducing greenhouse gas emissions. The study propose a hypothesis:

Hypothesis (H_1): municipal waste treatment has a reducing effects on greenhouse gases emissions

Effects of economic growth on greenhouse gases emissions

Environmental problems are intricate, sometimes linked to societal and economic activities, and they can affect every corner of the globe. These problems go beyond political lines and pose significant threats to people's well-being, productivity, and safety. Polluting the air and water, making solid and hazardous waste, destroying soil, cutting down trees, changing the climate, and reducing biodiversity are all examples of such problems (Addai et al., 2022).

It is important to think about if lowering GDP might serve as an improved strategy to meet the EU's goal of "living well, within environmental limits" because there are doubts about whether or not societies can be sustainable through green growth. More and more, academics and politicians are debating and researching this topic. After a long hiatus beginning in the 1970s, figures like Latouche (2003) brought the concepts of "limits to growth" and "degrowth" back into the spotlight in the new millennium. After the inaugural Degrowth Conference in Paris in 2008, the field of degrowth quickly gained traction as a topic of study on a global scale. Interest was already high before the 2008–2009 financial and economic crisis, and there was a sudden surge in scholarly work on the topic of "degrowth" (Weiss and Cattaneo, 2017).

Increased economic activity has significant effects on ecological footprint, according to research by Mrabet and Alsamara (2017) that looked at economic growth and ecological footprint in Qatar. Economic expansion leads to environmental degradation, according to a study conducted in Azerbaijan by Mikayilov et al. (2018) that looked at the effects of growth on the environment from 1992 to 2013. Development in the financial industry boost ecological footprints (Baloch et al. 2019). Despite contradictory findings by Destek et al. (2018) and Bello et al. (2018), numerous additional studies evaluating the EKC hypothesis suggest that changes in income level affect ecological footprint (Ulucak and Bilgili 2018; Charfeddine and Mrabet 2017). Solarin and Al-mulali (2018) investigated the connections between FDI, CO2 emissions, ecological footprint, and carbon footprint using panel analytic techniques. They found that FDI had no effect on ecological footprint. A further study that looked at how various microeconomic characteristics in recently industrialized nations were related to ecological footprints confirmed the EKC theory (Destek and Sarkodie 2019).

A number of recent research have confirmed the presence of a correlation between rising economies and emissions of carbon dioxide (Fávero et al., 2022; Khan et al., 2022). By analyzing ten EU member states' GDP growth and CO_2 emissions from 1981 to 1995, Bengochea-Morancho et al. (2001) finds significant variation in emission mitigation measures, underscoring the need to tailor emission reduction efforts to each country's unique economic circumstances.

Nevertheless, Acaravci and Ozturk (2010) acknowledge the diversity among EU member states and, using autoregressive distributed lag (ARDL) bounds, examine the cointegration method in nineteen European nations. Their findings indicate a link of causality between CO2 emissions, energy consumption, and economic development in those nations. From this vantage point, Bilan et al. (2019) examine the effects of renewable energy sources and carbon dioxide emissions on gross domestic product (GDP) and find a correlation between the two. The correlation between GDP growth, energy consumption, and CO2 emissions is well-documented (Halicioglu, 2009). According to Dogan and Seker (2016), one tool to lessen our impact on the natural world is to increase the consumption of renewable energy sources. This will help cut down on greenhouse gas emissions. Research by Breed et al. (2021) and others highlights the potential of fuel consumption regulation as a tool to decrease CO2 emissions, as transportation accounts for 25% of all energy associated emissions.

Globally, CO_2 emissions have been steadily increasing due to rising final demand, according to an analysis by Jiang and Guan (2016). The authors found that CO_2 emissions via coal usage increased at the fastest rate. According to Mendonç et al. (2020), energy is a key component in driving economic growth and advancement, which in turn impacts our fundamental well-being. Societal discourse tactics and the full economic growth agenda are thus crucial to the capacity to deal with global warming and secure a sustainable environment. Even while energy seems an essential driving force of economic expansion, the negative impact on welfare can be mitigated by fostering the proper kind of improvement and decreasing risk, since energy consumption is naturally affected by commerce and the level of technology.

The impact of economic expansion on CO_2 emissions was the focus of an investigation from 2017 that included 31 developing nations. In their study, Aye et al. (2017) used a dynamic panel threshold framework to demonstrate a strong correlation involving growth and CO_2 emissions. They found that, under modest growth conditions, economic expansion reduces CO_2 emissions, but under substantial growth conditions, it increases them. Using energy consumption, economic growth, and other macroeconomic variables, Kalmaz and Kirikkaleli (2019) offer an empirical evidence to the modeling of CO2 emissions in developing nations. Their research proves that CO2 emissions, energy consumption, and other macroeconomic variables are all interrelated and reach a long-run equilibrium. Based on the above literature review, the study propose a hypothesis that:

Hypothesis (H_2): Economic growth promote rise in greenhouse gases emissions

Technological advancement effects of greenhouse gases emissions

The effect of technological progress on carbon emissions is growing. This has prompted numerous researchers to keep digging into the link between new technologies and increased carbon emissions (Zhu, 2022; Hu et al., 2022), as mentioned by Zhang and Chen (2022). The connection between new technologies and greenhouse gas emissions is a contentious topic, with opposing arguments. In the first place, experts in the field think that carbon emissions can be reduced when the rate of technical advancement rises. Energy utilization is improved, and prices are reduced as a result of technological inventiveness, which in turn lessens carbon dioxide emissions (Vural, 2021: Li et al., 2022). According to Mcqueen et al. (2020), new technologies like low-temperature energy sources can make direct air capture more affordable. This will encourage enterprises to minimize and directly use the carbon dioxide they create, ultimately leading to a decrease in carbon emissions. He et al. (2021) used information collected from 25 Chinese provinces between 2002 and 2015 to examine the effect of low-carbon technology innovation on carbon emissions; they concluded that low-carbon technology helps with carbon emission reduction, and sustainable development. The connection between environmental damage and metrics was investigated by Suki et al. (2022) using a bootstrap autoregressive distribution lag (BARDL) model. The study's conclusions demonstrated that technological innovation can increase the usage of renewable energy sources and decrease emissions of carbon.

