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The Path to Effective Resource Management: Exploring the Impact of Eco-Friendly Innovations, Clean Energy Transition, Economic Development and Trade in G-7 Countries

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Received: 21 April 2025 | **Revised:** 29 December 2025 | **Accepted:** 6 February 2026

Keywords: clean energy transition | eco-friendly innovation | effective resource management | material footprint | MMQR

ABSTRACT

As one of the international economic organizations, the G-7 countries are composed of the world's leading industrialized countries. In addition, the role of the G-7 countries in global warming is another issue that is constantly debated. Concerns have been raised about these very wealthy nations' capacity to manage their resources sustainably. Examining the factors that contribute to efficient resource management in these nations has grown in significance. The goal of this research is to look at how eco-friendly innovations, clean energy transition, economic development, and trade affect effective resource management in the G-7 nations. The material footprint is used as a gauge for efficient resource management. The Method of Moments Quantile Regression (MMQR) approach, which is a novel method, was used in this research to examine the G-7 nations' yearly data for the years 1990–2019. Eco-friendly technologies lower the material footprint in the G-7 nations, according to MMQR findings. Results are statistically significant for the majority of quantile levels (0.1–0.7). Clean energy transition also reduces the material footprint of the G-7 countries, with statistically significant results at all quantile levels. Economic development increases the material footprints of G-7 countries; findings are statistically significant at all quantile levels. The material footprint is consequently increased by trade, and the results are statistically significant at various quantile levels (0.5–0.9). Additionally, the research tests robustness using other panel estimators and achieves similar findings. Lastly, the paper offers policy suggestions for G-7 nations' efficient resource management.

1 | Introduction

Among the most crucial worldwide concerns for environmental and economic sustainability is effective resource management (Ramzan et al. 2023; Sun et al. 2023). Environmental risks include soil, water, and air pollution, biodiversity loss, and greenhouse gas emissions (hereafter, GHGs) resulting from the extraction, processing, and consumption of resources necessary to meet the contemporary world's economic demands (Pothen and Welsch 2019; Sahoo et al. 2021). These findings are significantly impacted by the fact that the globe uses fossil fuels to a degree of around 80%. But from 1990 to 2020, GHGs rose by more than 50% However, non-renewable energy will account

Abbreviations: CF, Carbon footprint; GHGs, Greenhouse gas emissions; EC, Energy consumption; EG, Economic growth; EQ, Environmental quality; RE, Renewable energy; EF, Ecological footprint; WDI, World Development Indicators; MF, Material footprint; MMQR, Method of Moments Quantile Regression; CSD, Cross-sectional dependence.

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for 80.2% of the world's energy consumption (hereafter, EC) in 2020; this represents a mere 2.1% decline from 1990 (World Bank 2023). Forecasts for population and economic growth (hereafter, EG) in the next decades indicate that there will likely be a significant rise in the demand for products and services globally (Charlier and Fizaine 2023). This will make resources even more in demand and make environmental issues worse. Within the framework of SDG 8 and SDG 12, the United Nations Development Programme implemented the Sustainable Development Goals (SDGs), which also provide significant guidance to nations for the sustainable use of natural resources until 2030 (Razzaq et al. 2021). This is done to guarantee that countries will have enough resources in the future and to lessen the damaging impact that exploiting natural resources and products has on the environment.

Environmental issues have been the subject of several research that have focused on CO_2 emissions. However, since it restricts environmental consequences to air impacts, this criteria is insufficient for effective resource management (Wackernagel and Rees 1998; Al-Mulali et al. 2015; Ansari et al. 2020; Nathaniel et al. 2021; Sahoo et al. 2021). For instance, CO_2 emissions in low- and middle-income nations are increasing now as high-income countries shift to a more offshore material-intensive manufacturing phase (Bruckner et al. 2012; Castellani et al. 2021). Therefore, more accurate measurement of environmental impacts is required. The notion of material footprint (hereafter, MF), also known as raw material consumption, was introduced by Wiedmann et al. (2015). It is a consumption-based resource use indicator that provides a more precise and all-encompassing assessment of environmental consequences. The MF is the amount of all materials extracted to meet a country's final demand, including materials involved in imports (Liedtke et al. 2014; Pothen and Welsch 2019; Liu et al. 2022). MF differs from domestic material consumption (DMC) in this regard. While DMC only measures the amount of raw materials used in a country or region (Wang et al. 2022), the MF is found by subtracting the raw material equivalent (RME_E) of exports from the sum of domestic production (DE) and raw material equivalent (RME_M) of imports (Jin et al. 2021; Karakaya et al. 2021). Consequently, it is possible to properly gauge the source of the strain on natural resources and the demand for commodities from high-income nations (Ansari et al. 2020).

Between 1970 and 2023, the worldwide average per capita material consumption rose from 7.4 metric tons to 12.6 metric tons; by 2060, it is expected to have doubled from its present level (United Nations 2021; Diaconaşu et al. 2022; Sun et al. 2023; GMFD 2023). Based on statistics from 2023, Qatar has the biggest average MF per person, weighing 65.3 metric tons. After Qatar, Oman comes in at 49.4 metric tons, followed by Luxembourg at 49.5 metric tons. China leads the world with 35 billion metric tons of total MF, followed by the United States (10 billion metric tons) and India (7 billion metric tons) in that order. China's MF has grown almost eighteen times since 1970, India's MF has grown about five times, while the United States' MF has grown about 1.5 times (GMFD 2023). Effective resource management or a reduction in the MF are critical for reversing this tendency. The only way to mitigate environmental consequences like biodiversity losses and resource consumption is via effective resource management (Sun et al. 2023). The factors that determine the MF must be given careful consideration in relation to this matter. Numerous studies on the topic have been published in the literature in relation to commerce, industrialization, urbanization, and economic development (Pothen and Welsch 2019; Wang et al. 2022; Sun et al. 2023; Charlier and Fizaine 2023). Nonetheless, research on the connections between eco-friendly innovation and MF as well as the clean energy transitions has also added to the body of literature in recent years (Razzaq et al. 2022; Sun et al. 2023; Ozturk et al. 2023).

First of all, the world's and many civilizations' futures have been directly impacted by development-oriented policies. The global economy today is showing the effects of the strategies many low-income nations have adopted for EG, including declining rates of poverty, rising rates of urbanization, rising levels of per capita income, and advances in human development. The global poverty rate, which was 38% in 1990, decreased to 8.4% by 2020 (World Bank 2022). However, compared to 1950, when there were fewer than one billion people living in cities, there are now almost four billion. Urbanization rates are significantly rising, even in the most disadvantaged regions of the world—Africa and Asia (United Nations 2019). By 2050, there will be 10 billion people on the planet, according to predictions, despite the pace of population increase in the globe declining (United Nations 2022). Each of them is the outcome of the historical process's material advancement brought about by EG. The topic of domestic resource consumption and MF has also been covered in studies on the connection between EG and effective resource management. These studies have generally shown that resource usage and economic development are intertwined, that EG increases the MF and that development initiatives are incompatible with finite resources (Pothen and Welsch 2019; Cibulka and Giljum 2020; Wang et al. 2022; Charlier and Fizaine 2023). There is ongoing discussion regarding whether the differences between environmental and economic aims make EG important or whether ecologically friendly development contradicts economic goals (Goldin and Winters 1995; Ekins 2002; Meadowcroft 2005; Bailey 2015; Ottelin et al. 2018; Khan et al. 2024).

