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by Shaifali Rathi

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ABSTRACT

Globalization unfolds itself continuously representing its characteristics in form of economic integration, policy transfer across borders, cultural exchange, and dissemination of technological advancements in the new digitalized times. Mitigating climate change requires the development and implementation of environmentally friendly technologies and the use of innovative measures. This paper examines how different types of globalization influence and affect the adoption of green technologies. We use country-level data for the globalization index (KOF), development of environmentally related technologies by total technologies(ET) , carbon dioxide emissions per capita interaction with globalization, environmental taxes as a percentage of total tax revenue of government(TAX), environmentally related ODA as a percentage of total allocated ODA (ODA), mortality by exposure to ambient ozone(OZO) and total energy supply index(TES) for 81countries for the years 1990 to 2019 and using advanced panel data modelling. The various globalizations are separately examined which include trade, finance, informational and interpersonal globalizations. The empirical results show that globalization can positively and significantly influence the introduction of green technologies in all countries. The results are quite robust when using different alternative model specifications. The results of this study also show how the adoption, collaboration, acceleration and transfer of green technologies between economies worldwide can be promoted and accelerated.

1.INTRODUCTION

The urgency and willingness to address the environmental difficulties that the world faces, which have a negative impact on nations' economic development, have gone up during the past several years on a global scale.(S. C. Karmaker, 20221) Remediation of the environment with cutting-edge technology and expertise can drastically lower expenses and enable countries to tackle their environmental problems. In order to achieve more ambitious environmental goals, the cost of prospective environmental interventions may be decreased through the invention of new methods and the development of cleaner technology for lowering environmental pollutants.

(Qamar, Muhammad Zaid, 2021) When we define technology, we usually mean the use of several distinct abilities, techniques, protocols, and methodologies for any kind of practical use or to accomplish specific goals like scientific inquiry or investigation. (Qamar, Muhammad Zaid) Green technology is defined as technology that uses, produces, or is distributed in a way that is environmentally benign. The term "green technology" refers to the ongoing development of tools, methods, and products that minimize the harm that human activity does to the environment and its resources. Natural resources, i.e nonrenewables, are scarce in our world (Muhammad Zaid

Qamar, 2021) Many natural habitats are already endangered, extinct or face danger on the face of the Earth as a result of human activity.

According to Global Footprint Network estimates from 2018," "humans are consuming natural resources 1.7% faster than the Earth can replenish itself". It is therefore imperative that we as a society invest in green technology. Green technology also seeks to provide alternative energy sources that do not deplete critical fossil fuels. It is also important in combating global warming by reducing the emission of greenhouse gases such as nitrogen and carbon dioxide. Green technologies include the use of solar energy, fuel cells, wind energy, geothermal energy, etc.

Du, K., & Li, J. (2019).) In a 2007 report, the Intergovernmental Panel on Climate Change (IPCC) stated that human activities are the main cause of climate change. This has led to a number of dire consequences, including the increasing frequency and intensity of some extreme weather events, the widespread melting of snow and ice, and the rise in average global sea levels.

(Per Rodriguez, Kate, 2023) The most effective green technologies are those that lessen the negative environmental effects of other technologies and contribute to the mitigation of climate change.

(Per Rodriguez, Kate, 2023) Green technology combats climate change in a number of ways, such as estimating the potential reduction in CO2 emissions from new methodologies, providing corporations with the tools to achieve de-carbonization, substitution of low-carbon, toxic operations with low-carbon alternatives and consuming less energy, enabling better land use that conserves natural resources, and utilizing gas-free electric vehicles (EVs) for supply chain transportation and distribution. Li, J., and Du, K. (2019) Prominent economists, such as Arrow et al. (2009) and Krugman (2009), have emphasized the critical role that research and development play in reducing greenhouse gas emissions. Carbon dioxide is the most significant greenhouse gas by volume, and it is mostly released by the burning of fossil fuels (IEA, 2012) and therefore, solutions to overcome the negative potential consequences of climate change and environmental protection require the inclusion of a range of green technologies and innovations. (Kerui Dua, Jianglong Lib). Globalization has accelerated rapidly in the 20th century, resulting in an increase in cross-border links across a range of domains, including trade, commerce, and cross-cultural interactions. Because technical breakthroughs are implemented more quickly owing to globalization, technology adoption is still accelerated (Rawda Alejla). This study looks into how countries' adoption of green technology (GTA) is affected by globalization. We examine the primary drivers of GTA and highlight the significance of globalization. We employ KOF globalization index country-level data to separate out the influence of globalization and we use environmentally related patents by total technological patents (ET), the interaction of level of CO2 emissions per capita with globalization, environmentally related taxes by the total tax revenue of

government(TAX), environmentally related ODA by total allocated ODA (ODA), mortality by ambient ozone(OZO), total energy supply index(TES) for a sample of 81 countries and use advanced panel data modelling. The globalization process induces innovation and accelerates technology transmission. GTA is a complex developmental process dependent on individual constructs. Globalization brings improvements GTA through the transfer of knowledge and enhancing and encouraging competition internationally.