The correlation between urbanization, income, technological advancement, and carbon emissions was studied by Feng et al. (2009) and conclusion made that greenhouse gases emissions were estimated to be significantly impacted by rising income per capita, fast urbanization, and technological innovation. According to their findings, technological innovation typically results in lower levels of carbon emissions since it introduces sophisticated technology into the country. Energy consumption, economic growth, and technological advancement were determined to have significant impacts on lowering CO_2 emissions in Ali et al. (2016), which centered on determining environmental quality. Research by Weber and Neuhoff (2010) demonstrated that advances in technology are inversely related to lessening environmental quality. Researchers came to the conclusion that new technology leads to less harmful, more energy-efficient products and services for the environment. Based on his analysis of the correlation between renewable energy, technological progress, and ecological pollution, Irandoust (2016) concluded that the use of renewable energy sources and advancements in technology greatly lessen pollution, leading to an improvement in environmental quality. At the same time, there are academics who contend that new technology doesn't help underdeveloped nations cut their carbon emissions.

According to Ganda (2019), technical advancements lead to better energy utilization, which in turn increases emissions in the environment. The investigation went on to say the majority of emerging countries use traditional energy sources, which are big polluters. Therefore, technical advancements in underdeveloped economies often lead to higher carbon emissions rather than lower ones. Environmental pollution in low-income nations tends to rise alongside technological progress. (Bai et al., 2020). The study propose a hypothesis based on the above literature review that:

Hypothesis (H_3): Climate Technologies are distractive to greenhouse gases emissions.

METHODOLOGY

Data Sources and Description

In order to minimize the damage to the environment and strike as much of a balance as possible between sustainability and growing the economy, climate change mitigation strategies needs to be promoted as a new tool. In response to the above, this study seeks to empirically analyze the dynamic impact of climate technologies, economic growth and municipal waste generation and treatment on greenhouse gases emissions from 2005Q1 to 2020Q4 in United Kingdom. To achieve this objective, data were sourced from International Monetary Fund (IMF) and Organization for Economic Cooperation and Development (OECD) database on:

1. Greenhouse gases emissions: The United Kingdom has pledged to reduce its national emissions of greenhouse gases (GHG) in compliance with the Paris Climate Agreement, and this indicator indicates their yearly mitigation (NDCs) efforts measured in million metric tons equivalent. This is the dependent variable that the study is employing.
2. Gross domestic product: One way to look at the state of the economy in the UK is by looking at the gross domestic product (GDP). It is a measure of the overall worth, at the current market price, of all

final goods and services produced in the nation over the selected period. This measure is employed as an independent variable and a proxy for economic growth. This is measured in billions of Pounds Sterling

iii. Climate technologies: Greenhouse gas emissions and combating climate change are the primary goals of climate technologies. This indicator is used as independent variable in the study. It captures United Kingdom's percentage of all environment-related technologies.

iv. Municipal waste recycling: Any procedure that recovers and reprocesses waste materials into new goods, materials, or substances, whether for the original or additional uses, is considered municipal waste recycling. This variable is used as independent variable and proxy for municipal waste generation and treatment. It is measured in thousands of tons equivalent.

Empirical analysis procedures and model specification.

For Vector Error Correction Model to be employed, data from time series that are non-stationary and cointegrated must exist. Tests for stationarity are therefore conducted to examine the regression equation for the hypothesis H_0:$\rho = 0$ (there is a unit roots), is employed to determine if the time series data is stable or not. This study uses the Augmented Dickey-Fuller (ADF) and Phillip-Perron (PP) test because of its capacity to adjust for autocorrelation difficulties. The procedure is estimated as follows:

$$\mathrm{y}_t = \gamma + \rho \mathrm{x}_{t-1} + \varepsilon_t \qquad (1)$$

y_t represent variables of interest, γ denotes the constant term, and ε_t is the error term, ρ is the parameter slopes for lagged variables, which becomes 1 in presence of unit root. Using unit diffencing, the equation is transformed into

$$\Delta \mathrm{y}_t = \gamma + \varepsilon_t \,, \quad \text{where } \Delta = (1 - \mathrm{B}) \qquad (2)$$

Next, test for cointegrating equation in the studied series using the Johenson cointegration test was conducted. To identify the cointegration of the study variables, Johansen (1991) employ two tests: Trace test and Maximum Eigenvalue test. For $(\mathrm{r} = 0, 1, \ldots \mathrm{x} - 1)$, trace statistics test the alternative hypothesis of x cointegrating connections with the null hypothesis of r cointegrating relationships, where x is the number of variables under consideration This equation can be expressed using the following formula:

$$\mathrm{LR}_{trace}\left(\frac{\mathrm{r}}{\mathrm{x}}\right) = -\mathrm{T} \sum_{i=r+1}^{x} \log\left(1 - \gamma_i\right) \qquad (4)$$

The Maximum Eigenvalue statistic compares the alternative hypothesis of $(\mathrm{r} + 1)$cointegrating links with the null hypothesis of r cointegrating associations for $(\mathrm{r} = 0, 1, \ldots \mathrm{x} - 1)$. Here are the steps to calculate the test statistics:

$$\mathrm{LR}_{max}\left(\frac{\mathrm{r}}{\mathrm{x}} + 1\right) = -\mathrm{T} \log\left(1 - \gamma\right) \qquad (5)$$

where γ is the maximum eigenvalue and T is the sample size.