It is shown that although economic development has distinct consequences on effective resource management, so does a rise in trade volume. The rise in trade volume between nations and the percentage of foreign trade volume in a nation's gross domestic product are two ways to measure the growth in trade. The share of foreign trade volume in gross domestic product also indicates the level of trade openness of the country (Amna Intisar et al. 2020). The scope of economic activity expands as a nation's trade volume or trade openness rises. Consequently, resource and EC rises as a result (Cole 2006; Sohag et al. 2015). A better level of welfare and faster output growth are the theoretical underpinnings of economic development. Over time, rising income also raises the standard of living and raises the demand for consumer products in society, even when increased output results in a greater use of capital and natural resources. Although increased production leads to higher usage of fossil fuels and greenhouse gas emissions, it also results in a rise in the amount of material mined to meet a nation's ultimate demand—referred to as the material footprint—due to increased consumption (Pothen and Welsch 2019). Trade might also result in this. Countries' increased import levels, driven by

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rising welfare, contribute to a greater material footprint in addition to importing more consumer items. The question of whether there is a linear or nonlinear relationship between economic factors and environmental degradation is sometimes contentious. These relationships are considered linearly but also non-linearly within the scope of the Environmental Kuznets Curve (EKC) hypothesis (Makarov and Alataş 2024; Ulussever et al. 2024). The Kuznets Curve, developed by Simon Kuznets, is responsible for the EKC, which shows how non-linearly changes in economic factors affect the environment (Xiao et al. 2025). In their study on material footprints, Pothen and Welsch (2019) stated that the relationship between income growth and material footprints is S-shaped, different from EKC. Countries without energy-saving strategies see higher increases in the use of energy and resources as a consequence of increasing trade (Sharif Hossain 2011). Additionally, this circumstance indicates a shift away from effective resource management and a rise in environmental pollution. Conversely, trade openness does contribute to the transfer of energy-efficient technology to less developed nations. This will lower the amount of energy needed to achieve a certain output level (Sohag et al. 2015). Additionally, there is evidence that there is a non-linear link between trade and energy use. Based on these research findings, the connection is U-shaped in high-income nations but inverted U-shaped in low- and middle-income ones (Shahbaz et al. 2014; Alam and Murad 2020). Studies conducted recently have also considered the impact of trade diversification. Trade diversification is the process of altering the composition of an economy's basket of commodities and improving it via innovation in order to change the structure of exports and production (Shahzad et al. 2021). Through business diversification, energy utilization and material impact are reduced (Shahzad et al. 2021; Sun et al. 2023).

In terms of maintaining effective resource management, the significance of renewable energy (hereafter, RE) transition is growing every day. The use of RE or clean energy transitions significantly reduces the material footprint, in contrast to economic development and increased trade levels. Although increased economic growth and consumption lead to a greater use of natural resources and raw materials, renewable energy sources enable production and, consequently, consumption activities to be carried out with clean, limited resources without harming the environment. As a result, although the use of renewable energy in production reduces carbon emissions (Xiao et al. 2025), there is also consumption through the use of fewer raw material-dependent goods (Sun et al. 2023). This practice also contributes to reducing the material footprint. Increasing the usage of RE is seen to be an effective and viable way to lessen pollution in the environment (Shahbaz et al. 2020; Doğan et al. 2021; Sun et al. 2022). Renewable energy sources (REs) include sun, wind, geothermal, and biofuels; fossil fuels do not (Regueiroo-Ferreira and Alonso-Fernández 2023). Primarily via decreasing reliance on fossil fuels, these forms of energy may lower air pollution and provide security in energy availability. In the same way, it may result in lower energy costs, better human health and air quality, better environmental effects, and higher employment (Miao et al. 2022). The RE transition is also aligned with SDG 7 (Ozturk et al. 2023). By 2030, SDG 7 encourages the adoption of cleaner fossil fuel technologies and clean energy (Adams and Nsiah 2019). Based on statistics from 2020, the global percentage of RE usage in final EC is 19.8%; this represents a 3.1-point increase from 1990 levels. RE use is 11.2% in the USA, 14.8% in China, 18.6% in Germany and 8.5% in Japan (World Bank 2023). Particularly, the findings of research on this topic indicate a strong correlation between the use of RE sources and advancements in the reduction of CO_2 emissions as well as ecological and MFs. (Bilgili et al. 2016; He et al. 2022; Sun et al. 2022; Ozturk et al. 2023; Sun et al. 2023). Studies on the relationship between CO_2 emissions, MF, and RE usage have also produced contradicting findings (Adams and Nsiah 2019; Jiang et al. 2022; Sahoo et al. 2021). The majority of low- and middle-income nations get the conclusion that using RE increases CO2 emissions or MF. The primary cause of this outcome is believed to have been the delay in the dematerialization process and the appearance of the requirement for new materials early in the development of RE resources (Regueiro-Ferreira and Alonso-Fernández 2023).

However, it is impossible to downplay the significance of technological progress and the use of eco-friendly innovations (green innovation) in resolving environmental issues and minimizing the impact of material goods (Razzaq et al. 2022; Sun et al. 2023). All actions taken by companies to create novel concepts, provide effective procedures, or implement technology with the intention of lessening environmental impact and promoting ecological sustainability are referred to as eco-friendly innovations (Rennings 2000; Zhang et al. 2017). On the other hand, they stand for all innovations in economic activities that help save resources and energy (Razzaq et al. 2021). Although these innovations decrease the MF directly by reducing carbon capture and storage, they also indirectly decrease it by increasing RE sources, energy efficiency, and the more effective use of conventional resources (Lee and Min 2015; Costantini et al. 2017; Razzaq et al. 2022). By doing this, nations may improve their energy efficiency and connect the fair carbon neutrality aim to climate resilience. Conversely, although innovations and new technologies do improve resource efficiency, their marginal impacts are progressively diminishing. The scale's quick increase might need more investment in natural resources (Newell 2009; Chen and Lee 2020). Based on the relationships between technical advancement, eco-innovation, and environmental quality (hereafter, EQ), eco-innovations reduce energy intensity and environmental degradation at the national, sectoral, and corporate levels. Clearly, there is a benefit to eco-innovation and effective resource management that adheres to the MF paradigm (Mensah et al. 2018; Chen and Lee 2020; Ozturk et al. 2023). From a theoretical point of view, the adoption of new technology and environmentally friendly innovations should help lessen the material footprint. In this regard, eco-friendly innovations will, first of all, lessen the material footprint by reducing the excessive use of raw materials brought about by development based on conventional manufacturing processes (Razzaq et al. 2022). On the other side, low-emission technologies like carbon capture or electrification in businesses can help reach low material footprint objectives and more efficient use of raw resources (Karakaya et al. 2021).

