Birokrasi: Jurnal Ilmu Hukum dan Tata Negara
Volume. 4, Nomor. 2, Juni 2026
e-ISSN: 2987-8632; p-ISSN: 2987-8624; Hal. 83-106
DOI: https://doi.org/10.55606/birokrasi.v4i2.2395
Tersedia: https://journal-stiayappimakassar.ac.id/index.php/Birokrasi

The Green Customs Initiative in the Context of Adaptive Policy: A Bibliometric Mapping of Past and Present Research

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Abstract. Amidst rising global pressure regarding sustainability and cross-border trade, customs agencies are no longer viewed merely as gatekeepers but as strategic actors in global environmental governance through the Green Customs Initiative (GCI). This research aims to uncover the evolutionary patterns of GCI research within the context of adaptive policy, map its intellectual structure, and identify future thematic directions. The methodology employs a bibliometric analysis of documents sourced from the Web of Science database, utilizing VOSviewer software to perform co-authorship, bibliographic coupling, and co-word analysis.The results demonstrate that the dominance of scientific actors in this field is determined more by the strength of collaboration networks than by the mere volume of publications. The findings identify that the primary intellectual foundations of GCI research rest upon the critical relationship between environmental regulation, international trade, market responses, and eco-innovation. Furthermore, country-level analysis highlights the central roles of China, the United States, and the United Kingdom in shaping the knowledge structure of this domain. Overall, these findings underscore that the GCI has evolved into a multidisciplinary field that requires an adaptive policy framework to respond to the dynamics of ecological risks and global trade demands through institutional flexibility and cross-actor collaboration. By integrating environmental protection into border management and risk assessment, this study provides a strategic reference for customs authorities to move toward a more responsive and knowledge-based green customs administration.

Keywords: Adaptive Policy; Bibliometric; GCI; International Trade; Vosviewer.

1. INTRODUCTION

Amidst rising global pressure regarding sustainability, cross-border trade, and the enforcement of environmental regulations, customs agencies are no longer viewed merely as gatekeepers of the flow of goods and state revenue, but also as strategic actors in global environmental governance (Stevenson, 2016). In this context, the GCI has emerged as an international partnership aimed at strengthening the capacity of customs and border protection authorities to facilitate legal trade and prevent the illegal trafficking of environmentally sensitive commodities, including hazardous waste, toxic chemicals, endangered species, and ozone-depleting substances (Cheng et al., 2019; Cung et al., 2021; Nair et al., 2020; Zhang et al., 2024; Zhao et al., 2019). Since its launch in 2004, the GCI has evolved as an umbrella for collaboration across international organizations and multilateral environmental agreements. Furthermore, the World Customs Organization (WCO) has designated green customs as one of the focus areas in its Strategic Plan 2022–2025, signaling that this issue is becoming increasingly central to global customs policy.

These developments have become even more important because transboundary environmental issues are dynamic, complex, and fraught with uncertainty. The illegal trade of wildlife, hazardous chemicals, waste, and other sensitive commodities does not occur in a static

Naskah Masuk: 09 Maret 2026; Revisi: 07 April 2026; Diterima: 05 Mei 2026; Tersedia: 13 Mei 2026

situation; the patterns, methods, actors, and regulatory pressures continue to change in line with market developments, technology, and international policies. In such situations, rigid policy approaches are often inadequate. Literature on adaptive policy asserts that effective policies under conditions of uncertainty must be designed to be adjustable as conditions change, new knowledge emerges, and unpredictable shocks occur (Kumar et al., 2023; Murphy et al., 2024; Page West & Gemmell, 2021). Accordingly, the adaptive governance approach emphasizes the importance of continuous learning, regular monitoring, broad participation, transparency, and iterative adjustments to decisions.

In this context, the GCI can be understood not only as a technical customs training program but also as a form of institutional arrangement that is relevant when read through an adaptive policy perspective. The GCI works through cross-agency coordination, the development of guidelines, training, capacity building, and information exchange to help border officials respond to changing threats of illegal trade and the demands of implementing multilateral environmental agreements. Its partnership structure involves various international organizations and treaty secretariats such as UNEP, WCO, INTERPOL, CITES, the Basel Convention, Rotterdam Convention, Stockholm Convention, Minamata Convention, OPCW, and other partners. This collaborative, gradual, and capacity-building-based character shows that the GCI has a strong overlap with the logic of adaptive policy, which demands flexibility, inter-agency coordination, and the ability to adjust policies in the face of changes in the strategic environment.

The main actors in this issue include customs administrations as front-line oversight executors, border officials as technical enforcement implementers, international organizations and MEA secretariats as providers of regulatory frameworks and normative support, and national governments as policy designers and providers of institutional support. The relationship among these actors determines the effectiveness of green customs enforcement, especially in terms of regulatory harmonization, information exchange, capacity development, and synchronization between trade facilitation goals and environmental protection. This is important because the GCI's official website itself asserts that customs and border protection officers are the first line of defense against illegal transboundary trade, making their capacity building a fundamental necessity in the chain of compliance and enforcement (Akhtar & Saha, 2020; Geng et al., 2019; Zhang et al., 2024).

