UNIVERSIDADE ESTADUAL PAULISTA – UNESP
FACULDADE DE ENGENHARIA DE BAURU – FEB
PROGRAMA DE PÓS-GRADUAÇÃO EM ENGENHARIA DE PRODUÇÃO

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Economic Trade Diversification and Environmental Sustainability

Bauru
May, 2025

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PhD thesis presented to 'Programa de Pós-Graduação em Engenharia de Produção' at 'Faculdade de Engenharia de Bauru' of São Paulo State University "Júlio de Mesquita Filho" (UNESP) to obtain the degree of PhD in Production Engineering.

Supervisor: Prof. Dr. Diogo Ferraz

Bauru
May, 2025

S525e

Shahzadi, Irum
Economic Trade Diversification and Environmental Sustainability / Irum Shahzadi. -- , 2025
115 p.

Tese (doutorado) - Universidade Estadual Paulista (UNESP), Faculdade de Engenharia, Bauru,
Orientador: Diogo Ferraz

1. Trade Diversification. 2. OECD. 3. Panel Data. 4. Renewable Energy. 5. Agriculture. I. Título.

Sistema de geração automática de fichas catalográficas da Unesp. Dados fornecidos pelo autor(a).

UNIVERSIDADE ESTADUAL PAULISTA

Câmpus de Bauru

ATA DA DEFESA PÚBLICA DA TESE DE DOUTORADO DE IRUM SHAHZADI, DISCENTE DO PROGRAMA DE PÓS-GRADUAÇÃO EM ENGENHARIA DE PRODUÇÃO, DA FACULDADE DE ENGENHARIA - CÂMPUS DE BAURU.

Aos 26 dias do mês de maio do ano de 2025, às 9h, por meio de Videoconferência, realizou-se a defesa de TESE DE DOUTORADO de IRUM SHAHZADI, intitulada **ECONOMIC TRADE DIVERSIFICATION AND ENVIRONMENTAL SUSTAINABILITY**. A Comissão Examinadora foi constituída pelos seguintes membros: Prof. Dr. DIOGO FERRAZ (Orientador(a) - Participação Virtual) do(a) Departamento de Engenharia Química e Produção / Universidade de São Paulo - USP, Prof. Dr. ENZO BARBERIO MARIANO (Participação Virtual) do(a) Departamento de Engenharia de Produção / Universidade Estadual Paulista Unesp Faculdade de Engenharia Câmpus Bauru, Prof. Dr. HERICK FERNANDO MORALLES (Participação Virtual) do(a) Departamento de Engenharia de Produção / Universidade Federal de São Carlos, Prof. Dr. EDUARDO POLLONI SILVA (Participação Virtual) do(a) Engenharia de Produção / Universidade Federal de Mato Grosso do Sul - UFMS, Prof. Dr. FABRÍCIO MACIEL GOMES (Participação Virtual) do(a) EEL/USP. Após a exposição pela doutoranda e arguição pelos membros da Comissão Examinadora que participaram do ato, de forma presencial e/ou virtual, a discente recebeu o conceito final:_APROVADA_____. Nada mais havendo, foi lavrada a presente ata, que após lida e aprovada, foi assinada pelo(a) Presidente(a) da Comissão Examinadora.

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DEDICATION

To Allah, and my Husband;

To my lovely family;

To my supervisor Prof. Dr. Diogo Ferraz*;*

To the friends who supported me at this stage of my life.

ACKNOWLEDGMENTS

I shall begin by thanking my supervisor, Prof. Dr. Diogo Ferraz, for his supportive and encouraging assistance throughout my trajectory.

I gratefully thank Dr. Gagan Deep Sharma and Dr Buhari Dogan for agreeing to help with the first article.

I would like to thank the UNESP (São Paulo State University) – 'Programa de Pós-Graduação em Engenharia de Produção' at 'Faculdade de Engenharia de Bauru' for all support and infrastructure to develop this research.

I offer my thanks to my lovely husband Dr Umer my parents, my sisters, my family and friends for their love, support, and encouragement.

There is no demand for women engineers, as such, as there are for women doctors; but there's always a demand for anyone who can do a good piece of work.