The objective of this study is to determine the effects of eco-friendly innovations, clean energy transition, economic growth, and trade on effective resource management. While many previous studies in the literature concentrate on environmental

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consequences within the framework of CO2 emissions and ecological footprint, this study examines the MF within the perspective of effective resource management, taking into consideration recent breakthroughs. This study on G-7 countries is expected to substantially enhance the field due to the scarcity of studies on these nations.

The G-7 nations include Japan, Canada, Italy, the United States, Germany, France, and the United Kingdom—account for 9.74% of the global population as of 2022, while 14.21% of all urban residents live in these nations. On the other hand, these seven countries constitute 43.23% of the world GDP and 30.33% of world trade (World Bank 2023). Around 18.9% of the world's MF will belong to the G-7 by 2022. In 1970, this percentage was around 40.6%; by 2022, however, it had drastically dropped. This outcome is also significantly impacted by the policies that the G-7 nations have put in place (GMFD 2023). Focusing on the G-7 countries is significant for several reasons. These countries continue to struggle with environmental issues despite their great attempts to address them (Caijuan et al. 2024). Particularly for high-welfare economies like the G-7 countries, material footprint, as a consumption-based indicator, has to be examined. The G-7 countries' issues are more evident in their material footprints than in metrics like CO_2 or ecological footprints. As for the G-7 countries, we anticipate filling the gap in the literature on this topic.

The study has contributed significant new findings to the literature. Material footprint is a relatively new scale based on consumption, and there isn't much research on the subject in the literature. The majority of research in the literature looks at environmental effects using production-based metrics such as ecological footprint, greenhouse gas, and CO_2. This viewpoint is insufficient for both sustainable development and environmental degradation. In recent years, the idea that consumption-based material footprints significantly impact environmental issues has gained considerable traction (Ozturk et al. 2023). In this context, the concept of material footprint has greatly helped shift the focus on environmental impact from production to consumption. However, the study's contributions to the literature also have a significant import in terms of their innovative value. The current state of environmental degradation in the G-7 countries, along with a new perspective on the environmental and climatic impacts of their economic development, highlights a significant research gap regarding how economic development, trade, clean energy transitions, and eco-friendly innovations affect the material footprint of these countries. Furthermore, all contributions are presented using cutting-edge methodologies and estimators, such as the Method of Moments Quantile Regression (MMQR), which underscores the innovative value of this study for future research.

The research evaluated data spanning from 1990 to 2019. The Global Material Flows Database was used in the study to collect data on effective resource management that represented the MF. Additionally, the World Bank's World Development Indicators (hereafter, WDI) were used to collect statistics on the RE transition. The OECD database is used to collect information about eco-friendly innovations. GDP per capita statistics illustrating economic development and trade data illustrating the trade-to-GDP ratio were made available by the World Bank via its WDI.

The study was analyzed using the Method of Moments Quantile Regression (MMQR), a relatively new methodology. The robustness of the MMQR results was investigated in this research utilizing empirical statistics of dynamic ordinary least square (DOLS), fully modified ordinary least square (FMOLS), and the Driscoll-Kraay estimator in order to provide the empirical findings of the study more specificity. The magnitudes, signs, and significances of every coefficient in the FMOLS, DOLS, and Driscoll-Kraay specifications are almost the same. In every method, there is a negative connection between the CET and MF variables. A negative association between the variables MF and EFI is shown using relationship analysis. All three strategies provide a favorable link, according to an analysis of the relationship between GDP and MF factors. Finally, it is shown that there is a positive link between the variables TRD and MF. The investigation of the association between the MF and EFI variables reveals that the variables have a negative relationship for all quantiles when the MMQR data are looked at. The findings illustrating the relationship between the CET and EFI variables also indicate how the G-7 countries' transition to RE reduces their MF universally. At the 1% significance level, each quantile level's findings are statistically significant. Conversely, it is shown that the MF variables and GDP have a positive correlation. At the 1% significance level, every quantile level discovery is statistically significant. Data analysis examining the relationship between trade openness and the MF in the G-7 shows that trade openness raises the MF in these nations. Naturally, there are variations in the data' statistical significance throughout quantile levels. These findings show that the GDP and MF connection in this research is consistent with the findings of studies conducted in the literature by Karakaya et al. (2021) and Razzaq et al. (2022). However, the findings from Ozturk et al. (2023) and Sun et al. (2023) as well as the results from CET and MF corroborate one another. The research conducted by Razzaq et al. (2021) and this one have similarities regarding the EFI and MF association. The study consists of five sections, including the introduction. After the introduction, the literature on the topic is covered in the second section under the topics of technological advancement, eco-friendly innovations, and EG and commerce. The data and methods were analyzed, and comprehensive details on the data set and technique were provided in the third section. Results and discussion take up the fourth section. Results from the Driscoll-Kraay, FMOLS, MMQR, and DOLS techniques are normally addressed here. The last section is devoted to conclusions and policy recommendations.

2 | Review of Literature

2.1 | Economic Development, Trade and Effective Resource Management

There is always a trade-off between EQ and economic development, even while economic development helps to reduce poverty and increase wellbeing (Sahoo et al. 2021). Due to the use of natural resources, EG eventually has a deteriorating impact on EQ. The high material and EC needed during the manufacturing of goods susceptible to foreign trade results in environmental issues in addition to the benefits of trade, such as increased EG and the decrease of poverty (Sun et al. 2023). The global per capita income level, which was 455 dollars in

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1960, climbed by around 28 times to 12743 dollars by 2022, according to World Bank statistics from 2023. To put it simply, the global yearly growth rate of per capita income is 5.5%. On the other hand, world trade increased approximately 13 times between 1980 and 2022. In light of these findings, it is imperative that effective resource management take into account the trade-off between environmental degradation, trade expansion, and economic development. The literature on this topic contains a number of significant investigations. The link between material usage and national income growth was examined by Pothen and Welsch (2019) in the context of the Environmental Kuznets Curve (hereafter, EKC). Indicators of domestic material consumption and MF were utilized in relation to material usage. Findings for 144 countries for the years 1990–2008 did not support the existence of the EKC. The association between MF and income growth was found to be S-shaped.