The inspiration for this research comes from the growing importance of climate change in today's globalized world and the resulting impact on GTA by countries. Our study aims to answer the question of how important globalization is for the introduction of green technologies. Several mechanisms through which globalization affects GTA have been identified. (Skare, M., & Soriano, D. R. (2021)) While globalization can boost economic growth, the different economic, social and political dimensions of globalization in different countries affect the degree of technology adoption. This is one reason for using the fixed effects model and account for country fixed effects in our study. The results show us that globalization is a necessary (but not sufficient) condition for GTA. For a country to move more quickly toward the adoption of green technology, economies need policies to increase the globalisation index which are the real drivers of spillovers and competition, on knowledge. The remainder of this article is organised as follows. Section 2 contains a literature review. Section 3 outlines the hypotheses, data and variables. Section 4 give the methodology used to address the research question and the research results. Section 5 discusses and highlights the implications for future research and policy suggestions in the conclusion.

2.REVIEW OF LITERATURE

(Alejla, R. (2023).) First off, an idea by Al-Rodhan, (2006) suggests that there are currently multiple definitions concerning different parts of globalizing influences based on the different definitions of globalization. But the scholars choose one term that seems particularly pertinent to the conversation at hand, contending that globalization “is a process that encompasses the causes, course, and consequences of transnational and transcultural integration of human and non-human activities.” Researchers conclude in the simple terms that globalization “involves economic integration; the transfer of policies across borders; the transmission of knowledge; cultural stability”.(Alejla, R., 2023) It is also critical to note that technology globalization transfers wealth from the countries that are most developed to the least developed nations in an orderly way. In this way, Awosusi, (2022) established that the BRICS countries altogether "dominated the world with 29% in 2016 and increased to 34% in 2018" (p. 594), indicating that the progression of technological innovations does in fact, start from the developed countries that hold the power. This evidence was based on patent applications. Chen and Lee (2020) point out that when adopting

new technologies, the environment also needs to be taken into account. This is because, despite worries that technological advancements raise CO2 emissions, there is proof showing that technological innovation in affluent nations can lower carbon dioxide emissions in neighboring countries.

Cuerva, Triguero-Cano(2014) conducted empirical research on "drivers of green and non-green innovation in low-tech SMEs". They highlighted the importance of role of globalization in influencing the adoption green technologies along with internal and external drivers in shaping innovatio . They concluded that globalization may act as a catalyst for green innovation in small and medium sized enterprises.

- Importance of globalization for green technology adoption:

Understanding how globalization influences green technology innovation can help identify mechanisms to accelerate the development and adoption of sustainable technologies on a global scale (Zhang et al., 2022). As countries become increasingly interconnected through trade and investment, the diffusion of green technologies can contribute to address environmental challenges on a broader scale, emphasizing the importance of the study.(Kang & Lee, 2021).Chaudhary , Verines(2015) provided insights into the environmental consequences of land use practices and we can indirectly conclude that globalization can significantly impact land use patterns which may lead to increased need for sustainable and innovative technologies to mitigate biodiversity loss and environmental degradation.

The relationship between GTA and globalization has to do with how the country opened its doors to foreign investments, firms' participation, technology and knowledge integration. Of the various factors that influence whether or not a person or a firm will adopt a technology; Straub (2009) expanded on adoption and diffusion theory.

It was found by Miranda et al. in 2016 that the decision to adopt or reject specific technological solutions or innovations is diffuse and nonlinear. (Skare, M., & Soriano, D. R. (2021).) However, just because information spreads over the globe due to globalization does not mean that this content is accessible for all nations and organizations equally and hence may not benefit although the developing nations are not explicitly excluded.

Research has shown that factors such as sustainable process technology adoption (Fu et al., 2018), personal resources in agriculture (Bukchin & Kerret, 2018), green education quality, and knowledge sharing Esthi (2023) are crucial in promoting the uptake of eco-friendly technologies. The impact of outward foreign direct investment on green technology processes varies across countries (Zhu & A-zhong, 2018). Organizations must address challenges such as institutional

pressures, environmental awareness, and technological changes to enhance green innovation performance (Wang et al., 2022; Khdair & Jabbar, 2022). Integrating sustainability into supply chain decisions is crucial for adopting green practices in manufacturing sectors (Alnsour, 2023).

Ahmer Bilal (2022) found that globalization shows a significant positive association with environmental pollution in the OBOR countries. Arshian Sharif found negative impact of globalization on G7 countries. Isaac K. Ofori found positive impact of globalization on green growth indicators for 23 African countries. Woerter in 2017 studied the impact of policies of Austria, Germany and Switzerland on Green Energy technologies at firm levels. Ahmed and Le (2020) investigated the links between Information communication technology, trade globalization and carbon dioxide emissions.They highlighted complex interactions between them and found that globalization ,when measured by trade globalization index ,can influence the environmental performance which indicates a potential connection with the development an diffusion of green technologies. Ahmad, M., & Wu, Y. (2022) explored the role of green productivity growth, eco-innovation and economic globalization in order to achieve ecological sustainability in OECD economies. They emphasized the potential of globalization to drive green productivity growth and environmental sustainability.