Edith Clarke

ABSTRACT

The prime objective of this thesis is to evaluate the role of trade diversification, and renewable energy for environmental sustainability. In doing so, the authors have done detailed bibliometric review study on trade diversification, its drivers and its impacts on environment. In the next step, the study examined the role of trade diversification, and renewable energy for developed countries (OECD) related to industrial sector. In the last step, authors attempt to evaluate the role of agriculture sector trade, green energy for environmental sustainability of a developing country (Brazil). The global economies are highly concerned about the balance between climatic issues and attaining sustainability in the industry and agricultural sector. Still, empirical evidence regarding the nexus of these variables is scant and needs appropriate policy-level attention. Using various panel data and time-series diagnostic measures, this research revealed some interesting findings. Overall, the results are found robust as tested via quantile regression and other methods. Also, the pairwise Granger causality detects unidirectional and bidirectional causalities between variables. This research recommends enhanced spending in the research and development and green energy projects. Further, land resources and foreign investments must be efficiently utilized to limit their influence on rising pollution levels.

Keywords: Trade Diversification; OECD; Panel Data; Renewable Energy; Agriculture; Efficiency; Brazil

RESUMO

O principal objetivo desta tese é avaliar o papel da diversificação do comércio e das energias renováveis para a sustentabilidade ambiental. Para isso, os autores realizaram uma revisão bibliométrica detalhada sobre a diversificação do comércio, seus fatores determinantes e seus impactos sobre o meio ambiente. Na etapa seguinte, o estudo examinou o papel da diversificação comercial e das energias renováveis nos países desenvolvidos (OCDE), com foco no setor industrial. Por fim, os autores buscaram avaliar o papel do comércio no setor agrícola e da energia verde para a sustentabilidade ambiental de um país em desenvolvimento (Brasil). As economias globais estão altamente preocupadas com o equilíbrio entre as questões climáticas e a busca pela sustentabilidade nos setores industrial e agrícola. No entanto, ainda são escassas as evidências empíricas sobre o nexo entre essas variáveis, o que exige atenção adequada no nível das políticas públicas. Utilizando diversos dados em painel e medidas diagnósticas de séries temporais, esta pesquisa revelou resultados interessantes. De modo geral, os achados mostraram-se robustos, testados por meio de regressão quantílica e outros métodos. Além disso, a causalidade de Granger em pares detectou relações causais unidirecionais e bidirecionais entre as variáveis. Esta pesquisa recomenda o aumento dos investimentos em pesquisa e desenvolvimento, bem como em projetos de energia verde. Ademais, os recursos fundiários e os investimentos estrangeiros devem ser utilizados de forma eficiente para limitar sua influência sobre o aumento dos níveis de poluição.

Palavras-chave: Análise Envoltória de Dados; eficiência ambiental; indicadores; energia renovável.

Table of Contents

DEDICATION 1
ACKNOWLEDGMENTS 1
ABSTRACT 1
RESUMO 1
LIST OF TABLES 5
LIST OF FIGURES 6
CHAPTER 1 7
INTRODUCTION 7
1.1. Study Background 7
1.2. Primary Research Problem 11
1.3. Research Gap 12
1.4. Main Objectives and Secondary Aims of the Thesis 13
1.5. The Interconnectedness Between Research Studies 14
CHAPTER 2: What do we learn from Nexus between trade diversification and structural change: Informing the future about climate action and Sustainability 16
2.1. Introduction 16
2.1.1 Study Background 16
2.1.2 Study Objective & Contribution 21
2.2. Data and Methodology 23
2.2.1. Bibliometric Dataset 23
2.2.2. Bibliometric analysis 24
2.3. Empirical Results 25
2.3.1 Social structure: analysis of authors' productivity characteristics 25
General Overview 25
2.3.2 Intellectual structure: on Evolution of Research over Time 29
Co-citation analysis 29
Co-occurrence of keywords 31
2.3.3 Conceptual structure: discussion on the conceptual evaluation of economic complexity over time 32
2.4. Discussion of findings 40
2.5. Policy Implications and the Future Research Agenda 41
2.6. Conclusion and Implications 42
CHAPTER 3: Heterogeneous Impacts of Import Product Diversification on Energy Efficiency: What We Learn from the Experience of OECD Countries 45
3.1. Introduction 45
3.1.1. Motivation and Background 45