In a different research, Cibulka and Giljum (2020) looked at the connections between EG, quality of life, and resource footprint in 173 nations between 1990 and 2015. Resource footprint, MF and carbon footprint (hereafter, CF) are discussed separately. The link between MF and CF and economic progress is linear, but the relationship between MF and CF and quality of life is logarithmic. Charlier and Fizaine (2023) calculated the GDP elasticity per MF, in contrast to earlier research. The empirical data collected for 163 countries during the period 1990–2015 show that there is no evidence of saturation of raw material demand and no absolute difference between GDP and material consumption. These results indicate that the current development initiatives are not resource-constrained and that the reliance on raw materials persists. The findings of Wang et al. (2022) investigation are also crucial for a more focused sample. The relationship between the MF and economic development in 62 nations that were part of the Belt and Road Initiative between 1990 and 2015 was examined, and it was found that these countries' overall growth and material consumption were similar. Karakaya et al. (2021) also looked at the motivations for the usage of materials, using a particular sample of EU member states. Domestic material consumption and MF were considered within the context of material usage. The findings for the years 2000–2017 demonstrate that although domestic material use declined, the MF grew throughout that time. An increase in income is the component that contributes most to the growth in the MF. In their research, Razzaq et al. (2022) used the Quantile ARDL technique for China to look at the asymmetric impacts of resource consumption connected to urbanization and infrastructure development as a result of EG. The findings for the years 1990–2018 show that long-term increases in the MF are mostly caused by EG, urbanization, and infrastructure development.

The connections between commerce and resource consumption, however, are also the subject of research. The problem was studied in terms of EC and CO_2 emissions in relatively older research. Sharif Hossain (2011) looked studied the dynamic linkages for nine newly industrialized (NIC) nations between 1971 and 2007 in terms of CO_2 emissions, EC, EG, and urbanization, including trade openness. A unidirectional causality relationship was discovered in the short term between EG and trade openness and CO_2 emissions, between EG and EC, and between trade openness and EG and urbanization, despite the Granger causality test results not supporting a long-term relationship. In summary, trade openness may be considered to have no long-term impact on EQ while having a short-term direct and indirect impact (via EG) on EQ. Sohag et al. (2015) examine the impact of trade openness while concentrating on the connection between technological innovation and EC in Malaysia from 1985 to 2012. The ARDL approach yielded data that supported the idea that technological innovations and increased trade openness had a rebound effect on EC in Malaysia. Using a 43-year data set covering the years 1970–2012, Alam and Murad (2020) looked at the impact of trade openness on RE consumption for 25 OECD nations. The ARDL, DOLS, and FMOLS techniques' findings indicate that trade openness eventually leads to a rise in the usage of RE. Studies that deal with the problem within the context of trade diversification also exist. Shahzad et al. (2021) investigated the association between export diversification and EC using the FGLS, GMM, DOLS, and FMOLS techniques and data for ten newly industrialized countries from 1971 to 2014. Due to their export-oriented economies, the NIC nations have a significant dependency on EC. The study's findings indicate that export diversification and EC have a negative and substantial connection. Resource scarcity is suppressed by the decline in resource demand brought about by export diversification. In Sun et al.'s study from 2023, many factors in Russia, Brazil, India, South Africa, China and Turkey are taken into consideration as they investigate the connection between trade diversification and MF. The impact of trade diversification on the MF in all slices in BRICST nations between 1990 and 2019 is negative and substantial, according to the research, which employed the MMQR to identify asymmetric correlations.

2.2 | Clean Energy Transition and Effective Resource Management

One of the primary causes of the rise in carbon intensity and MF is the high use of fossil fuels. Effective resource management is incompatible with this circumstance. Renewable or clean energy transition is crucial to effective resource management (Vanegas Cantarero 2020; Sun et al. 2023). Studies have lately looked at the link between the RE transition and MF, even though the relationship between the renewable or clean energy transition and environmental consequences is often explored within the framework of CO_2 emissions in the literature. There isn't much research on the connection between the MF and the RE transition, however (Sun et al. 2023). sing the EKC as a framework, Bilgili et al. (2016) looked at the effects of RE consumption on EQ in 17 OECD nations between 1977 and 2010. Based on the study's FMOLS and DOLS estimating techniques, which used CO_2 emissions as a gauge of EQ, the validity of the EKC hypothesis was determined. Additionally, because of its negative effect on CO_2 emissions, RE consumption is beneficial to the environment. Using yearly data covering the years 1971–2018, He et al. (2022) investigated the link between China's RE and GHGs as a measure of environmental sustainability. Because RE consumption has a negative impact on GHGs, it contributes to environmental sustainability, according to research findings utilizing the ARDL approach. FMOLS and DOLS estimation results also support the finding. In ten newly industrializing nations, Miao et al. (2022) investigated the ecological footprint (hereafter, EF) and financial globalization

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implications of RE consumption between 1990 and 2018. The use of RE has a beneficial impact on EQ within the context of EF in all quantiles, according to the findings of the MMQR. In addition, the findings of the panel causality test point to a one-way causal relationship between EF and RE. Similar to this, Sun et al. (2022) used the MMQR to analyze, based on data collected between 1995 and 2018, how RE contributes to the reduction of environmental pollution in the BRICS nations. The findings show that at higher emission quantiles, RE has an impact on lowering environmental pollution.

The relationship between RE consumption and EQ, on the other hand, has been the subject of research that come to different conclusions than anticipated. Adams and Nsiah (2019) also looked at 28 sub-Saharan African nations' CO_2 emissions from 1980 to 2014 in connection to the utilization of RE. The usage of RE lowers short-term CO_2 emissions but raises long-term emissions, according to the study's conclusions based on FMOLS and GMM estimators. The primary reason for this unexpected outcome is that 28 Sub-Saharan African nations still haven't achieved the point where using RE would have a favorable environmental impact. In addition, Jiang et al. (2022) looked at the EF and utilization of RE in 17 APEC members between 1995 and 2019. Long-term data from the FMOLS and DOLS techniques demonstrate that using RE results in a larger EF. The member nations of APEC must thereby increase direct foreign capital investment, trade and production harmony, and resource and technology transfer. Sahoo et al. (2021) examined the relationship between MF and RE consumption, specifically in relation to urbanization, human capital, foreign trade, and natural resources in the BRICS countries between 1990 and 2016. This study is one of several that tackles the issue within the framework of MF. The findings showed that the BRICS nations' RE consumption raises the MF, which has a detrimental impact on the EQ. This surprising outcome may be attributed to the possibility that mineral resources in these nations are being depleted by RE technologies that use RE flows like solar and wind energy. For the G-20, Ozturk et al. (2023) came to a predictable opposite conclusion. The findings from the MMQR indicated that the RE transitions decreased the MF in all quantiles in their research examining the impact of RE on the trade-adjusted MF in the 1990–2020 timeframe. The asymmetric link between the shift to RE and the MF was examined by Sun et al. (2023) in the context of a study carried out for the BRICST nations between 1990 and 2019. The impact of the RE transition on the MF was determined to be negative and substantial based on the findings obtained using the MMQR. In light of this, the RE transition facilitates efficient and long-term resource management. In seven European nations with the greatest rates of RE consumption, Regueiro-Ferreira and Alonso-Fernández (2023) also looked at how the consumption of RE affected the MF within the framework of the EKC model. The results demonstrated that RE has a favorable impact on the MF and helps reduce the use of fossil fuels.