The central concept in this research, the GCI, can be defined as an international partnership and institutional arrangement designed to strengthen the ability of customs apparatus to monitor legal trade as well as detect and prevent the illegal trade of commodities

regulated by multilateral environmental conventions and agreements. Meanwhile, the adaptive policy perspective emphasizes that policy should not be treated as a frozen final design, but rather as a tool that needs to be monitored, evaluated, and continuously adjusted according to changes in context. Thus, reading the GCI through the lens of adaptive policy allows researchers to understand how institutional capacity, policy learning, network coordination, and implementation flexibility interact in green customs governance.

Although the issues of green customs and adaptive governance are gaining more attention, the landscape of literature specifically linking the GCI with adaptive policy still appears scattered and has not been systematically consolidated. Preliminary searches indicate that publications on the GCI are still heavily dominated by institutional documents, implementation guides, policy reports, and studies that are contextual or limited to specific cases, while bibliometric studies mapping the intellectual structure, dominant themes, author networks, and the direction of research development at the intersection of GCI and adaptive policy are still very limited. On the other hand, scientometric studies on adaptive governance actually show that this field is developing rapidly, especially on the issues of flexibility, social learning, resilience, and environmental governance. This gap makes bibliometric mapping relevant, so that the development of knowledge in the field of GCI is not read in isolation like scattered puzzle pieces on a seminar floor.

Starting from these conditions, this research is motivated by the need to conduct science mapping of research developments concerning the GCI in the context of adaptive policy. Through a bibliometric approach, this research is directed to uncover patterns of knowledge development from the past to the present, identify dominant and emerging themes, and examine how the GCI is positioned in policy discourses that are adaptive, collaborative, and responsive to uncertainty. The main question driving this research is: how can bibliometric analysis reveal the patterns of research evolution concerning the GCI in the context of adaptive policy, both in terms of themes, intellectual structure, and future development directions.

More specifically, this research aims to: (1) identify clusters and major research flows regarding the GCI and adaptive policy through bibliographic coupling analysis; and (2) evaluate trends and the direction of future research theme development through a co-word analysis approach. Thus, this research is expected to provide a theoretical contribution by expanding the discussion on adaptive policy, adaptive governance, and transboundary environmental governance, while offering practical contributions for policymakers, customs authorities, and international organizations in designing green customs strategies that are more responsive, collaborative, and knowledge-based. Ultimately, an understanding of the

knowledge structure and evolution of themes in this field is expected to serve as a strategic reference for academics, customs authorities, and environmental policymakers. This article is structured with the following flow: the first part presents the introduction and research objectives; the second part explains the bibliometric methodology; the third part presents the results of mapping past and present themes; the fourth part discusses theoretical and practical implications; and the fifth part presents the conclusion, limitations, and future research agenda.

2. METHODOLOGY

Bibliometric approach

Bibliometric analysis is a quantitative technique used to examine bibliographic datasets through science mapping methods (Donthu et al., 2021). This approach is designed to offer a structured and comprehensive overview of a particular academic field. Compared to traditional methods such as meta-analysis and systematic literature reviews, it allows for the examination of a significantly larger body of literature. One of the advantages is minimizing researcher bias, as this technique does not require the exclusion of articles during the sampling stage (Fauzi, Nguyen, et al., 2023). This analytical framework consists of two primary components: performance analysis and science mapping (Noyons et al., 1999). While performance analysis focuses on measuring the academic impact of authors, journals, or institutions through publication and citation metrics, science mapping investigates the interconnections between these elements to reveal the intellectual structure of a field (Cucari et al., 2023; Donthu et al., 2023; Fauzi et al., 2025; Fauzi, Han, et al., 2023). In this study, bibliographic coupling and co-word analysis are applied to achieve the research objectives.

a. Bibliographic coupling is used to uncover both the current landscape and recent developments in a research area (Donthu et al., 2021). The method relies on the assumption that two documents citing the same references are likely to share thematic similarities (Rojas-Lamorena et al., 2022). The degree of overlap in their reference lists, known as bibliographic coupling strength, serves as an indicator of related research fronts (Hasumi & Chiu, 2022).
b. Co-word analysis explores conceptual relationships by identifying how frequently terms appear together in titles, keywords, or abstracts (Zupic & Čater, 2015). It assumes that clusters of co-occurring terms represent key thematic areas, and that high-frequency terms signal central or emerging topics in the literature (Jafari Roodbandi et al., 2022). The patterns formed by these co-occurrences assist scholars in identifying new trends and potential future directions within the field (Donthu et al., 2021).