Globalization can also have negative impact on the adoption green technologies. The concentration of high-tech industries can hinder green innovation efforts and lead to increased environmental pollution (Jiao-ping et al., 2022). Globalization can also create pressures that prioritize economic motivations over environmental concerns, potentially slowing down the adoption of green technologies (Huang & Wu, 2010; Botelho et al., 2023). Moreover, the rapid urbanization process in many Global South cities due to globalization has led to fragmented adoption of green city concepts, indicating a challenge in integrating sustainable practices in rapidly developing regions (Zain et al., 2022). High investment costs associated with adopting new high-tech production systems can also act as a barrier in the widespread adoption of environmentally friendly technologies (Xuan & Sandorf, 2020). Furthermore, the indirect impacts of high-tech industry development, driven by globalization, can counteract efforts to reduce carbon emissions hence creating a potential conflict between economic growth and environmental sustainability (Gu et al., 2020).

With the growing awareness of environmental issues globally, studying the impact of globalization on green technology innovation can provide insights into how international cooperation and policies can be leveraged to promote sustainable development (Allan et al., 2021).

- Carbon emissions and globalization interaction:

They have a complex interaction, influencing technological innovation and environmental

sustainability. Technological innovations are crucial in reducing CO2 emissions Shahbaz et al. (2020). As industrialization progresses, advancements in technology can result in falling trend of carbon emissions (Zhang & Chen, 2021). Green technological innovation has been shown to effectively reduce carbon emissions by enhancing energy efficiency (Cai et al., 2021). Also, carbon emissions trading policies can indirectly influence green innovations by affecting research investments (Liu et al., 2022).

Green technology innovation plays a significant role in reducing carbon emissions (Gao et al., 2022). Profit-seeking companies strategically choose technological innovation to promote low-carbon production and reduce carbon emissions per unit of output (Cui et al., 2022). Moreover, the transfer of low-carbon technology can moderate carbon emissions, particularly in regions with high carbon intensity (Mi et al., 2023).

Technological innovation not only directly reduces carbon emissions but also influences carbon emission intensity (Feng et al., 2022). Industrial restructuring can enhance technological innovation, thereby reducing carbon emission intensity (Wang et al., 2022). Furthermore, green technology innovation significantly improves carbon emission performance (Du et al., 2022). The deepening of globalization has made foreign innovation efforts crucial for obtaining new technologies, impacting greenhouse gas emissions (Yu et al., 2023).

- Other factors are also crucial for shaping the landscape of GTA:

There is a very important role of environmental regulations to significantly promote green technology innovation in certain regions (Zhang et al., 2022). Shamal Chandra Karmaker found the positive role of environmental taxes on technological innovation According to Lee, S. K. (2020), bilateral cooperation should be created to boost economic development and mitigate environmental degradations in developing nations through official development assistance (ODA) and supportive policies.

Additionally, the intention of enterprises to adopt green technology can be influenced by various factors, including ownership structures and different types of environmental regulations (Xia et al., 2021). Moreover, the development of green innovation capabilities within high-tech industries can have spillover effects that contribute to the overall advancement of green technologies (Pan & Yan, 2023). Furthermore, the adoption of green computing practices can help decrease the carbon footprint of information and communication technologies, highlighting the importance of internal organizational decisions in promoting sustainability (Airehrour et al., 2019). incentives, information accuracy, and cognitive factors play significant roles in farmers' adoption of green technologies (Hong, 2023; Wu & Zhou, 2021; Dong et al., 2023). Organizational factors, external environments, and green values also influence the adoption of green technology (Zailani et al., 2014; Gao et al., 2022).

It is important that we boost trade and foreign aid to developing nations in order to support their economic expansion. According to Lee, S. K. (2020), the effectiveness of mitigating climate change from the perspective of international collaboration will increase when the economic position and environmental policies in poor countries are improved and well-established.

Therefore it is important to consider a holistic approach that incorporates factors such as environmental regulations, enterprise intentions, industry capabilities, and internal organizational practices to have the widespread adoption of green technologies and encourage sustainable development. We find that there exists a significant literature gaps on the study of the impact of globalization on green technology adoption and also green technology as an independent subject. The main open innovation determinant is globalization (Sezen, Sag & Alpkan, 2019). Open innovation is guided by university-industry networks (Huggins et al.,2020). New innovations that are brought about by globalization are focused more on products and less on processes. (Skare, M., & Soriano, D. R. (2021)). In low-income countries, there are lower technology and knowledge spillover effects than in high to middle income countries.So, developing countries do not get the entire prospective benefits from GTA. Ejiaku, S. A. (2014) found the problems faced by the developing countries in their quest to maximize the potentials of technology. According to them poor government policies, inadequate and insufficeint infrastructure, and lack of training and qualifications contribute to the creation of hurdles in transitioning and uptake.

The following are the study's main literary contributions: first to examine the role of trade, financial, interpersonal and informational globalization separately. Most studies primarily study the financial and trade globalization impacts on digital technology or technological innovation instead of GTA. Second, to examine the impact of the level of carbon emissions that influence the effects of globalization. Third, there are lack of studies that use direct indicators of globalization and here we will be using KOF indicator. Different research use data on trade, FDI, and openness. Third, this study looks at the years 1990 to 2019 for 81 countries to provide a more up-to-date and comprehensive view.

3.HYPOTHESES, DATA AND VARIABLES

Given the growing importance of globalization and climate change, this research aims to explore the following hypotheses:

H1: There is a positive impact of trade globalization and a positive relation between the volume of carbon dioxide emissions and the impact of trade globalization on green technology adoption(GTA)

H2: There is a positive impact of financial globalization and a positive relation between the volume of carbon dioxide emissions and the impact of financial globalization on GTA

H3: There is a positive impact of informational globalization and a positive relation between the volume of carbon dioxide emissions and the impact of informational globalization on GTA

H4: There is a positive impact of interpersonal globalization and a positive relation between the volume of carbon dioxide emissions and the impact of interpersonal globalization on GTA

We use data for 81 countries. The list of countries included in the study are shown in Table 1.