2.3 | Techological Progress, Eco-Friendly Innovations and Effective Resource Management

The literature should also contain information about the strong connection between eco-friendly innovations or technological advances and effective resource management. Eco-innovations also play a major role in effective resource management. Most research indicate that technological innovations contribute to lower CO_2 emissions and better EQ (Gerlagh 2007; Ang 2009; Yang and Li 2017; Chen and Lee 2020). The connection between eco-innovations and MF is in a similar predicament (Razzaq et al. 2021; Razzaq et al. 2022; Ozturk et al. 2023). Recently, studies have addressed the MF in terms of environmental sustainability and effective resource management, even though the relationship between technological advancement, eco-innovation, and environmental impacts is primarily examined in the literature within the framework of CO_2 emissions and EF. However, research has been done on this link at the national, industry, and business levels. Lee and Min's (2015) research, which was based on Japanese manufacturing industry groups, examined the connection between R&D spending for eco-innovation and environmental performance. Data gathered between 2001 and 2010 indicates that, when considering carbon emissions as an environmental performance metric, there is a negative correlation between green R&D spending and emissions. Zhang et al. (2017) used the System GMM technique to investigate the effects of eco-innovations on CO_2 emissions in 30 Chinese provinces between 2000 and 2013. According to empirical findings, the majority of China's eco-innovation initiatives successfully lower carbon emissions. Mensah et al. (2018) looked at the effect of innovation on CO_2 emissions in 28 OECD nations between 1990 and 2014, according to another research. The study's conclusions show that innovation is crucial to lowering CO_2 emissions in the majority of OECD nations. Wurlod and Noailly (2018) found that 17 OECD nations had comparable results. During the period of 1975–2005, the effect of green innovation on energy intensity was investigated in 14 industrial sectors across 17 OECD nations. It was found that, in most cases, green innovation helped to lower energy intensity. Similar to this, Chen et al. (2022) looked at the connection between eco-innovation and EQ in the aviation transportation industry, which both welcomed innovation and had an impact on environmental deterioration because of the G-7 nations' heavy reliance on fossil fuels between 1990 and 2017. The research that used the Cross Sectional Augmented ARDL and Westerlund and Edgerton techniques came to the conclusion that eco-innovation and air travel are significant factors in mitigating environmental deterioration.

Taking a different approach, Chen and Lee (2020) used data from 96 nations to investigate the relationship between technological innovations and CO_2 emissions from 1996 to 2018. There was no discernible lowering impact of technical innovation on global CO_2 emissions in this research, which is one of the few that used spatial econometric methodologies on the topic. But nearby nations' CO_2 emissions are greatly reduced by technological innovations in high-income, high-technology, and high-CO_2 countries. Nonetheless, a further noteworthy finding is that technological innovation has a greater impact on lowering CO_2 emissions in countries with higher levels of globalization. Usman and Hammar (2021) examined the effects of technological innovations on the EF in APEC nations between 1990 and 2017; they came to a negative conclusion on the issue. They also looked at the influence of these innovations on financial development, EG,

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TABLE 1 | Details of variables.

Code of variables	Variables	Description of data	Source of data
MF	Material footprint	Consumption-based Material Footprint (Tonnes Per Capita) used as an indicator for effective resource management	Global Material Flows Database (2023)
CET	Clean energy transition	Renewable energy consumption (% of total final energy consumption)	World Bank (2023)
EFI	Eco-friendly innovations	Patents on environment-related Technologies	OECD (2023)
GDP	Economic development	GDP per capita (constant 2015 US$)	World Bank (2023)
TRD	Trade	Trade (% of GDP)	World Bank (2023)

TABLE 2 | Overview Statistics.

Variable	Quantity of observations	Mean	Standard bias	Min.	Max.	Jarque-bera analysis	Prob value
MF	210	24.02461	6.453955	11.854	41.354	15.26	0.0005
CET	210	9.203524	6.568762	0.61	22.67	18.37	0.0001
EFI	210	9.657905	2.718911	5.13	15.75	36.47	0.0000
GDP	210	37480.4	7292.43	27490.63	60698.01	25.60	0.0000
TRD	210	48.69002	18.37327	15.81031	88.51987	8.89	0.0117

and population. Technological innovations increase the EF, which has a detrimental impact on EQ, according to the study's conclusions employing panel cointegration, FGLS, AMG, and CCEMG methodologies. Increasing international collaboration on research and development as well as bolstering coordinated initiatives for cleaner innovation are essential to enhancing EQ. Finally, Razzaq et al. (2021) employed the MMQR in their study, which focused on the asymmetric relationship between green innovation and consumption-based MF in 11 countries with very high material consumption, one of the more recent studies examining the relationship between eco-innovation and MF. The findings demonstrate that MFs are decreased via green innovation. The impact of green innovation on China's MF and EG between 1990 and 2018 was studied by Razzaq et al. in 2022. The quantile ARDL method study's findings demonstrate that, over time, green innovation greatly lowers the MF. Short-term findings showed similar patterns. Ozturk et al. (2023) found that green innovation lowers the MF in all quantiles in their study examining the impact of green innovation on the trade-adjusted MF for G-20 countries in the 1990–2020 period. This finding was derived from the MMQR.

TABLE 3 | VIF Values.

Variables	VIF	1/VIF
TRD	1.66	0.602418
CET	1.59	0.629172
EFI	1.43	0.699925
GDP	1.14	0.873463
Mean VIF	1.46	—

TABLE 4 | Pesaran (2004) CD Test.

Variables	CD-Test	*p*-value
MF	5.66	0.000
CET	15.76	0.000
EFI	23.57	0.000
GDP	21.85	0.000
TRD	16.57	0.000
Slope heterogeneity test		
Test	Value	*p*-value
$\hat{\Delta}$	11.264	0.000
$\hat{\Delta}_{adjusted}$	12.593	0.000

3 | Data and Methodology

The present research assessed the effects of clean energy transition, eco-friendly innovations, economic development and trade on the effective resource management of G-7 nations from the period of 1990–2019. Thus, using the Global Material Flows Database, the research obtained data on efficient resource management that represented MF. Additionally, data regarding the switch to sustainable energy was gathered using WDI by World Bank. Data on environmentally friendly innovations were taken from the OECD database. The World Bank's WDI provided the GDP per capita data that indicates economic

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TABLE 5 | CADF and CIPS Tests.