Research design and data collection procedure

To gather relevant literature, a specific search query (see Table 1) was developed using carefully selected keywords related to pro-environmental behaviour, tourism, and related disciplines. The search was conducted within the Web of Science (WoS) database using the topic search (TS) function, which retrieves content from article titles, abstracts, and keywords. WoS is recognized for its reliability and comprehensiveness, encompassing over 21,100 peer-reviewed journals and having served the academic community for over four decades (Pranckutė, 2021; Zyoud et al., 2017). This study exclusively focuses on journal articles for their scholarly rigor and thorough peer-review standards. Other types of publications, such as books, book chapters, conference papers, editorials, and non-peer-reviewed materials, were deliberately omitted. The bibliometric analysis and visualization of the scientific network were carried out using VOSviewer version 1.6.20.

Table 1. Search string in WoS database.

No	Keywords	Justification
1	(custom* OR border* OR trade OR "trade facilitation" OR "trade regulation" OR enforcement) AND	Identify literature related to GCI
2	(environment* OR green OR sustainab* OR wildlife OR chemical* OR waste OR ozone) AND (policy OR governance OR regulation OR adaptation OR resilience OR flexibility OR "policy learning")	Identify literature related to policy adaptation

The Scopus database was searched on 7 March 2026. The number of documents after the first search was 1,029. After limiting to only journal publications, the number of publications was reduced to 909 (Figure 1). The total citations gathered during this period were 24,448 and 20,804 (without self-citations). With growing scholarly interest in the subject, the number of publications is expected to rise, potentially contributing to the advancement of science parks and university commercialization.

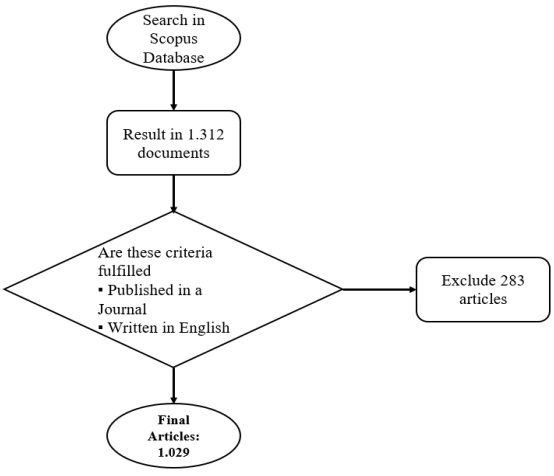

Figure 1. Flowchart the process of article selection.

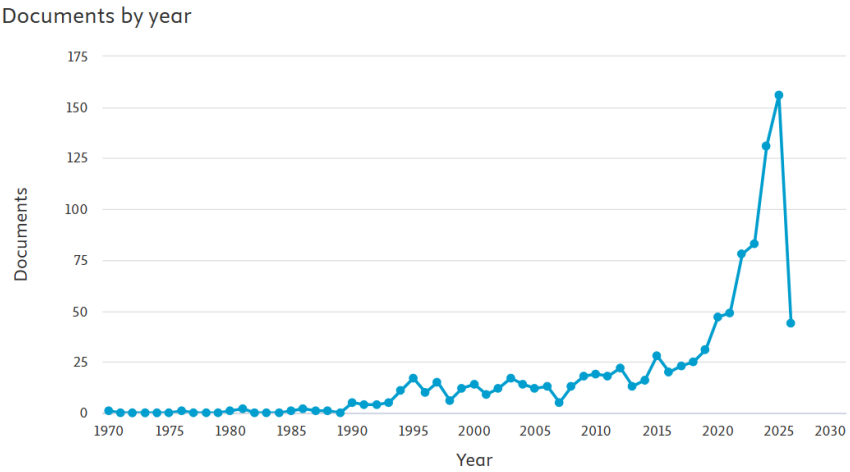

Figure 2. Number of publications and citations on GCI in the Context of Adaptive Policy.

Source: Web of Science, Authors' own work.

3. FINDINGS AND DISCUSSION

Findings

Co-authorship Network of Institutions

The institutional co-authorship network consists of 3,722 organizations. By applying a minimum threshold of 2 documents per organization and at least 4 citations per organization, 126 organizations were identified that met the analysis criteria. A higher number of publications and citations indicates greater institutional influence within the studied research field. Furthermore, Table 2 presents the organizations that have contributed to this field based on their publication output.

Table 2. Top 15 Institutional Collaborations in the GCI in the Context of Adaptive Policy.