The best lag order, as calculated by the Sequential Modified LR test statistic, Final Prediction Error (FPE), and Akaike Information Criteria (AIC), was employed since lag selection is crucial in VECM. The study proceed to estimate VECM and analyze the effects among the regressors and the dependent variable. An extension of the VAR model that takes long-term equilibrium relationships among variables into consideration is the Vector Error Correction Model (VECM). According to Enders (2015), it works well with cointegrated variables, which means that there is a common relationship over the long term even while there are short-term variations. Additionally, it shows how fast the model recovers from a temporary external shock. Generally, VECM is given by:

$$\Delta \mathrm{GHG}_t = \alpha + \xi \mathrm{GHG}_{t-1} + \gamma \mathrm{LGDP}_{t-1} + \varsigma LMWR_{t-1} + \lambda \mathrm{CLT}_{t-1} + \sum_{i=1}^{k-1} \mu_i \Delta \mathrm{GHG}_{t-i} + \sum_{j=1}^{k-1} \gamma_j \Delta \mathrm{LGDP}_{t-J} + \sum_{m=1}^{k-1} \varsigma_m \Delta \mathrm{LMWR}_{t-m} + \sum_{n=1}^{k-1} \lambda_j \Delta \mathrm{CLT}_{t-n} + \Gamma\, \mathrm{ECT}_{t-1} + \varepsilon_t \quad (6)$$

Where ΔGHG represent the variable of interest (greenhouse gases), the $(1 \times \mathrm{k})$ matrix coefficients of the long-run endogenous variables (greenhouse gases, gross domestic product, climate technologies and municipal waste recycling) are denoted by ξ, γ, ς, and λ respectively. The coefficient of speed of adjustment ECT_{t-1} is depicted by Γ. The $(1 \times \mathrm{k})$ matrix coefficients of the short run dynamics of the variables are shown as μ_i, γ_j, ς_m,and λ_j. k is the VAR order, ε_t represent the error term, α is the constant term. The study moves on to examine the dynamic behavior of the data series using impulse response analysis. .Examining the short- and long-term dynamics of the series that the shock explains at various horizons, we analyzed the forecast error in terms of shocks to the structure. The impulse response function is given by:

$$P_{ji}^{(m)} = \frac{\partial Y_{j,t+m}}{\partial \varepsilon_{it}}, m = 1,2, \ldots \quad (7)$$

Where $p_{ji}^{(m)}$ is the (j, i) element of the matrix, $\mathrm{p_m}$ depict the response of $Y_{j,t+m}$ to a random shock ε_{it}. The study provides the following equation to quantify the variance decomposition effects of shocks on variables in both short- and long-term responses:

$$X_{t+h} - X_{t+\frac{h}{t}} = M_0 w_{t+1} + M_1 w_{t+2} + \cdots + M_k w_{t+h} \quad (8)$$

Variance of the forecast error of the i^{th} variable is then given by

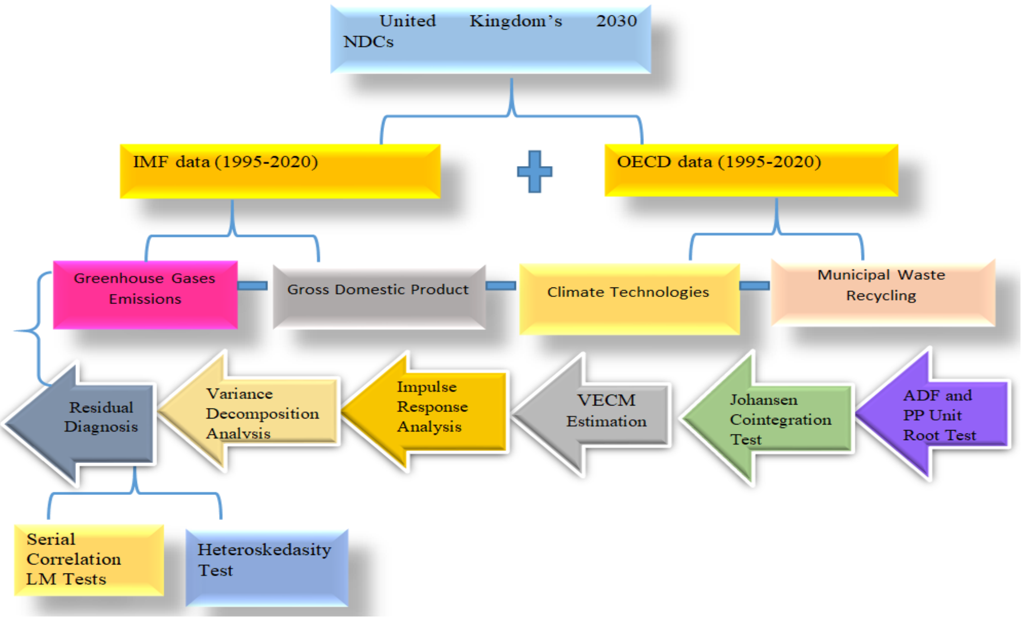
$$var(X_{it+h} - X_{it+\frac{h}{t}}) = \sum_{k=1}^{n} \sum_{j=0}^{h} M_{ik}^{j2} var(w_{kt}) \quad (9)$$

Thus the contribution or percentage of variance of X_{it} explained by the kth shock is given by

$$\frac{\sum_{j=0}^{h} F_{ik}^{j2}}{\sum_{k=1}^{n} \sum_{j=1}^{h} M_{ik}^{j2}} \quad (10)$$

White Heteroskedacity test and Serial Correlation LM tests was then used to test the parameter residuals. The diagram below illustrate the study's data analysis processes.