Table 1: list of countries

Algeria	Egypt	Latvia	Romania
Argentina	Estonia	Lebanon	Russia
Armenia	Finland	Liechtenstein	Saudi Arabia
Australia	France	Lithuania	Serbia
Austria	Georgia	Luxembourg	Singapore
Azerbaijan	Germany	Malaysia	Slovak Republic
Bahamas	Ghana	Malta	Slovenia
Belarus	Greece	Mexico	South Africa
Belgium	Hungary	Moldova	Spain
Bosnia and Herzegovina	Iceland	Monaco	Sri Lanka
Brazil	India	Morocco	Sweden
Bulgaria	Indonesia	Netherlands	Switzerland
Canada	Iran	New Zealand	Thailand
Chile	Ireland	Norway	Tunisia
China	Israel	Pakistan	Turkey
Colombia	Italy	Panama	Ukraine
Costa Rica	Japan	Peru	United Arab Emirates
Croatia	Jordan	Philippines	United Kingdom
Cyprus	Kazakhstan	Poland	Uzbekistan
Denmark	Kenya	Portugal	Venezuela
			Vietnam

These 81 countries were selected according to data availability on green technology adoption and globalization.

Variables that generally appear in literature to measure the adoption and especially innovation of green technology are expenditure on R&D number of patent within the environmental technology field. The first one is mostly considered as the input for innovative activities and the second is the output. The arguments for and against these indicators have been reviewed in Popp ,2012 .We use the Development of environmentally related technologies as a percentage of total technologies(ET) as our dependent variable, which is the proxy for the green technology adoption by the countries. Here ET (dependent variable) is used as a proxy for GTA.

KOF Globalization Index: It measures the three main dimensions of globalization: economic, social and political. KOF is an acronym for the German word "Konjunkturforschungsinstitut". It was developed by Axel Dreher at the ETH Zurich, Switzerland. The different KOF indexes are used which represent types of globalization. Trade defacto KOF is used for trade global, Financial defacto KOF is used for financial globalization, Informational defacto KOF is used for informational globalization, and Interpersonal defacto KOF is used for interpersonal globalization. These are used separately as independent variables in four different models and each index is formed by the following constituents as in Table 2

Table 2: Description of 2023 KOF Globalization Index

Source: KOF Variables (Gygli, 2019)

Dimension	Variable Name
Trade Globalization, de facto (TRADE)	Trade in goods and services Trade partner diversity
Financial globalization defacto (FIN)	FDI Portfolio investment International debt, reserves and income payments
Interpersonal Globalization defacto (INTER)	International voice traffic International tourism and students Migration
Information Globalization (INFO)	International patents High technology exports Internet bandwidth Television access

Dependent variables:

- Trade globalization : (Trade defacto KOF- TRADE, for model 1):

Trade globalization has both positive and negative effects on green technology innovation and adoption (Almeida & Moraes, 2013). On one hand, trade globalization allows for the exchange of goods and technologies across borders, enabling the transfer of green technology solutions to different parts of the world and facilitating the scaling up of green technology innovation. On the other hand, trade globalization can also lead to the outsourcing of production to countries with lower environmental standards, resulting in a potential increase in pollution and resource depletion. Informational globalization, on the other hand, can greatly benefit green technology innovation and adoption (Đorić, 2022).

- Financial globalization : (Financial defacto KOF- FIN, for model 2):

Financial globalization, characterized by the increasing integration of financial markets and the free flow of capital across borders, has both positive and negative implications for green tech innovation. Researchers have highlighted the importance of examining the interplay between various factors, such as globalization, financial development, and innovation, in shaping the trajectory of green technology progress .(Umar & Safi, 2023)(Li & Liao, 2020). On the one hand, improved access to capital and financial resources can facilitate the development and commercialization of cutting-edge green technologies (Huang et al., 2021) Multinational corporations and venture capitalists, drawn by the growth potential of green industries, may provide crucial funding and expertise to green tech start-ups and research initiatives. This influx of global capital can accelerate the pace of innovation, enabling green tech companies to scale up their operations and bring their products to a wider market(Zhang, 2023). Additionally, the development of green finance instruments, such as green bonds and sustainability-linked loans, can direct capital towards environmentally-friendly projects and incentivize businesses to adopt eco-friendly practices. However, the pursuit of short-term profits driven by financial globalization can also have negative consequences for green tech innovation and adoption. The pressure to maximize shareholder value may lead companies to prioritize quick financial returns over long-term investments in sustainable technologies.

- Informational globalization : (Informational defacto KOF- INFO,for model 3):

With the widespread access to information and knowledge through the internet, researchers and innovators in the field of green technology can easily share their findings, collaborate on projects, and learn from each other's experiences. informational globalization provides access to a vast amount of data and research on green tech innovation, which can help accelerate the development and adoption of sustainable technologies globally (Đorić, 2022). However, there are also negative impacts of and informational globalization on green tech innovation and

adoption (Navarrete et al., 2021). One negative impact is the potential for intellectual property theft and the unauthorized replication of green technologies (Almeida & Moraes, 2013). This can hinder the incentive for companies to invest in green tech innovation if they fear that their ideas and inventions will be stolen.