Rank	Organization	Country	Documents	Citations	Total Link Strength
1.	School of Economics, Southwestern University of Finance and Economics	China	5	14	13
2.	Department of International Business, Tamkang University, New Taipei City	Taiwan	6	13	12
3.	Department of Accounting, Ming Chuan University, Taipei	Taiwan	4	9	11
4.	Department of Medical Research, China Medical University Hospital, China Medical University	Taiwan	3	88	6
5.	Department of Public Finance and Taxation, National Kaohsiung University of Science and Technology	Taiwan	2	2	6
6.	Adnan Kassar School of Business, Lebanese American University, Beirut	Lebanon	3	76	5
7.	Faculty of Economics, Administrative and Social Sciences, Nişantaşı University	Turkey	2	65	5
8.	School of Economics, Southwestern University of Finance and Economics	China	2	10	5

9.	Center for Energy and Environmental Policy Research, Beijing Institute of Technology	China	4	289	4
10.	Department of Economics, Division of Management and Administrative Sciences, University of Education, Lahore	Pakistan	2	8	4
11.	Faculty of Business and Economics, University of Narowal, Narowal	Pakistan	2	8	4
12.	Higher Education Department, Government of the Punjab, Lahore	Pakistan	2	8	4
13.	School of Management and Economics, Beijing Institute of Technology, Beijing	China	4	294	4
14.	Department of Banking and Finance, CTBC Business School, Tainan	Taiwan	2	2	3
15.	Department of Business Administration, ILMA University, Karachi	Pakistan	2	56	3

Source: Scopus, Authors' own work.

Based on the results of the institutional collaboration analysis, the School of Economics, Southwestern University of Finance and Economics (China) ranks first with 5 documents, 14 citations, and a total link strength of 13. This position indicates that the institution possesses the strongest network connectivity compared to other organizations in the dataset, identifying it as the most central institutional actor in the publication network for this theme.

In second place, the Department of International Business, Tamkang University, Taiwan, recorded 6 documents, 13 citations, and a total link strength of 12. Although its document count is slightly higher than the top rank, it sits below because its collaborative relationship strength within the network is still slightly lower. This demonstrates that institutional dominance is determined not only by the volume of publications but also by the intensity of connectivity with other institutions. Furthermore, the Department of Accounting, Ming Chuan University, Taiwan, ranks third with 4 documents, 9 citations, and a total link strength of 11. This institution shows a fairly strong contribution, particularly in terms of consistent involvement in the research network, despite having lower publication output and citations than the two ranks above.

Overall, these top three institutions illustrate that dominance within the organizational network is driven more by central roles in scientific collaboration than by citation counts alone. Consequently, they can be regarded as the primary drivers in shaping the knowledge structure in this field, significantly advancing institutional collaboration within research on the GCI.

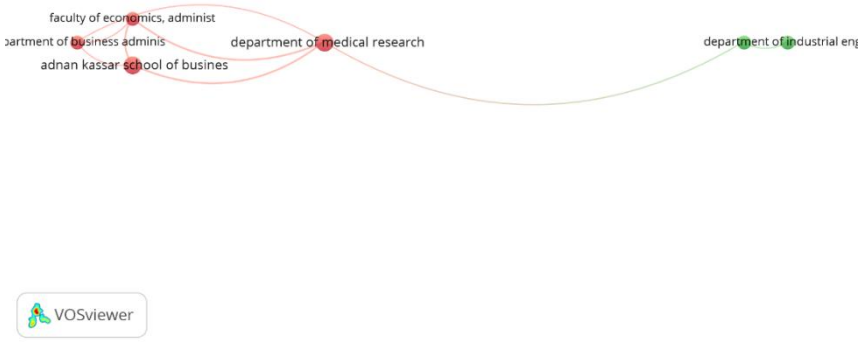

Figure 3. Network visualization of universities' published papers on in the GCI in the Context of Adaptive Policy.

Source: VOSviewer, Authors' own work.

Co-authorship Network of Countries

Based on the analysis settings in VOSviewer, the minimum number of documents per country was set at 4, while the minimum number of citations per country was set at 1. Out of a total of 112 countries identified in the data, 53 countries met these thresholds and were included in the further analysis. Table 3 shows that China dominates research publications on the GCI within the context of adaptive policy with 246 documents, 6,470 citations, and a total link strength of 140, followed by the United States and the United Kingdom, confirming the strong contribution of these countries in shaping the network and scientific impact in this field.

Table 3. Publishing Countries in Research on the GCI in the Context of Adaptive Policy.

Rank	Country	Documents	Citations	Total Link Strength
1.	China	246	6470	140
2.	United States	198	5191	96
3.	United Kingdom	88	4048	77
4.	Pakistan	32	1005	55
5.	India	77	1148	45
6.	Australia	45	1196	44
7.	Canada	45	933	41
8.	Indonesia	36	261	37
9.	Turkey	23	900	37
10.	Germany	44	773	34
11.	Spain	24	494	33
12.	France	25	503	31
13.	Malaysia	19	234	30
14.	Saudi Arabia	17	340	29
15.	Taiwan	24	459	29

Source: The author's view is based on the findings derived from the analysis using VOSviewer.