Figure 3: Data analysis procedures chart



Source: Authors construction

EMPIRICAL RESULTS

Descriptive Statistics

From table 2, gross domestic product, climate technologies, greenhouse gases and municipal waste recycling reflect an average of 7.51, 9.33, 629.24, and 8.62 respectively. The highest values recorded for gross domestic product, climate technologies, Greenhouse gases and municipal waste recycling for the selected years (1995Q1 to 2020Q4) are 7.71, 13.28, 778.38 and 9.06 respectively. Likewise, the minimum values recorded are 7.23, 5.30, 408.97 and 7.56 respectively. Gross domestic product, climate technologies, greenhouse gases and municipal waste recycling deviate from the sample mean by 0.14, 2.92, 111.22 and 0.52 respectively.

In measures of normality, regarding asymmetric of series, it can be seen from table 2 that all the variables have negative skewness from the average mean. The Kurtosis indicating the peakness or the flatness of the distribution show that all the variables are platykurtic in nature, (< 3), which means that their dataset or points has more values that are less than their mean values. .From the table the Jarque-Bera probability for the variables indicates a normal distribution of the series.

Table2: Descriptive Statistics Results

	LGDP	CLT	GHG	LMWR
Mean	7.505773	9.330385	629.2427	8.618907
Maximum	7.713494	13.28000	778.3847	9.064135
Minimum	7.230730	5.300000	408.9651	7.561122
Std. Dev.	0.135190	2.925627	111.2256	0.523378
Skewness	-0.480571	-0.044489	-0.459442	-0.857494
Kurtosis	2.376615	1.312082	1.870802	2.152329
Jarque-Bera	1.421769	3.095065	2.296055	3.964709
Probability	0.491209	0.212772	0.317262	0.137745
Note: LGDP(Gross Domestic Product), CLT(Climate Technology), GHG(Greenhouse Gases), LMWR (Municipal Waste Recycling)				

Source: Authors compilation from eviews.

Unit Root Test

According to Moon and Perron (2004), the presence of a unit root in the model is the null hypothesis. Table 3 presents the series unit root's outcomes. The findings of the unity root at the level and the first difference are displayed in table 2. This may be shown by comparing the critical thresholds of the test statistics at the 1, 5, and 10% significance levels with the values that were observed of both the Augmented Dickey-Fuller (ADF) and Phillip-Perron (PP) test statistics.

Table 3: ADF and PP Unit Root Test Results

Phillip-Perron (PP)					
At Level					
		GHG	ENT	LGDP	LMWR
With Constant	t-Statistic	1.7906	-0.8456	-2.2504	-2.2497
	Prob.	0.9997	0.8015	0.1902	0.1904

With Constant & Trend	t-Statistic	-2.3682	-1.1144	-1.0387	-0.4144
	Prob.	0.3939	0.9210	0.9333	0.9858
At First Difference					
		d(GHG)	d(ENT)	d(LGDP)	d(LMWR)
With Constant	t-Statistic	-11.7642	-10.3274	-10.4627	-10.6431
	Prob.	0.0000***	0.0000***	0.0000***	0.0000***
With Constant & Trend	t-Statistic	-12.9211	-10.2964	-10.8989	-11.2747
	Prob.	0.0000***	0.0000***	0.0000***	0.0000***
Augmented Dickey-Fuller (ADF)					
At Level					
		GHG	ENT	LGDP	LMWR
With Constant	t-Statistic	0.7952	-1.2526	-2.1777	-2.7334
	Prob.	0.9936	0.6489	0.2157	0.0720*
With Constant & Trend	t-Statistic	-2.5570	-1.1217	-1.1420	-1.0737
	Prob.	0.3008	0.9196	0.9161	0.9276
At First Difference					
		d(GHG)	d(ENT)	d(LGDP)	d(LMWR)
With Constant	t-Statistic	-10.9756	-3.2803	-10.4692	-3.4396
	Prob.	0.0000***	0.0004***	0.0000***	0.0002***
With Constant & Trend	t-Statistic	-11.1557	-3.3408	-10.8504	-4.2924
	Prob.	0.0000***	0.0048***	0.0000***	0.0048***
Note: * ,**, *** indicate 1%, 5%, 10% significant level respectively. : LGDP (Gross Domestic Product), CLT (Climate Technology), GHG (Greenhouse Gases), LMWR(Municipal Waste Recycling).					

From table 3 above, since the absolute values of the test findings are less than the significance criterion as established by (Mackinnon, 1991), there is compelling evidence of non-stationarity at level for both Augmented Dickey-Fuller (ADF) and Phillip-Perron (PP). It is seen that the series variables are mixed order in intergration. Few of them are stationary at level. However, at first-order differential level all variables are stationary and significant at 1% level with respect to intercecpt and with intercept and trend. This suggests integrating all variables I (1), with the exception of municipal waste recycling, which is integrated to I (0).

Cointegration test result and VAR lag order selection criteria analysis

After considering the Sequential Modified LR test statistic, Final Prediction Error (FPE), and Akaike Information Criteria (AIC), the best lag order was shown to be lag length 1. Table 5 shows the outcomes of the Johansen cointegration test. Gross domestic product, climate technologies, Greenhouse gases and municipal waste recycling are all interrelated variables that are linked by cointegration. The study has shown that this relationship is longer and more stable. Gross domestic product, climate technologies, Greenhouse gases and municipal waste recycling trace statistics and maximum eigenvalue are displayed in Table 5. Cointegration between independent and dependent variables at a significance level of 5% demonstrated a long-term dynamic link between independent and dependent variables.