- Interpersonal globalization : (Interpersonal defacto KOF – INTER , for model 4):

Interpersonal globalization also plays a crucial role in green technology innovation and adoption. On the positive side, interpersonal globalization allows for the exchange of ideas and knowledge across borders. Through international collaborations, conferences, and partnerships, experts in the field can come together to exchange ideas, share best practices, and work towards common goals. However, there are also negative impacts of interpersonal globalization on green tech innovation and adoption (Navarrete et al., 2021). One negative impact is the cultural and regulatory barriers that can impede the global adoption of green technologies (Navarrete et al., 2021). These barriers can include differences in environmental policies and regulations, as well as cultural resistance to adopting new technologies (Đorić, 2022).

In addition, the effects of the control variables included in the model are examined in order to ensure robustness and achieve better results. Below in table 3, we summarize the variables used in the study

Table 3: Dependent and Control Variables

VARIABLE NAME	MEASUREMENT	DATA SOURCE
Enivronmental Technology (ET)	Development of envt related tech, % of all tech	OECD
Trade globalization (trade)	Trade defacto KOF	KOF
Financial globalization (fin)	Financial defacto KOF	KOF
Informational globalization (info)	Informational defacto KOF	KOF
Interpersonal globalization (inter)	Interpersonal defacto KOF	KOF
Carbon dioxide emissions (CARBON)	CO2 emissions, (metric tons per capita)	WORLD BANK
Environment taxes (TAX)	Environmental-related	OECD

	taxes, as %of total tax revenue	
Environment Official Development Assistance (ODA)	Environmentally related ODA, as % of total allotted ODA	OECD
Mortality (OZO)	Mortality by ambient ozone	OECD
Energy supply (TES)	Total energy supply index	OECD

Control variables used in the study –

Fewer studies have examined the policy response dimension of green growth. The variables, in particular, grasp the level of institutions but could have also discussed other policy instruments in terms of further support for the adoption of GTA, like eco-innovation R&D and environmental taxes. Woerter in his study in 2017 used ODA , environmentally related taxes (TAX)and total energy supply index(TES) in their study to see green technology adoption by countries due to policy interventions.

1. Environmentally related taxes as a percentage of total taxes by government (TAX):

Environmental tax refers to a policy in which taxes are levied on activities and products that hurt the environment. In 2020, Khan looked at the influence of technical improvement and public-private relationship investment on sustainable environment in China. Their findings indicate that the implementation of tax incentives and subsidies for green technology innovation can significantly contribute to the reduction of consumption-based carbon emissions. For instance, Shao et al. (2021) employed a model study to explore the connections between green technological innovation as well as renewable energy sources with regard to carbon neutrality. Their research revealed that tax incentives for renewable energy and green technology development have a positive correlation with achieving carbon neutrality Within the BRICS countries, Razzaq et al.'s (2021) work examined how asymmetric relationships exist between green technology innovations and consumption-based carbon emissions. However, their research shows that there are varying effects of tax measures promoting green technology innovation on carbon emissions in different quantiles using a quantile-on-quantile framework. Woerter and Stucki T., 2017 found out that environmental taxes, renewable energy, financial development, greenfield FDI, ecological impact and green growth are all correlated over a longer period with GTA.I. (Cutcu, D. Cil, and C. Karis).(Karmaker, S.C, 2021) Environmental taxes have the potential to stimulate innovation and promote the implementation of current remediation techniques. Financing research and

development programs to promote technologies, whether directly by polluters or through third-party innovators, is economically advantageous for several reasons. These taxes may also have unfavourable effects. Environmental levies may hinder the uptake and innovation of green technology in high and middle Income nations (Islam et al., 2012).

One of the main reasons is that environmental taxes increase the costs of production for businesses, particularly those involved in green technology. This can make it more difficult for these businesses to compete with traditional, polluting industries that are not subject to the same tax burdens. Additionally, environmental taxes may divert financial resources away from research and development efforts in green technology. This can hinder the advancement and innovation of new environmentally friendly technologies (Daszkiewicz, 2020). Another reason environmental taxes can negatively impact green tech adoption and innovation is that they may create uncertainty and instability in the market which can hinder investments towards green technology projects, as they may be unsure of the long-term viability and profitability of these investments.

2. Environmentally related ODA as a percentage of total allocated ODA:

Garrido et al. (2015) discussed the "2030 Agenda for Sustainable Development", emphasizing the importance of international cooperation and assistance in achieving sustainable development goals. The study highlighted the role of ODA in supporting initiatives related to environmental sustainability and technology transfer in developing countries. Cirera and Maloney (2017) explored the innovation paradox in developing countries, highlighting the challenges and potential for technological catch-up. This study highlighted the importance of external support which included ODA, in building technological capabilities. Saberi et al. (2018) examined the potential of blockchain technology in sustainable supply chain management and Anderson et al. (2017) discussed the use of Earth observation in advancing the 2030 Agenda for Sustainable Development. (This research emphasized the role of technology in monitoring and addressing environmental challenges) ODA can facilitate access to such technologies, thereby promoting green tech innovation in recipient countries. Hence ODA may play a role in fostering GTA by providing resources and expertise to the recipient countries.