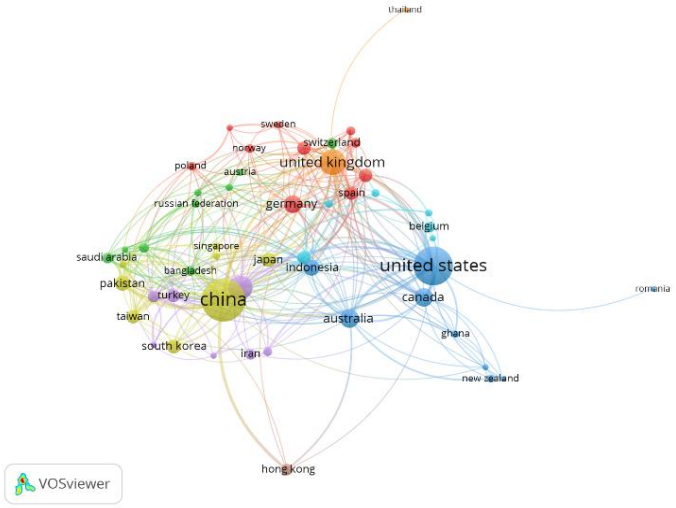

Figure 3. Network Visualization of Publishing Countries in Research on the GCI in the Context of Adaptive Policy.

Source: VOSviewer, Authors' own work.

Bibliographic coupling

The initial stage of this analysis was conducted by establishing appropriate citation thresholds to ensure a reliable and meaningful visualization of the network structure. Out of a total of 1,459 documents, 139 met the criteria with a minimum of 23 citations. Several iterations were performed to test various thresholds before finally determining the most optimal network map. Setting a balanced threshold is crucial; if set too high, important clusters may potentially be excluded, whereas if set too low, the emerging clusters can become overly dense and overlapping, thereby reducing the clarity of the visualization. Consequently, this study highlights the most cited publications in this field (see Table 4). Subsequently, these 139 selected documents were used to map the primary thematic groups representing the current discourse on the GCI within the context of adaptive policy.

Table 4. Top 10 documents in bibliographic coupling analysis.

No	Author	Journal	Scope	Citation	TLS
1.	(Cole & Elliott, 2004)	World Economy	Do environmental regulations influence trade patterns? Testing old and new trade theories	135	15
2.	(Cole et al., 2010)	Ecological Economics	Trade, environmental regulations and industrial mobility: An industry-level study of Japan	154	12
3.	(Cole & Elliott, 2003)	Journal of Environmental Economics and Management	Determining the trade-environment composition effect: The role of capital, labor and environmental regulations	688	9
4.	(Costantini & Mazzanti, 2012)	Research Policy	On the green and innovative side of trade competitiveness? the impact of environmental policies and innovation on EU exports	436	8

5.	(J. Xu et al., 2016)	Journal of Cleaner Production	A two-echelon sustainable supply chain coordination under cap-and-trade regulation	241	7
6.	(Copeland, 1994)	Journal of Environmental Economics and Management	International trade and the environment: Policy reform in a polluted small open economy	171	5
7.	(X. Xu et al., 2017)	International Journal of Production Economics	Supply chain coordination with green technology under cap-and-trade regulation	522	4
8.	(Kammerer, 2009)	Ecological Economics	The effects of customer benefit and regulation on environmental product innovation. Empirical evidence from appliance manufacturers in Germany	547	4
9.	(Li et al., 2023)	Renewable Energy	Role of renewable energy and fiscal policy on trade adjusted carbon emissions: Evaluating the role of environmental policy stringency	188	3
10.	(Kellenberg, 2009)	Journal of International Economics	An empirical investigation of the pollution haven effect with strategic environment and trade policy	289	3

Source: The author's view is based on the findings derived from the analysis using VOSviewer.

Figure 4 displays the network visualization generated through bibliographic coupling analysis. The visualization reveals four clusters, represented by red, green, blue, and yellow. These clusters were labelled through an inductive process by re-examining key representative articles within each group. The labels were then derived by synthesizing recurring topics and thematic patterns that characterize the main research directions within each cluster.