Table 4: VAR Order Selection Criteria Test Result.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-779.6153	NA	103.6111	15.99215	16.09766*	16.03483*
1	-699.7767	114.0848*	76.06444*	15.66891*	17.46256	16.39441
2	-777.5098	3.996205	137.6283	16.27571	16.80325	16.48909
3	-774.3769	5.690391	179.2661	16.53830	17.48788	16.92239
4	-768.7910	9.689832	222.6541	16.75084	18.12245	17.30563
Note: * indicates lag order selected by the criterion, **LR:** sequential modified LR test statistic (each test at 5% level), **FPE**: Final prediction error, **SC**: Schwarz information criterion, **AIC:** Akaike information criterion, **HQ:** Hannan-Quinn information criterion						

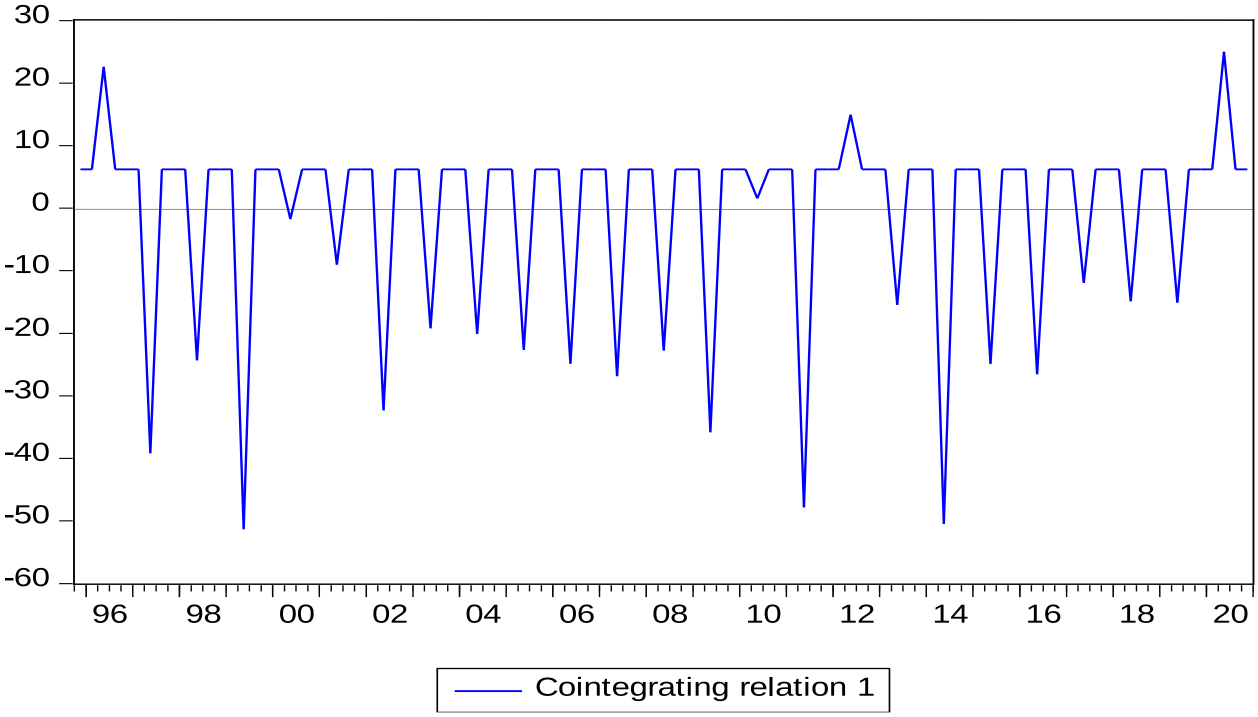
These two tests disprove the idea that no cointegrating equation exists, which is the null hypothesis. Both Trace statistics and Max-Eigen Statistic values are all higher than its critical values at none, at most 1, at most 2 and at most 3, and statistically significant at 0.05 significant level

Table 5: Johansen cointegration test results (Trace and maximum eigenvalue).

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	Critical Value (0.05)	Prob.**
None *	0.480766	189.0513	47.85613	0.0000
At most 1 *	0.334587	122.8559	29.79707	0.0000
At most 2 *	0.389641	81.90395	15.49471	0.0000
At most 3 *	0.452141	40.95198	3.841466	0.0000
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	Critical Value(0.05)	Prob.**
None *	0.480766	66.19541	27.58434	0.0000
At most 1 *	0.334587	40.95198	21.13162	0.0000
At most 2 *	0.389641	40.95198	14.26460	0.0000
At most 3 *	0.452141	40.95198	3.841466	0.0000
Note: Max-eigenvalue test indicates 4 cointegrating eqn(s) at the 0.05 level, * denotes rejection of the hypothesis at the 0.05 level, **MacKinnon-Haug-Michelis (1999) p-values.				

Figure 4 illustrates a correlation between the research variables over the long run. As the grid line crosses the zero line multiple times, long-term equilibrium is approached. Statistical testing of the long-term effect of GDP, climate technologies and municipal waste recycling on greenhouse gas emissions was thus supported by the cointegration plot of the estimated VAR model.

Figure 4: Cointegration graph of variables



Source: Authors construction from Eviews

Vector Error Correction Estimates

Table 6: Vector Error Correction Model Estimation Results

Cointegrating Eq:	**CointEq1**			
D(GHG(-1))	1.000000			
D(CLT(-1))	-63.58091			
	(46.4176)			
	[-1.36976]			
D(LGDP(-1))	515.3374			
	(94.0334)			
	[5.48037]			
D(LMWR(-1))	-39.93240			
	(33.3683)			
	[-1.19672]			
C	6.223240			
Error Correction:	D(GHG,2)	D(CLT,2)	D(LGDP,2)	D(LMWR,2)
CointEq1	-0.800097	0.001306	0.000840	0.003167