	CADF		CIPS	
Variables	**Level**	**First difference**	**Level**	**First difference**
MF	−2.056	−3.997***	−1.989	−4.656***
CET	−0.225	−3.558***	−0.887	−5.157***
EFI	−2.179	−3.351***	−3.567	−5.081***
GDP	−1.841	−3.399***	−1.707	−4.025***
TRD	−2.102	−2.654***	−2.026	−3.892***

development and the trade data that shows the percentage of trade to GDP. Table 1 displays the variables' specifics along with an explanation of each.

The following is the model developed for the study:

$$MF_{it} = \alpha_i + \beta_1 EFI_{it} + \beta_2 CET_{it} + \beta_3 GDP_{it} + \beta_4 TRD_{it} + \varepsilon_{it}$$

A measure of effective resource management, material footprint (MF_{it}), eco-friendly innovations (EFI_{it}), GDP per capita (GDP_{it}), trade openness (TRD_{it}), unit effect (α_i), and error term (ε_{it}) are all represented by these acronyms.

MMQR, a recently developed technique, is the model that has been used. The main benefit of this MMQR model is that, unlike many other approaches, it is capable of capturing the heterogeneity and distributional differences between the response and explanatory variables at various quantiles (Jahanger et al. 2023). This makes it easier to see the true fluctuations in a dependent variable across many phases, which are not captured by linear techniques (Guan et al. 2023). Because it includes endogenous explanatory factors and individual effects in the panel data model, this method is very helpful (Basheer et al. 2023). The use of this econometrics analytical technique highlights the need for empirical modeling and estimate to account for the possibility of causal effects occurring across different quantiles or not. It prevents misspecification, which may occur from potential nonlinearity and/or structural breakdowns in linear (conditional mean based) models. It captures variability between quantiles (Adebayo, Akadiri, et al. 2022). MMQR outperforms other nonlinear estimation techniques due to its capacity to include a nonlinear model. The non-linear autoregressive distributed lag (NARDL) model, for example, does not choose benchmark norms to characterize the non-linear characteristics of exogenous elements. This approach allows for location-dependent asymmetry, since the parameter values of the variables vary according to their position inside the distribution's criteria. Based on all this, the MMQR is more legitimate and robust, particularly in addressing heterogeneity and endogeneity, as well as establishing asymmetrical nonlinear relationships; the outcome generated by MMQR, which provides structured quantiles, is non-crossing and intuitive. (Elbatanony et al. 2021; An et al. 2021; Hieu and Mai 2023). Consequently, due to its many benefits, the MMQR approach has been used.

According to modified scale and location parameter estimates, the conditional quantile model is described as follows:

TABLE 6 | Results of the Westerlund (2007) bootstrap cointegration test.

Statistics	**Value**	**Z-value**	***p*-value**
G_t	−3.724	−4.490	0.000
G_a	−15.919	−2.247	0.012
P_t	−14.414	−8.001	0.000
P_a	−20.597	−5.241	0.000

As shown by the conditional quartile, $Q_\tau(\tau/\ddot{E}_{it})$

$$MF_{it} = \alpha_i + \ddot{E}'_{it}\mu + \left(\Theta_i + \eth'_{it}\,\psi\right)\mathscr{E}_{it}$$

The values of the parameters required to be estimated are α, μ', Θ, and ψ'. The probability of $\left(\Theta_i + \eth'_{it}\,\psi\right) > 0$ and equal to 1 is also given. The discrete "i" represents the individual fixed effect.

$\eth$, which has been converted with element "c," indicates the chosen elements of the k-vector of $\ddot{E}$ and is shown as follows:

$$\eth_c = \eth_c(\ddot{E}),\ c = 1, 2, \ldots \ldots, \quad n$$

Since $\ddot{E}_{it}$ is distributed uniformly and independently for each constant "c," it is independent of time (t). In order to meet the moment conditions of MMQR, $\mathscr{E}_{it}$ is sufficiently orthogonally normalized to $\ddot{E}_{it}$ and redistributed among the individual's "c" in time (t). The following equation is created by transforming the equation.

$$Q_\tau(\tau|\ddot{E}_{it}) = (\alpha_i + \Theta_i q(\tau)) + \ddot{E}'_{it}\mu + \eth'_{it}\,\psi q$$

The dependent variable MF_{it} quantile distribution is defined as $Q_\tau(\tau/\ddot{E}_{it})$, while the vector parameters of the independent variables, such as CET, EFI, GDP, and TRD, are presented as $\ddot{E}_{it}$. The sample quantile, such as $(\tau - \text{th})$, represents the function of $q(\tau)$. The optimization problem may be derived as follows:

$$\min_q = \sum_i \sum_t \rho_\tau \left(R_{it} - \left(\Theta_i + \eth'_{it}\psi\right) q \right)$$

The function of verifying in equation is indicated as:

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TABLE 7 | Estimation findings of Driscoll-Kraay, FMOLS, and DOLS.

	Driscoll-Kraay		FMOLS		DOLS	
Variables	**Coefficient**	***p*-value**	**Coefficient**	***p*-value**	**Coefficient**	***p*-value**
CET	−0.6280052	0.000	−2.413741	0.000	−1.471411	0.000
EFI	−0.2120326	0.013	−0.6453359	0.000	−0.8157708	0.000
GDP	0.0002267	0.000	0.0007166	0.000	0.0004893	0.000
TRD	0.044934	0.136	0.3455512	0.000	0.4108549	0.000

$$“\rho_\tau(R) = (\tau - 1)\r{R}I\{\r{R} \le 0\} + T\r{R}I\{R > 0\}”$$

To provide more authenticity to the empirical findings of the research, the robustness of the MMQR results has been tested using the empirical statistics of dynamic OLS, fully modified OLS, and Driscoll-Kraay estimator in the present study. Phillips and Hansen's (1990) FMOLS approach can handle endogeneity and heterogeneity among cross-sectional units. On the other hand, the FMOLS is nonparametric, and the DOLS approach, which was commissioned by Kao and Chiang (2001), is parametric. The endogeneity problem may be handled using the DOLS estimator, which can provide unbiased estimators. Hence, compared to OLS regression, both FMOLS and DOLS regression models are more potent (Jahanger et al. 2023). When dealing with CSD, the Driscoll-Kraay regression, created by Driscoll and Kraay (1998), is very successful. The standard errors produced by this test are of similar quality for both unbalanced and balanced panels (Xie et al. 2024). By following Westerlund's (2007) method, we also performed cointegration analyses. When variables are non-stationary, cointegration analysis is used to assess the long-term correlations between them. To look at the possibility of CSD, the Pesaran (2004) test was used. The stationarity of the variables was tested in the research using the unit root test, as described by Pesaran (2007).