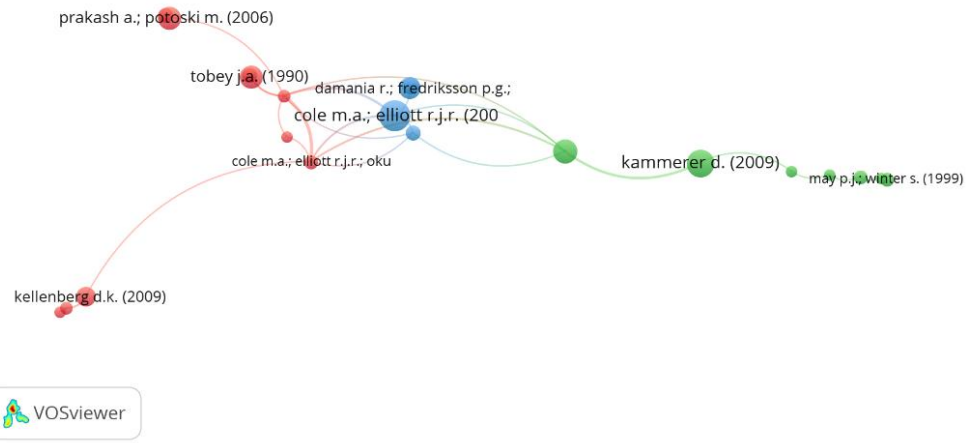

Figure 4. Network visualization of bibliographic coupling.

Source: VOSviewer, Authors' own work.

Environmental Regulation, Trade, and Market Responses

Cluster 1 (red), labeled Environmental Regulation, Trade, and Market Responses, comprises 10 publications and represents a theme highlighting the interconnectedness between environmental regulations, trade dynamics, and the responses of market actors to increasingly adaptive policy pressures. This group indicates that the scientific discourse within the cluster centers on how regulatory instruments and environmental standards influence economic behavior, competitiveness, and cross-border trade patterns. Consequently, environmental issues are no longer viewed merely as obstacles, but as strategic factors in market adjustment and global trade governance. This direction of discussion is reflected in representative publications such as (Cole et al., 2010; Kellenberg, 2009; A. Prakash & Potoski, 2006; Tobey, 1991), which collectively demonstrate strong academic attention to the relationship between environmental policy and economic response within the framework of international trade.

Compliance, Eco-Innovation, and Environmental

Cluster 2 (green), labeled Compliance, Eco-Innovation, and Environmental Management, consists of 7 publications and represents a theme focused on regulatory compliance, environmentally friendly innovation, and environmental management practices within organizations and industries. This cluster demonstrates that adaptive policy demands more than just formal compliance with rules; it also drives the emergence of eco-innovation as a strategic response to enhance organizational efficiency, reputation, and sustainability. In other words, environmental policy within this cluster is understood as a driver for institutional behavioral change, whether through monitoring mechanisms, innovation incentives, or the strengthening of managerial capacity in handling environmental issues. This direction is reflected in representative works such as (Kammerer, 2009; Winter, 2003), which collectively underscore the importance of integrating compliance, innovation, and environmental management in responding to increasingly dynamic policy demands.

Theoretical Foundations of Trade and Environmental Policy

Cluster 3 (blue), labeled Theoretical Foundations of Trade and Environmental Policy, includes 4 publications and illustrates the conceptual foundations explaining the relationship between international trade and environmental policy. This cluster is more theoretical in nature, as it examines how policy instruments, economic incentives, and regulatory frameworks influence the interaction between trade interests and environmental protection. In the context of adaptive policy, this cluster is vital because it provides the analytical groundwork for understanding why states, markets, and economic actors respond differently to environmental policies, depending on incentive structures and institutional conditions.

These theoretical contributions are evident in the works of (Damania et al., 2003; Elliott, 2010; Fredriksson, 1999). Which collectively strengthen the understanding of the political-economic logic behind the formulation and implementation of environmental policies within the global trading system.

A Summary of the bibliographic coupling analysis is presented in Table 5.

Table 5. Bibliographic coupling analysis.

Cluster no (color)	Cluster label	Number of publications	Representative publication
1 (red)	Environmental Regulation, Trade, and Market Responses	10	(Bacon et al., 2023; Cole et al., 2010; Cole & Elliott, 2004; Costantini & Mazzanti, 2012; Dechezleprêtre et al., 2015; Lovely & Popp, 2011; K. Prakash & Prakash, 2024; Tobey, 1990; Van Beers & Van Den Bergh, 2003)
2 (green)	Compliance, Eco-Innovation, and Environmental Management	7	(Costantini & Mazzanti, 2012; Kammerer, 2009; Kroes et al., 2012; Lo et al., 2006; May & Winter, 1999)
3 (blue)	Theoretical Foundations of Trade and Environmental Policy	4	(Cole & Elliott, 2003; Copeland, 1994; Damania et al., 2003; Ulph, 1996)

Source: The Authors' own work.

Co-word Analysis

Out of a total of 5,485 identified keywords, co-word analysis shows that 60 keywords exceeded the minimum occurrence threshold of 20 and were subsequently used in the thematic network mapping. This co-word analysis procedure was conducted by selecting keywords that appear simultaneously in the titles, abstracts, and keywords across the entire dataset. The clustering process was performed using VOSviewer, with several iterations of minimum thresholds tested to generate a robust and meaningful network visualization. These thresholds were adjusted through a series of trials until the most optimal network map was obtained, ensuring that the resulting clusters truly represent the critical and dominant themes within the field of study.