	(0.13533)	(0.00047)	(0.00021)	(0.00067)
	[-5.91206]	[2.79520]	[3.91182]	[4.70505]
D(GHG(-1),2)	-0.099951	-0.000653	-0.000420	-0.001584
	(0.10562)	(0.00036)	(0.00017)	(0.00053)
	[-0.94633]	[-1.79077]	[-2.50615]	[-3.01434]
D(CLT(-1),2)	-25.43546	-0.458475	0.026690	0.100696
	(29.6881)	(0.10251)	(0.04708)	(0.14768)
	[-0.85676]	[-4.47234]	[0.56689]	[0.68184]
D(LGDP(-1),2)	206.1600	0.336571	-0.283668	0.816160
	(69.3621)	(0.23951)	(0.11000)	(0.34504)
	[2.97223]	[1.40526]	[-2.57876]	[2.36542]
D(LMWR(-1),2)	-15.97490	0.026080	0.016763	-0.436758
	(21.7080)	(0.07496)	(0.03443)	(0.10799)
	[-0.73590]	[0.34793]	[0.48692]	[-4.04460]
C	-5.09E-15	8.32E-18	5.35E-18	6.97E-18
	(1.26638)	(0.00437)	(0.00201)	(0.00630)
	[-4.0e-15]	[1.9e-15]	[2.7e-15]	[1.1e-15]
Note: Standard errors in ( ) , t-statistics in [ ], LGDP(Gross Domestic Product), CLT(Climate Technology), GHG(Greenhouse Gases), LMWR(Municipal Waste Recycling)				

Source: Authors compilation from eviews

Next, the study team estimated the VECM model after confirming that the research data were cointegrated by the cointegration test. VECM model is used for estimate in cases when there is a cointegration relationship between the study variables (Enders, 2015). Instead, the VAR model can be used for estimate if the study variables are not cointegrated. Table 6 above shows the Vector Error Correction Model, which shows the long run and short run relationships among the variables. It also tells us how quickly the model gets back to equilibrium following a short-term shock or deviation from outside sources. A correction curve converging to equilibrium exists when non-stationary variables are cointegrating, as demonstrated by Engle and Granger (1987). Thus, a VECM depicts the structure's behavior over the short and long periods.

It is evidenced from table 6 above that the previous year’s deviation from long run equilibrium is corrected in the current period at an adjustment speed of 80%. Consequently, it takes around 1 year and 5 months to reach a stable condition. All signs point to the variables being very close to reaching their long-term equilibrium. In the long run, a 1% change in Climate technologies promote 63.58 metric tons reduction in greenhouse gases in the United Kingdom. This finding is similar to He et al. (2021) who also used information collected from 25 Chinese provinces between 2002 and 2015 to examine the effect of low-carbon technology innovation on carbon emissions and concluded that low-carbon technology helps with carbon emission reduction, and sustainable development. Likewise, a percentage change in Municipal waste recycling in the United Kingdom reduces their greenhouse gases by 39.93 metric tons. However, economic growth denoted by LGDP causes 515.33 metric tons rise in greenhouse gases as a result of a percentage change in LGDP. Mrabet and Alsamara (2017) have found similar trend in Qatar that, increased economic activity has significant effects on ecological footprint.

In the short run, it is observed from table 6 above that a percentage change in climate technologies and municipal waste recycling in UK ceteris paribus reduce their greenhouse gases by 25.43 and 15.97 respectively. However, GDP causes 206.16 metric tons increase in greenhouse gases due to a percentage change in GDP.

Impulse response analysis

According to Engle and Granger (1987), the error correction model might be confusing when it provides an unsuitable sign for the understudied variables in the short run. Consequently, the result is driven by an investigation of the model's dynamic behavior utilizing the variance-decomposition and impulse response techniques. According to Lütkepohl (1991), if all the roots have a modulus less than one and are located on the unit circle, then the predicted VECM is stable, or stationary. The model's unit roots are shown in Figure 5, which demonstrates this. All of the VAR model variables are stationary and appropriate for impulse response analysis because they all lie inside a single circle. Each error term follows a normal distribution pattern, and the system may have a cointegrated equation.

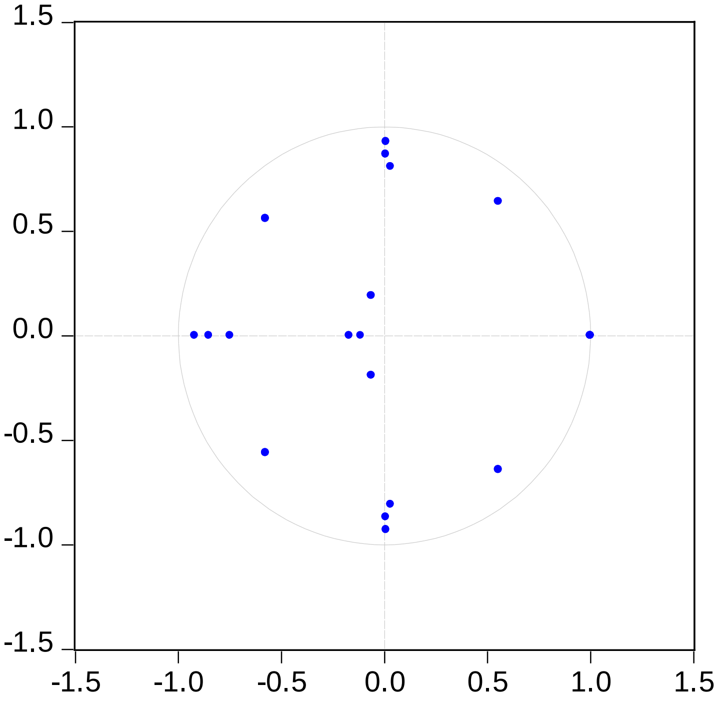
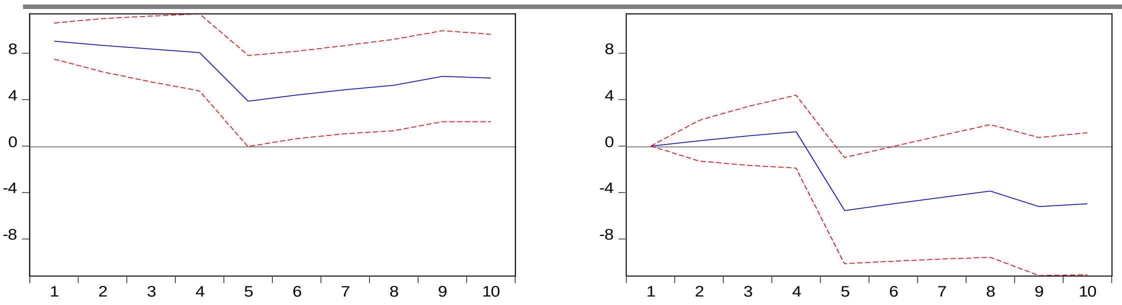