3.1.2. Contribution of the Study....49
3.2. Literature Review....50
3.3. Data Specification and Methods....53
3.3.1. Data Processing and Model construction....53
3.3.2. Estimation Methods....55
3.4. Empirical Results and Discussion....56
3.4.1. Preliminary Analysis....56
3.4.2. Co-integration Analysis....59
3.4.3. Panel Regression Empirics and Discussion....61
3.4.4. Robustness Check....64
3.5. Concluding Remarks....65
CHAPTER 4: Does Land Resources, Agriculture Exports, and Agriculture growth induce Agriculture related greenhouse gas emissions: Novel Findings in Context of Brazil....68
4.1. Introduction....68
4.2. Review of Literature....72
4.2.1. Role of Land Resources....72
4.2.2. Role of Agriculture Exports....72
4.2.3. Role of Renewable Energy....74
4.2.4. Role of Foreign Investment....75
4.2.5. Research Gap....75
4.3. Data and Methods....75
4.3.1. Theoretical Framework and Models....76
4.3.2. Estimation Methods....76
4.4. Results....82
4.4.1. Results Interpretation....82
4.4.2. Discussion....91
4.5. Conclusions and Policy Implications....93
References....98

LIST OF TABLES

Table 2. 1: Database information 23
Table 2. 2: Document Types 23
Table 2. 3: Document Contents and Authors' Collaboration 24
Table 2. 4: Document Contents of Web of Science and Scopus database 28
Table 2. 5: Index rankings 33

Table 3. 1: Summary of descriptive statistics 56
Table 3. 2: Results of Cross-Section dependence test 57
Table 3. 3: Results for panel unit root testing 58
Table 3. 4: Empirics for Co-integration analysis 60
Table 3. 5: Empirics for FMOLS cointegration 60
Table 3. 6: Full Panel- regression empirics 63
Table 3. 7: Robustness check with institutional factors 64

LIST OF FIGURES

Figure 2. 1 : Country Collaboration Map 26
Figure 2. 2: Three Field Plot co-authorship diagram network 27
Figure 2. 3: Keyword Co-Occurrence Network 29
Figure 2. 4: co-citation cluster analysis 31
Figure 2. 5: Trend Topics analysis 32
Figure 2. 6: Source Impact Annual Scientific Production 33
Figure 2. 7: Comparative evaluation of the performance of citations across journals 35
Figure 2. 8: Minimum Spanning Tree-Author's Keywords 36
Figure 2. 9: Thematic Map 38
Figure 2. 10: Conceptual Structure Map: MDS 40

Figure 3. 1: GDP, energy imports, carbon intensity and energy intensity of OECD countries 48
Figure 3. 2: Correlation matrix based on heat-map among the variables 58

CHAPTER 1

INTRODUCTION

1.1.Study Background

The nature, process, pace, and determinants of economic development have remained the cynosure for academic scholarship in economics and related domains. For more than two centuries, researchers have focused on macroeconomic development encompassing concerns like growth, innovations, policies, industrialization, etc. (Smith, 1776; Schumpeter, 1939, 1982; Keynes, 1936). Recent discussions in the literature have focused on concerns about growth and income inequality as well (Acemoglu and Robinson, 2002; Rodrik, 2014; Mazzucato, 2016).
The ongoing deliberations in the literature on production and structural transformation have underscored that complexity and diversity in production is a novel index of a country's level of development (Hidalgo et al., 2007; Hidalgo and Hausmann, 2009). The methodological underpinning of economic complexity attempts to measure the competitiveness of a country relating to export sophistication. A growing strand in the literature has explored the newer dimensions of economic development, illuminating the discussion on the new indices, related to complex production systems. Several methodological sophistication and policy-level discussions have emerged (Can and Gozgor, 2017; Neagu, 2019; Doğan et al., 2019; Doğan et al., 2022 Doğan et al., 2022). Nonetheless, the research continues to be fragmentary, creating the need to evolve a synthesis in the analytical discussions. The scope of research on economic complexity is an advancement of the traditional growth economics framework because it considers economic activities and the extent of economic diversification and qualitative assimilation. The literature on economic complexity enhances our understanding of how newer economic activities are intricately related to knowledge and skills and the degree of sophistication (Hidalgo, 2007; Hidalgo and Hausmann, 2009; Hidalgo, 2021), as discussed by Hidalgo and Hausmann (2009) and Hidalgo (2021), economic complexity is associated with ubiquity in economic activities inversely, encompassing how many countries can produce knowledge-intensive production that tends to network with economic processes. The extant seam in the literature on economic complexity describes that the newer economic activities increasingly rely on technological sophistication, the development of skills, and how policies on export diversification boost the process of diversification. Due to its emphasis on economic activities in technological sophistication and economic diversification, it largely relies on

industrial policies on innovation, employment, and growth opportunities. In line with traditional macroeconomic thinking, economic complexity scrutinizes factors on policies related to industrialization, innovation, and growth.