3. Total energy supply index (TES):

Total primary energy supply index (TES)was used by Ceyhun Elgin, Gökçer Özgür, for measurement of green tech adoption- it measures environmental and resource productivity. Gyamfi et al. (2021) noted that rent for environmental assets, level of income, and energy consumption all have an effect on the environmental quality of G7 economies as a whole. Santra (2017) emphasizes the vital role that technological innovation plays in enhancing the productivity of production-based energy and CO2 emissions in the BRICS countries. This implies that

improvements in energy productivity and CO2 emission productivity across different nations are largely driven by technological innovation. It has been discovered that the expansion of the credit and equity markets encourages the manufacturing of cleaner energy, but the global financial crisis of 2008 had a negative impact on this production.

(Santra, 2017). This indicates that financial market conditions can significantly impact the production and adoption of cleaner energy technologies, suggesting a complex relationship between financial systems and green technological innovation. Miao et al. (2019) found that green technological innovations have contributed to reducing energy absorption and CO2 emissions, thus enhancing production-based energy productivity and CO2 emission productivity. Mamun et al. (2015) found that financial markets and innovations have a positive relationship with cleaner energy production in OECD countries. This highlights the importance of financial systems in driving sustainable energy practices and green technological innovation.

4. Mortality due to ambient Ozone (OZO):

Mortality by ambient ozone(OZO) was used by Ceyhun Elgin, Gökçer Özgür, for measurement of green tech adoption- it measures environmental and resource productivity. Following a 10% improvement in each component, these displayed a higher percentage improvement in the GTA index. These point out which specific policy designs ought to be implemented first in order to increase the nations' uptake of green technologies. Sicard et al. (2020) provided an analysis of exposure to air pollution on the urban population in Europe. This study offers valuable insights into the spatial and temporal distribution of air pollution, which is essential for understanding the localized impact of mortality from ambient ozone. Coccia (2020) discussed the effects of atmospheric stability and air pollution on the transmission dynamics of diseases. Although this study focuses on the transmission of COVID-19, it raises the question of how mortality from ambient ozone, a form of air pollution, may influence the urgency and direction of green tech innovation.

Hence the control variables we used in the study are as follows: Environmental related taxes by total tax revenue(TAX), mortality due to ambient ozone(OZO), total energy supply index(TES), Environmentally related Official development assistance by total ODA (ODA).

Our empirical model also estimates how carbon dioxide emissions shape the impact of globalization on green technology adoption. In this study, we introduce a dummy variable, 'dummy_carbon,' assigned a value of 1 for the country that has average carbon emissions (metric tonnes per capita) greater than **6.104529435**. To capture the combined impact of carbon emissions and globalization we introduced the interaction term. We also account for country-specific effects by using country-wise fixed effects in all the models. To assess the effects of

different dimensions of globalization [i.e. trade globalization, financial globalization, informational globalization and interpersonal globalization] on Green technology adoption, we use the following four models in our study:

MODEL 1: ET= a.trade + b.traded*dummy_carbon + c.OZO +d.TAX + e.ODA + f.TES + country fixed effects + error

MODEL 2: ET= a.fin + b.fin*dummy_carbon + c.OZO +d.TAX + e.ODA + f.TES + country fixed effects +error

MODEL 3: ET= a.info + b.info*dummy_carbon + c.OZO +d.TAX + e.ODA + f.TES + country fixed effects +error

MODEL 4: ET= a.inter + b.inter*dummy_carbon + c.OZO +d.TAX + e.ODA + f.TES + country fixed effects +error

4.METHODOLOGY AND RESULTS

Table 4 indicates the summary of the variables . There are average of 11% Environmental patents in all the countries. The trade globalization index has average of 55.42, financial index, interpersonal index and informational index has averages of 61.4, 58.4 and 64.55 respectively. The carbon emissions averaged at 6.104 on the basis of which we will distinguish countries by creating dummy variable and the emissions range from 0.1424688 to 30.88212.

Table 4 - Description of the variables

Variable	Mean	Std. dev.	Min	Max
ET	10.97636	9.163346	0	100
TRADE	55.42948	19.65293	8	99
FIN	61.43331	21.34269	3	100
INTER	58.42378	22.85145	9	97
INFO	64.55285	19.82194	7	100
CARBON	6.104529	4.662944	0.1424688	30.88212
TAX	32.02948	24.31573	0.01	121.35
ODA	6.833442	3.297561	-12.14	20.77
TES	114.9348	36.76279	33.02	432.68
OZO	18.87373	16.70653	0.3	122.98

The study makes use of a panel data methodology to examine how globalization affects GTA. Panel data offers several advantages over time-series and cross-sectional data, including control for individual heterogeneity, a larger number of data points, greater degrees of freedom, and a reduction in collinearity between independent variables, thus enhancing the accuracy of econometric estimates.

Using panel data modelling technique enable us to examine the impact of globalization on Green technology adoption among countries. (Skare, M., & Soriano, D. R. (2021).) This removes the bias due to time series approach in this which results from individual countries. Fixed effects are suggested from the literature and also from the Hausman test. The Hausman test decisively rejects the null hypothesis that the unobserved individual effects are uncorrelated with the independent variables for all models in the study. Thus, we prefer the fixed effects model instead of the random effect model. We used country-wise fixed effects to account for the country-specific factors that do not change over the years.