4 | Results and Discussion

The descriptive data for MF, CET, EFI, GDP, and TRD are shown in Table 2. The mean values—MF at 24.02461, CET at 9.203524, EFI at 9.657905, GDP at 37480.4, and TRD at 48.69002—show the average levels of these variables. The standard bias for MF (6.453955), CET (6.568762), EFI (2.718911), EP (7292.43), and TRD (18.37327) represents the variability or dispersion around the means. The biggest and smallest reported values for all variables are shown by the minimum and maximum values in the Table 2. Significantly deviating from a normal distribution, as shown by the Jarque-Bera (J-B) normality test, which is significant for every variable at 0.05.

Table 3 displays the VIF test results performed to assess multicollinearity. The analysis indicates that the Variance Inflation Factor (VIF) values for the explanatory variables TRD, CEF, EFI, and GDP are below five. The tolerance values indicated as 1/VIF are also greater than 0.10, indicating that there is no multicollinearity problem.

It is well accepted that the random variables across cross-sections in panel data models are heteroscedastic when regressed. This suggests that the panel has to be cross-sectionally independent. However, panel data studies typically meet cross-sectional dependence (hereafter, CSD), which skews the results and inefficiently produces inefficient results. The literature offers a variety of methods that can be used to identify if CSD is a problem with the panel data in order to avoid this problem (Xie et al. 2023). This research uses the Pesaran (2004) test to examine CSD. The results of the CD test are shown in Table 4, where they indicate that all series are significantly dependent on each other across cross-sections at the 1% significance level. In addition, to explore the characteristics of the coefficients of slope and if there's heterogeneity, present study largely emphasizes Pesaran and Yamagata (2008) slope heterogeneity test. Following the Pesaran (2004) test, the slope heterogeneity test is conducted; Table 4 summarizes the findings. The concern of heterogeneous slope is validated by the test results shown in Table 4.

The present investigation is limited to using the second-generation CIPS unit root test to confirm the stationarity of the variables due to the apparent presence of cross section dependency and slope heterogeneity (Radmehr and Adebayo 2022). Thus, the CIPS and CADF tests, which Pesaran (2007) developed are used in this research. Table 5 displays the results of the CADF and CIPS tests. Every variable in the first difference is stationary, according to the findings of the CIPS and CADF tests.

We first determine if the variables are stationarily distributed before analyzing the long-term correlation between MF and the explanatory variables (CET, EFI GDP, and TRD). To achieve this, a cointegration test that takes CSD and slope heterogeneity into account must be used. As a result, the Westerlund cointegration test was used (Adebayo, Altuntaş, et al. 2022). The results shown in Table 6 show that there is a long-term cointegrating relationship between the parameters under investigation for both models, both in panel(P_t, P_a) and group statistics (G_t, G_a), rejecting the null hypothesis of lack of cointegration and in favor of the alternative. In particular, in both research models, long-term associations are confirmed for the CET, EFI, GDP, TRD, and MF.

Table 7 presents the findings of the Driscoll-Kraay, FMOLS, and DOLS estimate techniques prior to MMQR analysis. The results obtained from all three of these methods confirm the robustness and dependability of the estimations. We see that all of the coefficients from the FMOLS, DOLS, and Driscoll-Kraay specifications have nearly identical magnitudes, signs, and significances. Upon analysis of the results presented in Table 7, it can be shown that the CET and MF variables exhibit a negative correlation across all approaches. It is evident that every result from the three approaches is statistically significant. An analysis

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TABLE 8 | Estimation findings of MMQR approach.

Variables	Location	Scale	Quantiles								
			0.10	**0.20**	**0.30**	**0.40**	**0.50**	**0.60**	**0.70**	**0.80**	**0.90**
EFI	−0.2120**	0.0275	−0.2540**	−0.2427**	−0.2309**	−0.2194**	−0.2102**	−0.2007**	−0.1931**	−0.1840*	−0.1696
CET	−0.6280***	−0.1236***	−0.4392***	−0.4903***	−0.5430***	−0.5947***	−0.6361***	−0.6784***	−0.7126***	−0.7533***	−0.8183***
GDP	0.00022***	0.00004*	0.00015***	0.00017***	0.00019***	0.00021***	0.00022***	0.00024***	0.00025***	0.00027***	0.00030***
TRD	0.0449**	0.0166	0.0194	0.0263	0.0334	0.0404*	0.0460**	0.0517**	0.0563**	0.0618**	0.0706**

Note: The symbols *, **, and *** denote significance at 10%, 5%, and 1%, respectively.

of the association between the MF and EFI variables reveals a negative link between them. There is statistical significance in the results. An analysis of the association between GDP and MF variables reveals that all three approaches provide a favorable relationship. Furthermore, the results are statistically significant. The TRD and MF variables were also shown to be positively correlated. It can be seen that the Driscoll-Kraay technique yielded just one statistically insignificant result.

The MMQR findings are shown in Table 8. The results of the analysis of the relationship between the MF and EFI variables show that, for all quantiles, the variables have a negative association. At the 5% significance level, statistically significant results were found in the low quantiles (0.10, 0.20, 0.30) and medium quantiles (0.40, 0.50, 0.60). Various results were found at high quantiles. At the 5% significance level, a statistically significant result was found at the 70th quantile. Only at the 10% significance level is the result in the 80th quantile statistically significant. The 90th quantile result is not statistically significant. Table 8 also displays the results demonstrating the link between the CET and EFI variables. The results show that the switch to RE lowers the MF across all quantile levels in the G-7 nations. For every quantile level, the results are statistically significant at the 1% significance level. It is discovered that there is a positive association between the GDP and MF variables once the relationship is examined. At the 1% significance level, all of the quantile levels' findings are statistically significant. Analysis of the data demonstrating how trade openness affects MF in the G-7 countries reveals that trade openness raises MF in this group of nations. There are differences in the statistical significance of the results between quantile levels. It can be seen that the results are not statistically significant when obtained at low quantile levels (0.10, 0.20, and 0.30). It is observed that the findings at higher quantile levels (0.70, 0.80, 0.90) are statistically significant at 5% significance level. Different results are found for the middle quantile values (0.40, 0.50, and 0.60). At the 10% significance level, the 40th quantile level result is statistically significant. There is statistical significance at the 5% significance level according to the data obtained for the 50th and 60th quantile levels Figure 1.