Nowadays, global value chains and trade have connected the countries and deepened their dependence on each other. Anything related to trade affects the economy widely. The classical theory of comparative and absolute cost advantage of trade promotes the specialization in the production and export of the commodities in which the countries have an advantage over the others. Later, Heckscher-Ohlin's theory connects the specialization with factor intensity. In contrast, Prebisch and Singer (Hadass & Williamson, 2003) show that developing countries face adverse terms of trade conditions due to more agricultural items in their trade baskets. The traditional theories fail to foresee the increasing product diversity when establishing gains from free trade and specialization. After World War II, the trade scenarios and conditions changed and became more protectionist around the world; it posed a question on free trade. Foreign trade and resulting global value chains have raised many questions about export-led growth, sustainable development and climate change (Cole, 2004).

Amidst the recent US-China trade war and health risks, the global economic outlook seems gloomy. Global trade markets and policies are becoming uncertain to revive the connection between the trade and environment. At the same time, this connection has been found critical and strengthening for the countries which grow and open their economies. Every change in trade structure and policies does affect the environment in the long term. The famous ‘Pollution Heaven Hypothesis’ (PHH) emphasized the role of trade and pollution (Harrison & Eskeland, 1997). It explains that because of the increased trade, the location of the polluting production activity shifts to developing countries. Therefore, it is essential to strategically focus on import and export structure and their diversity which helps to achieve sustainable economic growth in the long run.

Energy demand, specifically fossil fuels, is primarily responsible for carbon emissions which is the prime cause of climate change. The major part of this energy demand depends on the oil and petroleum imports from the global market. It has been recorded that among the imports, energy imports consist of 20% of total energy use in developed countries (OECD, 2019). The researchers (Parteka & Tamberi, 2013) argue that as countries become rich and per capita income increases, they import and export more because they want to have more goods with more extensive varieties in their trade portfolio. Their income increases and consumption also increases. Highly developed and rich countries like the USA and Australia have diversified import structures. Diversification of imports is also supported by the inverted U-shaped

hypothesis (Cole, 2004) which says that as people's income grows, they can afford clean sources of energy and gradually high-income developed economies focus on the production of less energy-intensive or less polluted production of goods whereas they import energy-intensive goods. This argument is contrary to the traditional theories and rather than specialising countries de-specialise and expand as they grow. Energy efficiency is crucial in reducing costs and conserving resources, making economies more sustainable and resilient. Higher energy efficiency can contribute to GDP growth by lowering production costs, increasing competitiveness, and freeing up capital for investment in innovation and infrastructure. Import diversification reduces dependency on single suppliers or regions, enhancing economic stability and security against supply chain disruptions. Improved energy efficiency and a diversified import strategy strengthen national economies, ensuring long-term growth and sustainability. Energy efficiency is crucial in reducing costs and conserving resources, making economies more sustainable and resilient. Higher energy efficiency can contribute to GDP growth by lowering production costs, increasing competitiveness, and freeing up capital for investment in innovation and infrastructure. Import diversification reduces dependency on single suppliers or regions, enhancing economic stability and security against supply chain disruptions. Improved energy efficiency and a diversified import strategy strengthen national economies, ensuring long-term growth and sustainability.

Hence, it may not be necessary for countries to import what they cannot produce. Imported goods consist of both final products as well as inputs. Diversification of imports enhances consumer welfare because consumers now have more options and varieties of goods at better prices due to increased competition (Krugman, 1979). The import of final products and inputs shows the improvement in demand (consumer welfare) as well as the supply-side (productive efficiency) structure of the economy. Production efficiency takes place as more and more quality inputs are available. The competition whips up among domestic and foreign producers to gain market share because of new product entry in the market.