The three clusters emerging from the co-word analysis are: 1) Trade–Environmental Regulation and Adaptive Policy Enforcement, 2) Sustainability, Emission Control, and Decision-Making in Trade Governance, 3) Green Economy, Trade Openness, and Policy Transformation. These three clusters are closely linked to the research objective of understanding the intellectual structure of the GCI within the context of adaptive policy. The first cluster emphasizes the vital link between international trade, environmental protection, and regulatory enforcement, reflecting the GCI's position as a transboundary governance mechanism at the intersection of trade policy and environmental compliance.

The second cluster highlights the dimension of sustainability and the importance of adaptive decision-making, particularly in balancing trade facilitation, economic efficiency, and environmental protection. Meanwhile, the third cluster illustrates the broader macro-context the transformation toward a green economy, trade openness, and innovation which shapes the need for a customs system that is more responsive to the global sustainability agenda.

The top fifteen keywords from the co-word analysis are presented in Table 6. The keywords with the highest frequency of occurrence are "environmental policy" (178 occurrences), "sustainable development" (145 occurrences), and "commerce" (131 occurrences). In addition to their high frequency, these keywords also demonstrate strong total link strength 770, 644, and 752, respectively indicating their central position within the structure of research themes. These findings show that the primary direction of research regarding the GCI in an adaptive policy context remains centered on environmental policy, sustainable development, and trade issues, while simultaneously identifying critical areas for further development in future research.

Table 6. Top 15 keywords.

Rank	Keyword	Occurrences	Total link strength
1.	environmental policy	178	770
2.	commerce	131	752
3.	sustainable development	145	644
4.	china	109	553
5.	environmental protection	98	513
6.	international trade	117	464
7.	trade policy	109	448
8.	environmental economics	81	419
9.	sustainability	105	387
10.	article	49	355
11.	carbon emission	58	332
12.	carbon	49	317
13.	emission control	46	310
14.	environmental regulations	73	304
15.	trade-environment relations	59	297

Source: Authors' own work.

As presented in Figure 5, the illustration of the network structure from the co-word analysis yielded four clusters. These clusters were subsequently assigned appropriate labels based on the author's interpretation through a qualitative analysis of the representative keywords appearing within the network map.

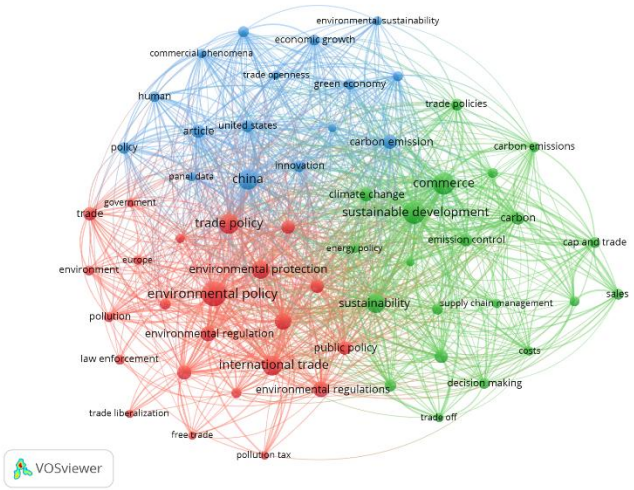

Figure 5. Network visualization of co-word analysis.

Source: Authors' own work.

Trade-Environmental Regulation and Adaptive Policy Enforcement

Cluster 1 contains keywords such as environment, environmental policy, environmental protection, environmental regulation, public policy, regulatory framework, law enforcement, government, international trade, trade policy, export, free trade, and European Union. This cluster can be interpreted as a theme highlighting the relationship between international trade, environmental protection, and public regulatory frameworks. In the context of the GCI, this cluster is highly relevant because the GCI essentially operates at the intersection of trade policy, environmental monitoring, and transboundary law enforcement. From an adaptive policy perspective, this cluster indicates that environment-oriented trade monitoring requires regulatory frameworks that are flexible, responsive, and capable of adjusting to changes in environmental risks, global trade patterns, and international law enforcement demands.

Sustainability, Emission Control, and Decision-Making in Trade Governance

Cluster 2 includes keywords such as sustainability, sustainable development, climate change, carbon emissions, emission control, environmental management, environmental technology, supply chain management, supply chains, decision making, trade policies, costs, and trade-off. This cluster represents the theme of environmental sustainability and policy decision-making within trade systems and supply chains. Within the GCI framework, this cluster relates to the efforts of customs and border authorities to not only monitor the flow of goods but also ensure that international trade does not exacerbate environmental degradation, carbon emissions, or practices contrary to the principles of sustainable development. From an adaptive policy perspective, this cluster emphasizes the importance of adaptive decision-

making when facing trade-offs between trade facilitation, cost efficiency, economic interests, and environmental protection goals.