The modified Wald test was done to check the heteroskedasticity and the Wooldridge test was done to check the autocorrelation. In this study, we employed the Fixed Effect method with Discroll and Kraay Standard errors for its ability to improve parameter estimation efficiency and provide robust results from limited data, ensuring precise estimates by accounting for autocorrelation, group-wise heteroscedasticity and cross-sectional dependence.

The model estimation results are presented in the following sections: the first section presents the effect of trade globalization on green technology adoption, the second section presents the effect of financial globalization, the third section presents the effect of informational globalization and the last section of interpersonal globalization.

Table 5: the result of the estimated panel fixed effect model 1.

VARIABLES	ET
trade	0.0543**
	(3.18)
Trade*dummy_carbon	0.252***
	(13.55)
TAX	3.931**

	(-2.89)
Other Control variables	*
N	560

t statistics in parentheses

* p<0.05, ** p<0.01, *** p<0.001

In Table 5, the coefficients of trade are positive and statistically significant, indicating that an increase in trade globalization leads to an increase in the adoption of green technologies by the countries. This outcome is consistent with previous research. One explanation for the positive and direct impact of trade liberalization on GTA is the fact that trade globalization allows for the exchange of goods and technologies across borders, enabling the transfer of green technology solutions to different parts of the world .((Almeida & Moraes, 2013))

The interaction term of dummy variable and trade globalization has a positive coefficient suggesting a direct relationship with GTA, this indicates that the countries that have above average carbon dioxide emissions can increase GTA by enhanced globalization of trade.

There is a positive and significant impact of the environmental-related taxes on the GTA which is also consistent with the literature. This is consistent with what literature can provide, where, as per the paper from Shamal Chandra Karmaker that environmental taxes may have a positive and statistically significant effect on GTA, which can advance the environmental knowledge and reduce carbon emission as well as sustainable development in high and middle-income countries, that is also capable of applying for others. The other control variables also have a positive effect on GTA.

Table 6: result of the estimated panel fixed effect model 2.

VARIABLES	ET
fin	0.101**
	(3.07)
Fin*dummy_carbon	0.219***

	(7.05)
Control variables	*
N	560

t statistics in parentheses

* p<0.05, ** p<0.01, *** p<0.001

In Table 6, the coefficients of fin are positive and statistically significant, indicating that an increase in financial globalization causes an increase in the adoption of green technologies by the countries. This positive impact can be explained of financial liberalization on GTA by the fact that financial globalization leads to the removal of barriers and trade restrictions leading to large capital flows and also greater investment opportunities for affirms and countries which is encourage and benefits GTA. This is consistent with previous researches. Improved access to capital and financial resources facilitate the development and commercialization of cutting-edge green technologies.(Huang et al., 2021). Multinational corporations and venture capitalists, encouraged by the growth potential of green industries, may provide crucial funding and expertise to startups and research initiatives. This influx of global capital can accelerate the pace of innovation and enable green technology companies to scale up their operations and bring their products to a wider market.(Zhang, 2023) Additionally, the development of green finance instruments, for example green bonds and sustainability-linked loans, can direct capital towards environmentally-friendly ventures and incentivize businesses to adopt eco-friendly practices.

The interaction term of dummy variable and financial globalization has positive coefficient suggesting an direct relationship with GTA, this indicates that the countries that have above average carbon dioxide emissions can increase GTA by enhanced financial globalization . The control variables have positive impact on GTA.

Table 7: result of the estimated panel fixed effect model 3.

VARIABLES	ET
info	0.223***
	(7.12)
Info*dummy_carbon	0.0378*

	(2.55)
Control variables	*
N	560

t statistics in parentheses

* p<0.05, ** p<0.01, *** p<0.001

In Table 7, the coefficients of info are positive and statistically significant, which indicates that an increase in informational globalization leads to an increase in adoption of green technologies by the countries. One explanation for this is the fact that, globalization of information, which is mostly facilitated by the Internet also has significant implications for intellectual property regimes domestically and internationally and also leads to increased competition and a better quality of life through access to information available in databases planetary and new opportunities in a business environment. It is also consistent with previous research by Doric, 2022.They found that with the widespread access to information and knowledge through the internet, researchers and innovators in the field of green technology can easily share their findings, collaborate on projects, and learn from each other's experiences. This can accelerate the development of new green technologies and accelerate their adoption globally. The interaction term of dummy variable and informational globalization has positive coefficient suggesting an direct relationship with GTA. The control variables also have positive impact on GTA.

Table 8: result of the estimated panel fixed effect model 4.

VARIABLES	ET
inter	0.239***
	(8.40)
Inter*dummy_carbon	0.176***
	(4.75)

Control variables	*
N	560

t statistics in parentheses

* p<0.05, ** p<0.01, *** p<0.001

In Table 8, the coefficients of inter are positive and statistically significant, which indicates that an increase in interpersonal globalization leads toincrease in the adoption of green technologies by the countries. This is because through interpersonal globalization, international collaborations, conferences, and partnerships, experts in the field can come together to exchange ideas, share best practices, and work towards common goals which helps in increasing GTA.
The interaction term of dummy variable and interpersonal globalization has a positive coefficient suggesting a direct relationship with GTA. The control variables also have a positive and dircet impact on GTA.