Economic diversification has been a challenge for developing as well as developed countries. World Trade Organization (WTO, 2019) defined economic diversification 'as a shift toward a more varied structure of domestic production and trade to increase productivity, creating jobs and providing the base for sustained poverty-reducing growth'. There are two categories of economic diversification; the first is domestic production diversification and the second is trade diversification which consists of both product (export and import) as well as geographic diversification in terms of exploring new markets. Tarde diversification is the need of the hour

because it gives a cushion from external shocks and volatility and avoids excessive dependence on one country or one product. It also helps to explore the ways to reduce their Carbon Dioxide (CO2) emissions. In today's global era countries are dependent on each other in various ways. The consumption needs are dependent on multiple and quality imports, which also fulfil the requirement of energy consumption. Hence, product import policies and diversification help to gratify the energy need in such a way that emissions are reduced (Joya, 2015; Balavac & Pugh, 2016).

The recent conference COP27 is perceived as a combined nations' effort to achieve sustainability goals in which international communities join in addressing global issues like climate change and pinpoint solutions for GHG emission reduction. Over the years, these issues have developed into a global challenge due to their harmful effect on the economic, political as well as on social sectors of the economy (Chakraborty and Maity, 2020, Dietz, Shwom, and Whitley, 2020). Even though roughly all economies are fixated on resources that release less to no emissions, but still a paramount challenge of emission reduction from agriculture and land-based activities is still extant because the major portion of global GHG comes from agricultural activities or other land-based activities. Meanwhile, agriculture has been the backbone of numerous economies, over the years expansion in the agriculture sector to regulate constant food supply to fulfil growing population needs has contributed to climate change. Some anticipate agriculture will become a major threat to climate change till reaching 2050. Therefore, to limit the global temperature from further rising and meet 20 Celsius targets, all economic areas of an economy including agriculture must lessen harmful GHG discharges (Lu and Dai, 2023).

In retrospect, agriculture production was mainly from the household sector which consumes less to no energy with limited transportation. However, with time, the development of agriculture into large-scale production might have altered this scenario because now the agriculture sector consumes nearly 30% of the total energy consumption which is dependent on fossil energy (Nguyen et al., 2021, Puri, 2022). Hence, agriculture is alleged to be an important source of greenhouse (GHG) emissions in most economies across the world (Zhao et al., 2020). Figure 1 displays the visual presentation of agriculture-related emissions and land-based emissions in Brazil. This shows the emissions from the agriculture sector have been significantly consistent while land-based emissions have shown less emissions in recent years compared to agricultural emissions. This might be due to the efficient use of land resources as improved land resources decrease their negative impact on environmental quality (De Pinto et al. 2016). However, the trade of agricultural products locally or across borders has a significant

effect on atmospheric quality. It tends to intensify emissions. Consequently, Figure 2 shows agricultural exports have meaningful effects throughout the time compared to agricultural land. This implies that exports from the agriculture sector play a crucial part in escalating emissions (Khan, Bin, and Hassan, 2019).

1.2.Primary Research Problem

The general research problem of this study focusses on the nexus between trade diversification, green energy and sustainable development in developed and developing countries. To analyze the research problem, it is essential to consider several aspects of the issue at hand. The first component is the existing state of trade diversification and its implications for sustainability. According to the literature, trade diversification could have beneficial economic implications, such as boosting competitiveness and reducing vulnerability to external shocks (UNCTAD, 2020). "Diversification per se raises critical issues of environmental impacts, social equity, and sustainability over time." At the same time, a large portion of the world's economies, particularly developing countries, depend on primary commodity exports, which is why governments require strategies to diversify their trade portfolios and focus more on value-added exports, including agricultural products.

For developed and developing economies alike, trade diversification, exports, sustainability, and future solutions are critical considerations. Hence, economic resilience and growth require the continued diversification of trade, which can be defined as the increase in foreign trade involving more goods and more markets. Trade diversification and sustainability are hard-earned victories that are rendered incredibly difficult by critical contemporary challenges such as climate change, resource scarcity, and social instability.

The latter (agriculture) sector is essential for many countries with large agricultural sectors. At the same time, it has been criticized for environmental degradation and exporting unsustainable agriculture practices and farming glean (Canton, 2021). Therefore, addressing these concerns requires a focused approach to integrating sustainability principles into agriculture production, supply chains, and trade agreements. Another component of the research problem is relevant future issues and solutions that could ensure the combination of diversification, exports, and sustainability. This aspect contains various potential solutions, strategies, and innovative technologies and practices that could help countries expand their trade and promote their long-

term strategies with minimal adverse environmental and social impact. Some of the potential solutions include investment in sustainable agriculture, renewable energy, green infrastructure, and circular economy, as well as negative-emission and energy-efficient technologies (Can et al., 2021).