Figure 5: Inverse Roots of AR Characteristic Polynomial graph

Source: Authors construction from Eviews

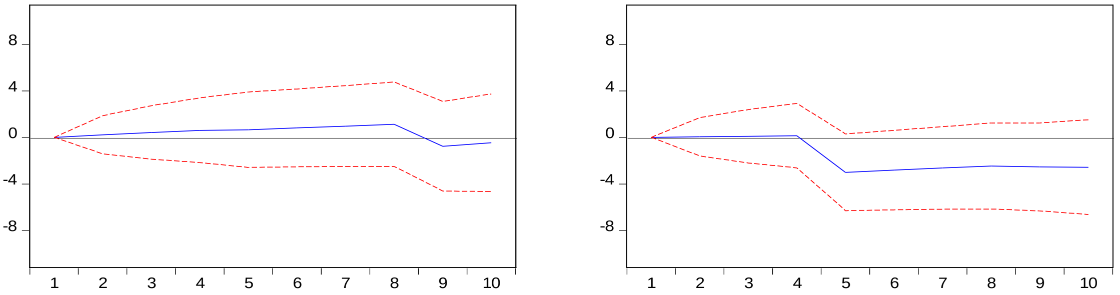
The impact of climate technologies, economic growth and municipal waste recycling on greenhouse gases are all examined with the aid of impulse response analysis. Figure 6 displays the findings of this study, which sets the number of responds to 10 periods and analyzes the impulse influence of the factors with the horizontal axis representing the time intervals and the vertical axis representing the impulse response's magnitude, with the number of lead periods as 1, 5, and 10 in the short run, medium term, and long run, respectively.

Figure 6A shows the response of greenhouse gases emissions to its own shocks. It can be observed that after receiving a one standard deviation shock, greenhouse gases emissions remains positive through the short run to the long run. It declines from 1st period to 5th period, then increase to the 10th period, still in the positive zone. The implication is that greenhouse gases emissions promote itself in both long and short run



A: Accumulated Response of Greenhouse gases to Greenhouse gases

B: Accumulated Response of Greenhouse gases to municipal waste recycling



C: Accumulated Response of Greenhouse gases to Gross domestic product

D: Accumulated Response of greenhouse gases to climate technologies

Figure 6: Accumulated Response to Cholesky One S.D. (no d.f. adjustment)Innovations ± 2 S.E.

Source: Authors construction from Eviews

Figure 6B shows that greenhouse gases emissions declines from the positive region in the 1st period (short run), then becomes negative from the 5th period through to 10th period (long run) after an impulse of one standard deviation by Municipal Waste Recycling. The implication is that in the long run Municipal Waste Recycling will reduce Greenhouse Gases in the United Kingdom. Likewise from figure 6D, greenhouse gases after receiving a one standard deviation shock from climate technologies decreased from the short run through to long run in the negative region. This also indicates that, Climate Technologies will reduce Greenhouse Gases both in the long and short run.

However, from figure 6C, after receiving a one standard deviation shock from economic growth, greenhouse gases emissions remains positive from the 1st period to the 9th period where it declined to the negative region through to the 10th period. This implies that in the UK economic growth will increase greenhouse gases in the short run but will turn to reduce it in the long run. Goodness and Prosper (2017) also used a dynamic panel threshold framework to demonstrate a strong correlation involving economic growth and CO_2 emissions. They found that, under modest growth conditions, economic expansion reduces CO_2 emissions.

Variance decomposition

In the short term, the error correction model occasionally fails to provide a realistic representation of the variables (Engle and Granger, 1987). As a result, variance decomposition emerges as a substitute for calculating the contribution of each independent variable to variations in the dependent variable. Table 7 is variance decomposition measuring the impact of exogenous shocks on variables over a ten-year period, accounting for both immediate and long term reactions.

Table 7: Results of Variance Decomposition of Greenhouse Gases

Period	S.E.	D(GHG)	D(LGDP)	D(MWR)	D(CLT)
1	9.917597	100.0000	0.000000	0.000000	0.000000
2	9.941016	99.68377	0.251327	0.061389	0.003511

3	9.960270	99.42545	0.456636	0.111538	0.006379
4	9.976107	99.21410	0.624611	0.152568	0.008725
5	13.72802	63.60624	29.95128	0.082380	6.360097
6	13.75798	63.50607	30.03945	0.097398	6.357082
7	13.78338	63.40259	30.13005	0.112601	6.354764
8	13.80503	63.29957	30.21985	0.127695	6.352881
9	14.06464	61.34126	30.21126	2.323460	6.124022
10	14.07228	61.28826	30.21374	2.380048	6.117959
Cholesky Ordering: D(GHG) D(LGDP) D(MWR) D(CLT), : LGDP (Gross Domestic Product), CLT (Climate Technology), GHG (Greenhouse Gases), LMWR (Municipal Waste Recycling)					

Source: Authors compilations from Eviews

It is evidenced in table 7 that, in the short run (1st period), 100% variation in greenhouse gases is explained by the variables own shocks or innovations. The independent variables climate technologies, economic growth and municipal waste recycling did not account for any variation in Greenhouse Gases emissions. During the medium term, 63.60% fluctuations in greenhouse gases is explained by the variables own shocks, the contribution of the independent variables in variations were climate technologies 6.36%, gross domestic product 29.95% and municipal waste recycling 0.08%.