This shows that trade openness of all types are essential determinant for technology transfer. Based on the World Economic Outlook (2018), globalization has helped to intensify the technology and knowledge transfer across countries. That is especially true for emerging markets. We looked at 81 high-income and middle-income economies across different environmental patents as technological variables.

Globalization is a key element that has shaped global competition and thereby innovation in the world, and it is what we are aiming to contribute to a more thorough understanding of it. Globalization is a necessary, if not sufficient, condition for green technology penetration. Further studies are required for both country and firm levels to show what is driving globalization and the GTA mechanism. Our work is a first step on that journey.

5.CONCLUSIONS

Globalization is an important and key channel by which innovation penetration affects green technology adoption, but not the only one. We have provided empirical evidence using the fixed effects panel data model for 81 countries on relationship between globalization and green tech adoption. This paper investigates the effects of four distinct forms of globalization—trade, financial, informational, and interpersonal —on GTA. We have used multidimensional variables for globalization (KOF index), the interaction of globalization and CO2 emissions and green technology adoption in this study. Green technology adoption rates differ across countries which

is due to the differences in the level of globalization.

This study indicates that there is a threshold effect regarding the Co2 emission levels. Globalization contributes highly to GTA in economies with high CO2 emissions. The results with the threshold are fairly robust to different model specifications. This self-fulfilling process of globalization and the spread of green technologies is why globalisation tends now to be seen as a sort of race-to-the-bottom involving its productivity component by policymakers and practitioners. Climate change mitigationis currently a global challenge leading to increased interest in fostering green technology innovation. The results provide important implications for policy makers on driving worldwide green technology cooperation to combat against a worldwide challenge such as climate change, e.g. accelerating the green technology infrastructure import, FDI and licensing between nations especially towards those less developed economies.

Future researchers should try to expand this study. With additional variables, a broader range of advanced econometric panel data techniques could be employed by future researchers and the model fit could be improved. The availability of the data conducted to our study has been limited by the Green technology adoption rate index. In addition, the literature review reveals a critical lack of uniform, comprehensive collection of environment-related variables as well. Policies cannot be effective and cannot be developed unless their magnitude or existing policies' effectiveness is understood.

The research paper offers several policy suggestions to encourage GTA. Policy recommendations aimed at increasing GTA and sustainable growth include implementing targeted globalization, implementation of global environmental standards and fostering international collaborations in R&D. Firstly, by International Collaboration & Knowledge Sharing i.e by establishing global research and development platform and fostering collaboration among nations and research institutions to develop and technologies. This can include joint funding for research projects, information sharing, and establishing international standards. Promote knowledge transfer by facilitating the transfer of green technology expertise from developed to developing nations through capacity building programs, training, and technology licensing agreements. Create global green technology markets to encourage international trade in green goods and services by removing trade barriers, harmonizing standards, and promoting fair competition.

Secondly, it requires protection and value of intellectual property rights—both domestically and internationally—by improving intellectual property rights (IPR) framework to increase technology innovation. Proper regulatory frameworks & clear and consistent standards must be in place for green technologies across borders to facilitate trade and ensuring quality.

Thirdly, by providing financial incentives & investment to establish global green technology funds and provide financial assistance to developing nations to invest in green infrastructure, research, and development. Promote green bonds and green investment funds to attract private capital towards green technology projects by offering tax incentives and guarantees for green investments. Individuals can invest in green technology by identifying individual stocks, mutual funds, index funds etc. that seek to reflect the market for environmental investments. Incentivizing clean energy exports by supporting domestic companies to develop green technologies through subsidies, tax breaks, and export financing to encourage the global adoption of their innovations. Putting in place global carbon pricing mechanisms to penalize polluting industries and promote green technology, such as carbon taxes or emissions trading schemes.

Fourthly, try to leverage the power of the private sector by facilitating public-private partnerships and encouraging collaboration between governments and businesses to develop and deploy green technologies at scale. Additionally, policymakers need to ensure that the nations' citizens broadly benefit from the positive growth of technological innovation and globalization. This includes ensuring innovative firms do not exploit their new advantages, so everyone can benefit from progress.

Lastly, the countries must support cultural exchange programs and promote global campaigns to raise awareness and educate the public about the benefits of green technologies and the urgency of climate action through international campaigns, media outreach, and educational programs. Support international exchange programs and foster collaboration among scientists, engineers, and policymakers from different countries to share best practices and learn from each other.

By implementing these policy suggestions, we can harness the power of globalization to accelerate the adoption of green technologies and create a more sustainable future for all.

Looking forward, the future of green technology adoption is inextricably linked to globalization. To harness its potential, policies must be crafted to address existing inequalities, foster equitable access to green technologies, and prioritize environmental sustainability in global governance. By optimizing globalization for green development, we can create a future where sustainable solutions flourish, driving economic growth, social well-being, and environmental protection for generations to come.

In summary, there is the plausible positive impact of globalization on green technology adoption., highlighting the importance of globalization of a nation hence to increase the GTA, countries must adopt globalization that will enhance technology and knowledge transfer. By leveraging its various facets and addressing its challenges, we can create a world where sustainable solutions are not just a choice, but a necessity, ultimately leading to a more equitable and resilient future for all.

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