The analysis of research problems among developed countries illustrates the focus on technology, innovation, and high-value-added industries to promote sustainability and trade diversification. Developed countries also promote green trade and eco-labeling schemes to ensure that their exports match ecological and social requirements (European Commission, 2021). Developed countries are in a much better position to tackle the issue while developing states could face significant obstacles due to a lack of resources, infrastructure, and market access limitations (IMF, 2021).

1.3.Research Gap

Although significant strides have been made in researching the complexities associated with trade diversification, agriculture exports, sustainability, and potential solutions to future challenges, significant gaps exist within the available literature. Understanding research gaps is important, as it helps in identifying where more research is needed and informing interventions to guide future research that could positively contribute to creating inclusive and sustainable patterns of trade. First, there is a significant research gap in the comprehensive analysis of the trade-offs and synergy between trade diversification and sustainability. Literature is saturated with evidence supporting that trade diversification has the potential to enhance growth and build resilience. However, there is a limited analysis of how trade diversification may impact environmental degradation, social inequality, and the ability to maintain inclusive outcomes and long-term sustainability. In this case, energy efficiency, trade diversification, and environmental degradation are the most obvious examples of factors that need extensive research and analysis (Sarin et al., 2022). Furthermore, more research is needed to analyze the various trade-offs within the context between gains on a short and long-term basis. Another research gap identified is on the sustainability of agriculture exports and their value chains. A significant gap exists on how agricultural exports are produced and the numerous environmentalists impacts inadequately addressed. Only minimal research has been conducted along these lines, and noted are currently competitive only across the economic argument. Thus, a deeper look should be taken to try and define the greenhouse gas emissions

of these exports are facilitated by intense farming, environmental policies, and foreign investment along with the exports of agriculture.

Secondly, this review indicates a research gap in future solutions such as technological innovations, policy reforms, and institutional mechanisms that can further trade diversification and enable sustainability. Although there is increasing interest in green technologies, circular economy strategies, and sustainable finance solutions, there is limited understanding of how these interventions can help address the challenges of trade diversification and its sustainability (Can et al., 2021). Therefore, the current research can explore how the solutions can increase trade competitiveness, reduce environmental degradation, and promote social integration. Similarly, there is limited knowledge of the existing enablers and inhibitors to the implementation of future solutions especially in developing countries. Thirdly, there is a research gap in the literature and comparison of developed vs. developing countries regarding trade diversification and exports. Although there is broad research on the trade dynamics of developed economies, there is limited research that compiles and analyses the trade patterns and sustainability efforts of the two groups. Understanding the similarities and differences between the practices will identify the best practices to learn and opportunities for support for capacity development on sustainable trade.

1.4.Main Objectives and Secondary Aims of the Thesis

The prime objective of the research is to explore the role of trade diversification and report novel outcomes, conclusions and implications apropos sustainability and green energy innovation in developed and developing countries. In doing so, first we have done the detailed evaluation and impacts of trade diversification for developed economies. In addition, we attempted to examine the role of agriculture trade and green energy for environmental sustainability. Trade diversification has been identified as one of the most critical reservations since it boosts economic resilience and decreases the reliance on a limited number of products or trading partners. Following the statement, the consequences of trade diversification for sustainability objectives have yet to be fully understood and related, including their standpoint from environmental, social, or economic considerations.

To investigate the synergies between trade diversification and sustainability, this study is expected to uncover innovative, creative, and supplementary measures and policy interventions. On the other hand, the secondary purpose is to embrace and explore the influence

of green technologies and environmentally friendly energy systems in expanding sustainable trade patterns. Green technologies like renewable energy and energy efficiency can alter international trade by decreasing carbon and material usage and introducing clean and green methods. Additionally, green power suppliers can enhance energy safety, and mitigate greenhouse gas emissions by reducing reliance on fossil fuels. In other words, this research can explore the role of technological revolution in promoting sustainable trade expansion.