In the long run (10th period), only 61.28% fluctuations is explained by greenhouse gases own shocks. Gross domestic product explained 30.21%, municipal waste recycling explained 2.38% and climate technologies 6.11%. Conclusion can be made that among the independent variables gross domestic product is the main contributor of variations in greenhouse gases in both short and long run, followed by climate technologies and municipal waste recycling. The impact of variations in greenhouse gases by the independent variables were greater in the long run than short run.

Diagnostic Test

Before the ultimate implementation of this VEC model, a variety of diagnostic tests were conducted. Table 8 and 9 contains the outcomes of those assessments. The model is exempt from heteroscedasticity, as evidenced by the Breusch–Pagan–Godfrey test score of 0.2336. Additionally, the Jarque–Bera test verified the normality of residuals. The absence of a series correlation for the lags h is the first null hypothesis to be tested in the VAR Residual Serial Correlation LM test. There is no evidence of autocorrelation between the residuals because the computed p-values for all four lags are more than 0.05, ruling out the possibility of rejecting the null hypothesis. Lag 1–h do not exhibit serial correlation; this is the second null hypothesis of the VAR Residual Serial Corellation LM test. There is no evidence of autocorrelation between the residuals for lags 1–h because the computed p-values for all four lags are greater than 0.05, ruling out the possibility of rejecting the null hypothesis.

Table 8: Heteroscedasticity Test Results

Joint test:		
Chi-sq	df	Prob.
109.9303	100	0.2336

Source: Authors compilations from Eviews

Table 9: VEC Residual Serial Correlation LM Tests

Lag	LRE* stat	df	Prob.	Rao F-stat	Df	Prob.
Null hypothesis: No serial correlation at lag h						
1	39.55547	16	0.3219	2.590517	(16, 269.5)	0.3219
2	103.1913	16	0.2581	7.619907	(16, 269.5)	0.2584
3	10.32113	16	0.8493	0.640622	(16, 269.5)	0.8495
4	96.07637	16	0.4058	6.998423	(16, 269.5)	0.4059
Null hypothesis: No serial correlation at lags 1 to h						
1	39.55547	16	0.3219	2.590517	(16, 269.5)	0.3219
2	163.7926	32	0.4410	6.342146	(32, 311.4)	0.4854
3	181.6751	48	0.2852	4.685473	(48, 310.2)	0.3026
4	188.0067	64	0.2210	3.585102	(64, 299.8)	0.2410

Source : Authors compilations from Eviews.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

The United Kingdom is working to achieve its 2030 Nationally Determined Contributions (NDCs) by addressing its climate-change concerns. This study examined the impact of climate technology, economic growth, and municipal waste recycling on greenhouse gas emissions using Vector Error Correction Model (VECM) and time-series data from 1995 to 2020.

At a first step, the empirical results validate the findings of stationarity for each variable. By using the unit root test, outcomes showed that there is a mixed order of integration for economic growth, greenhouse gases emissions, municipal waste recycling, and climate technologies, that is they are integrated at I(0) and I (1). All of the variables are linked by cointegration and Investigations have shown that the relationships among them are more prolonged and stable.

Municipal waste recycling and climate technology both help cut down on emissions of greenhouse gases, both now and in the future. Although economic expansion initially increases greenhouse gas emissions, it ultimately leads to a decrease in the long term. Finally, greenhouse gases emissions own shocks accounted for most of the variation in greenhouse gases emissions over the short and long terms. However, among the independent variables gross domestic product is the main contributor of variations in greenhouse gases in both short and long run, followed by climate technologies and municipal waste recycling.

Policy Recommendation

The study found that municipal waste recycling and climate technology effectively reduce emissions of greenhouse gases, which is important for dealing with environmental pollution in the United Kingdom and for achieving its Nationally Determined Contributions (NDCs) by 2030. Hence, in order to further succeed in managing environmental pollution, the government and other stakeholders should enhance policies and strategies governing them. Greenhouse gas emissions are reduced by climate technology. The authors suggest that, in order to achieve sustainable development for the environment, additional policies need be put in place to encourage higher levels of climate technology.

Reducing the impact of greenhouse gas emissions requires the development of encompassing strategies for adaptation and remediation that make use of emerging financial, organizational, and technical approaches. The UK's climate change and sustainability efforts will benefit from reduced emissions. Growing economies has been known to increase greenhouse gases emissions, which in turn cause significant long-term fluctuation. Consequently, the UK government's economic management team should enact rules and regulations to curb economic activity that increases emissions of greenhouse gases and instead support and finance green and low-carbon project efforts. Their National Determined Contribution (NDC) goal is to reduce emissions by 68% by 2030, and this will help them achieve that goal.

Study limitation

This study only looked at the impact of economic growth, recycling of municipal garbage, and climate technologies on greenhouse gas emissions in the the United Kingdom; it doesn't tell us anything about how these variables affect greenhouse gases emissions in other countries. Since other variables may potentially impact greenhouse gas emissions in United Kingdom, we cannot rule out the possibility that economic development, municipal waste recycling, and climate technology are the sole determinants of these emissions.

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Availability of Data and Materials: Datasets used and analyzed in this study are available on request from corresponding author

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