5 | Conclusion and Policy Recommendations

The G-7 countries are the first nations to have industrialized, and thus bear the most responsibility for global environmental damage. Concerns with sustainable resource management in these nations are raised by the fact that they are also consumer society. This research looks at how trade, EG, eco-friendly inventions, and the shift to clean energy affect effective resource management in the G-7. It is based on these issues. One major driving force for the study was the lack of previous research looking at the association between these factors in G-7 nations. This research is further distinguished by the use of the MMQR technique, which is a novel approach. Analyzing the MMQR results reveals that eco-friendly technologies help the G-7 nations have a lower MF. Results were shown to be statistically significant at the low (10th, 20th, 30th), middle (40th, 50th, 60th), and 70th quantile levels. The results of DOLS, FMOLS, and Driscoll-Kraay agree with those of MMQR. The discovery that eco-friendly technologies have

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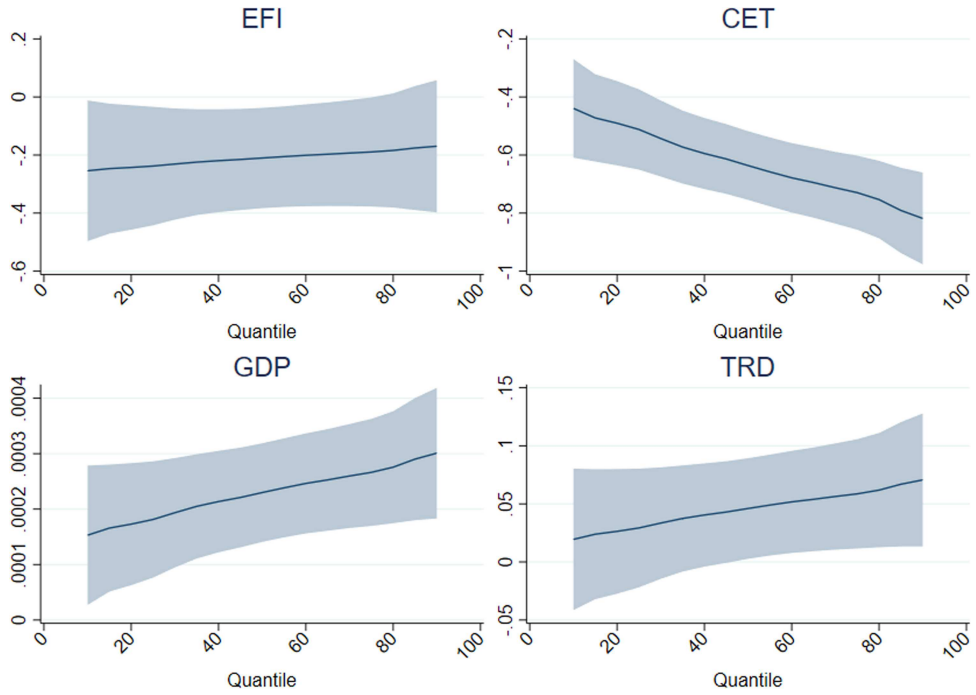

FIGURE 1 | shows a visual representation of the MMQR analysis. *Source:* Authors' own calculations.

decreased the material footprint in the G-7, a collection of developed and industrialized nations, emphasizes the significance of eco-friendly technology in the context of sustainable resource management for this group of nations. Analyzing the effect of clean energy transition on the MF of the G-7 nations reveals that this country group's MF is reduced by clean energy transition. At all quantile levels, the results are statistically significant at the 1% significance level. The results obtained from the MMQR estimator are likewise in line with the findings from the DOLS, FMOLS, and Driscoll-Kraay estimators. Additionally, these results show statistical significance at the 1% level of significance. The conclusion that using renewable energy lowers the material footprint in G-7 nations is significant because it emphasizes how crucial clean energy use is to efficient resource management in these nations and is a crucial discovery for environmental sustainability. Another conclusion indicates that the MF of the G-7 nations rises in tandem with economic progress. At the 1% significance level, the MMQR result is statistically significant across all quantile levels. The results from other techniques(FMOLS, DOLS, Driscoll-Kraay) agree with the MMQR results as well. Given that per capita GDP is the most commonly used indicator of economic prosperity, it is a noteworthy finding that an increase in per capita GDP leads to an increase in the material footprint in G7 countries. It has been shown that in G-7 nations, trade openness increases the MF. The results show that the 50th, 60th, 70th, 80th, and 90th quantiles are statistically significant, whereas the results for the lower quantiles are statistically insignificant. The results show that the findings using the FMOLS and DOLS estimators are statistically significant, but the results using the Driscoll-Kraay estimator are statistically invalid. Given the detrimental effects of increasing commercial activity brought about by globalization on efficient resource management, the result that trade openness increases the material footprint in G-7 nations should be taken into consideration.

Several policy suggestions have to be made in light of the study's results. To begin with, the G-7 nations need to encourage the use of eco-friendly technology for effective resource management. It is important to take action to boost the quantity of patents for eco-friendly technology. In order to guarantee efficient resource management, the G-7 nations need to intensify their efforts toward a sustainable energy transition. All industries should make an effort to switch to renewable energy, and the usage of fossil fuels should be phased out entirely by strong action. Policies should be created to support technologies that enhance recyclable inputs, and implementations should be proposed within the framework of the recycling economy. Within the renewable energy sector, mechanisms should be developed to ensure sustainable resource management, paying attention to the introduction of recycling requirements. Public measures should be implemented in the G-7 nations to stop households from unintentionally and excessively consuming. These measures ought to guarantee sustainable resource management. Legislation that discourages consumption should incorporate provisions that prolong the life of products. To lower the demand for planned obsolescence products, policies should be created. The repair economy should become more significant, and the circular economy's tenets should be embraced. For products which involve a lot of materials, tax laws should be created. G-7 nations need to impose limits on the imports of products having an enormous MF. Importing eco-friendly goods need to be a priority. There must be a shared objective across all societal groups in order to achieve successful resource management. G-7 nations need to work to raise awareness among the general public of the significance of sustainable resource management. Steps need to be made to create public policies that are grounded in environmental sustainability. Industries with a large MF and emissions should be subject to stringent environmental regulations. The use of eco-friendly technologies that demand little material utilization and save raw resources should be encouraged. In order to take

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crucial steps toward sustainable resource management, low material intensity criteria should be used for public procurement. G-7 nations should include provisions that will improve environmental sustainability and lower material consumption as they negotiate trade agreements for increased trade liberalization. Decoupling, or the separation of GDP growth from raw resource usage, must be implemented in a transparent and unambiguous way when deciding on national growth policies in the G-7. The G-7 nations should make sure that resources are managed effectively while keeping all of these factors in mind.

The study's limitation is that data constraints exclude the use of data from 2019 forward in the analysis. Future study should explore factors influencing effective resource management in nations with increased material consumption using time series analysis.

Author Contributions

Ömer Faruk Biçen: writing – review and editing, writing – original draft, conceptualization, project administration, funding acquisition. **Mustafa Necati Çoban:** investigation, writing – original draft, writing – review and editing, visualization, project administration, software, data curation, supervision, conceptualization.

Funding

The authors received no specific funding for this work.

Ethics Statement

The authors have nothing to report.

Consent

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Upon reasonable request, the corresponding author will provide the data supporting the study's findings.

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