Finally, another secondary aim of the thesis is to shed light on the various trade-offs and synergies between trade diversification and sustainability objectives in developed and developing economies. Although trade diversification is believed to be an important means for achieving economic growth and development, it is associated with substantial costs of environmental degradation, social exclusion, and resource depletion. Therefore, this research work will provide a systematic framework to evaluate the trade-offs attached to different diversification strategies. Thus, it will enable policymakers and international trade practitioners to make informed decisions about trade that prioritize sustainability objectives. The thesis will also explore avenues where trade diversification will have the greatest collaborative effect with sustainability objectives. Since promoting green value chains and sustainable consumption patterns will simultaneously help the economy and environment, the thesis will also consider the win-win outcomes of diversification for sustainability. Finally, the thesis will draw practical recommendations for policymakers, businesses, and public institutions to promote sustainable trade. By reviewing empirical evidence, case studies, and other relevant sources of policy analysis, the thesis will derive actionable insights tailored to priorities that will stimulate the application of evidence-based research. In essence, the objective of the thesis is to contribute to knowledge advancement and understanding in the field of sustainable trade development and to encourage trader partnership towards more sustainable and all-inclusive trade actions.

1.5.The Interconnectedness Between Research Studies

The three pieces of research complement each other and provide insights into the complex relationship between trade diversification and sustainability in terms of different dimensions and regions. However, considering that each research addresses particular aspects of this process, they can be seen as a comprehensive approach to understanding how the dimensions of this relationship interact concerning the objectives of sustainability. For instance, the first research explores the concept of economic complexity and its effects on two of the central

notions that play a crucial role in relationship trade diversification and sustainability. This research shows that, although the concept of economic complexity can inform the changes in export quality and trade diversity, it is much more complicated when it comes to revealing how this notion impacts other aspects. This research can serve as the basis for understanding how countries can use their economic complexity to develop sustainable trade patterns and achieve industry, innovation, and SDGs action.

On the other hand, the second research focuses on the energy sector and shows how the diversification of imported commodities is associated with the performance of energy efficiency in OECD countries. In other words, this research demonstrates that the diversity of imported commodities significantly affects the steep decline of energy and carbon intensity, which helps achieve environmentally sustainable or sustainable development goals. Moreover, the research reveals that the factors of energy efficiency will include economic growth, urbanization, and financial development.

The third research adds to this analysis of the agricultural sector and investigates the link between agro-sector exports, green energy, foreign investments, and greenhouse gas emissions in Brazil. The research employs the advanced tools of econometrics to reveal the links between land resources, foreign investments, and agro-sector exports concerning their impact on environmental sustainability. As a result, this research shows that green energy and agro-sector exports mitigate pollution in the developing region and push for more productive agriculture, supporting action on climate and life on land.

These three researches demonstrate the complex relationship between trade diversification and sustainability and underlie the importance of comprehensive strategies to achieve sustainable development by considering all these economic, environmental, and social issues. By applying the findings of these research, policymakers will develop evidence-based strategies to stimulate the diversification of trade while making it part of the local and global sustainability goals.

It is important to mention here that all chapters of this thesis were published as research articles in Journals Environmental Science and Pollution Research, Renewable Energy and Land Degradation and Development.

CHAPTER 5: Conclusion

This thesis aimed to explore the complex interplay between trade diversification, green energy, and environmental sustainability across diverse economic contexts—both developed and developing. The primary contribution of this research lies in its comprehensive and multi-dimensional analysis of how trade structures interact with sustainability goals, focusing particularly on export quality, economic complexity, and sectoral environmental performance. By using bibliometric methods, econometric analyses, and contextual case studies, this study fills significant gaps in the literature and offers critical insights for policymakers, international institutions, and researchers concerned with sustainable trade and environmental integrity.

Note that Chapter 2 conducted a bibliometric analysis that mapped the evolution of scholarly interest in export quality, trade diversification, and economic complexity between 1966 and 2021. The findings identified two core intellectual clusters—economic complexity and structural transformation—and highlighted emerging research themes related to sustainability, human development, and energy use. Moreover, it revealed geographic disparities in academic collaboration, particularly the underrepresentation of developing countries, and emphasized the need for integrated research efforts linking trade diversification with broader sustainability goals. Despite its contributions, the research has limitations. The bibliometric review was restricted to English-language publications in Scopus and Web of Science, potentially omitting significant contributions in other languages and databases. Additionally, the econometric models focused on aggregated national or sectoral data, which may obscure local dynamics. Future research should consider micro-level analyses, expand the scope to include multilingual and regionally diverse datasets, and further investigate the role of technological innovation and institutional quality in mediating the trade-sustainability nexus. Moreover, future studies could explore sector-specific pathways for green transition, particularly in vulnerable developing economies.

Further, Chapter 3 investigated the heterogeneous effects of import product diversification on energy efficiency within OECD countries. The analysis employed panel regression models and co-integration techniques, revealing that greater import diversification contributes to declines in both carbon and energy intensity. These findings support the inverted-U hypothesis, showing that developed countries with diversified trade portfolios tend to import cleaner technologies, which fosters greater environmental efficiency. The study also demonstrated the influence of

urbanization, economic growth, and financial development in driving energy efficiency improvements across OECD economies.

This study integrates a wide range of discussions from existing literature and establishes future research trajectories on export quality and economic complexity. It pioneers a quantitative framework to analyze export quality, diversification, and complexity using bibliometric methods, including thematic maps and trend topics. The findings emphasize that such analytical approaches enhance scholarly understanding within the international research community. Based on this evidence, policymakers and environmental scientists in OECD countries should focus on improving trade-energy and import-energy portfolios. Diversifying imports, particularly renewable energy equipment and high-tech products, can significantly enhance energy efficiency and reduce reliance on non-renewable resources. Future research should concentrate on country-specific analyses of import-led growth, helping design effective trade regulations aligned with sustainable development goals. Meanwhile, Albeaik, (2017) and Zhang et al., (2025) have emphasized to improve the economic complexity index, which can further update the in-depth knowledge of diversification, production and manufacturing indicators.

Finally, Chapter 4 focused on the Brazilian agricultural sector to assess whether land resources, agricultural exports, and sectoral growth drive greenhouse gas emissions. Using advanced econometric methods such as Quantile ARDL models, the chapter provided robust evidence that land use and agricultural practices significantly contribute to emissions. However, the use of green energy and targeted foreign investment can mitigate these environmental harms. These results are particularly timely given international climate negotiations, such as COP28, and are aligned with achieving SDGs 13 (Climate Action) and 15 (Life on Land).

Taken together, the three core chapters of this thesis highlight the multifaceted relationship between trade diversification and sustainability. While developed countries tend to benefit from diversified imports and green innovations, developing countries face structural and environmental challenges in managing trade-related emissions. The combined findings underscore the need for targeted policies that promote cleaner technologies, responsible land use, and inclusive trade strategies. Crucially, the thesis demonstrates that economic complexity, when aligned with green energy practices and supported by institutional collaboration, can serve as a pathway to sustainable development.

While previous studies have examined the relationship between agricultural productivity and carbon emissions, this study explores land resources, agricultural exports, renewable energy,

and foreign investment in Brazil. The results indicate varied connections among these factors, necessitating tailored regulatory strategies for agricultural sustainability. Although exports and investments can boost economic development, their inefficient use exacerbates environmental challenges. To promote sustainable land development, multidimensional policies focusing on climate action and responsible land management are essential.

A Systematic Literature Review (SLR) could be a valuable avenue for future energy efficiency and import diversification research, offering a structured synthesis of existing studies to identify trends, gaps, and opportunities. By systematically reviewing global best practices, methodological approaches, and policy frameworks, an SLR can provide a solid foundation for evidence-based decision-making. This approach would enable future researchers to build upon established knowledge rather than duplicating efforts, ensuring that policymakers and industry leaders have access to comprehensive insights. Additionally, an SLR can highlight overlooked aspects of energy efficiency and diversification strategies, guiding future investigations toward innovative and impactful solutions.

System Generalized Method of Moments (Sys-GMM) is a valuable estimation technique for addressing endogeneity issues in panel data. However, its reliance on instrument selection can sometimes lead to weak instruments, affecting the robustness of results. As a limitation, researchers must carefully assess instrument validity to ensure reliable conclusions. Future research could explore alternative estimation methods or refine Sys-GMM approaches to improve accuracy and strengthen empirical findings. A key limitation of this study is that non-linearity tests of the econometric models were not conducted, which may affect the accuracy of capturing complex relationships within the data.

Endogeneity tests play a vital role in econometric studies, helping to detect biases caused by omitted variables or simultaneous relationships. If such issues arise, the reliability of the thesis's findings may be affected, necessitating alternative methods like instrumental variables to ensure accurate results. Acknowledging this limitation enhances the research's credibility and highlights the importance of rigorous methodological approaches in economic analysis.

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