Green Economy, Trade Openness, and Policy Transformation

Cluster 3 contains keywords such as green economy, economic growth, economic development, trade openness, environmental sustainability, innovation, alternative energy, carbon emission, China, and the United States. This cluster can be understood as a theme highlighting the transformation toward a green economy in the context of economic growth and global trade openness. In relation to the GCI, this cluster reflects the macro-context shaping the need for a greener customs system—namely, the increasing global pressure to balance economic growth, international trade, and environmental sustainability. The adaptive policy perspective in this cluster is evident in the need for nations and institutions to continuously adjust trade policies and cross-border monitoring to align with the green economy agenda, technological innovation, and shifting international development priorities.

Overall, these three clusters indicate that the theme of the GCI in the context of adaptive policy is currently connected to three major axes: 1) Trade-environmental regulation and enforcement, 2) Sustainability and policy decision-making, 3) The green economy and global trade transformation. However, as the terms that emerged are still quite general, these results are more accurately interpreted as a conceptual foundation adjacent to the GCI, rather than a fully specific representation of "green customs." In other words, this map has "entered the orbit" of the topic but has not yet fully landed on the specific GCI terrain. This cluster underscores the importance of structured support mechanisms and innovation capacity in shaping the life cycle of entrepreneurial ventures. Table 7 presents the results of the co-word analysis organized by cluster labels and representative keywords.

Tabel 7. Co-word Analysis by Cluster.

Cluster no (color)	Cluster label	Number of keywords	Representative Keywords
1 (red)	Regulatory Enforcement and Trade–Environment Governance	23	environmental policy, environmental protection, environmental regulation, law enforcement, regulatory framework, international trade, trade policy
2 (green)	Sustainability Management and Adaptive Trade Decision-Making	21	sustainability, sustainable development, climate change, emission control, decision making, supply chain management, cap and trade
3 (blue)	Green Economy, Trade Openness, and Policy Transformation	16	green economy, economic growth, trade openness, environmental sustainability, innovation, alternative energy, policy

Discussion

The results of the institutional co-authorship analysis demonstrate that organizational dominance in the study of the GCI within the context of adaptive policy is not solely determined by the number of documents or citations, but also by the strength of inter-institutional connectivity within the collaboration network. The top-tier positions of the School of Economics, Southwestern University of Finance and Economics, alongside institutions from Taiwan, confirm that collaborative centrality is a vital factor in shaping the knowledge structure of this field. This finding can be explained through Social Network Theory, which posits that actors in more central positions within a network have greater access to information flows, resource exchanges, and opportunities to shape the research agenda (Appelbaum, 1997; Ding et al., 2024; Khaidir, 2013; Vilkaite-Vaitone, 2024). In this context, total link strength serves as an important indicator of an institution's capacity to act as a knowledge hub. This finding also aligns with the notion of epistemic communities, suggesting that policy knowledge production is often concentrated in institutions possessing high academic capacity, international networks, and proximity to strategic policy issues. Thus, institutional contribution to the GCI field appears to be determined more by the quality of scientific connectivity than by mere publication output.

At the country level, the dominance of China, followed by the United States and the United Kingdom, indicates that the GCI research landscape within an adaptive policy context remains heavily influenced by countries with high research capacity and strategic positions in global trade. China's dominance—with 246 documents, 6,470 citations, and a total link strength of 140—signals that trade-environment issues are developing robustly in a country facing simultaneous pressures of economic growth, industrialization, and sustainability demands. This finding is consistent with research (Killmer, 2000; Prinajati & Pratiwi, 2022). Showing that environmental policy, renewable energy, and cap-and-trade mechanisms are increasingly becoming part of trade discourse and modern economic governance. Theoretically, these results can be understood through policy diffusion theory and adaptive governance, which explain that countries with higher institutional capacity tend to be pioneers in responding to global environmental pressures, subsequently serving as a reference for others. The emergence of Pakistan, India, Indonesia, and Turkey in this network also shows that GCI discourse is beginning to expand into developing nations, although their scientific influence is not yet as strong as that of the core countries.

The results of bibliographic coupling show that the primary intellectual foundation of this field is built upon the relationship between environmental regulation, international trade, and market response. The "Environmental Regulation, Trade, and Market Responses" cluster confirms that the primary focus of the literature lies on the question of whether environmental regulation weakens competitiveness or, conversely, drives more innovative economic adjustments. This finding is highly aligned with classic works (Cole & Elliott, 2004; Copeland, 1994; Tobey, 1990). Which consistently discuss the interaction between environmental policy and trade dynamics. From a theoretical standpoint, this cluster can be read through the debate between the pollution haven hypothesis and the Porter hypothesis. The first hypothesis explains that strict regulation can drive industrial relocation to countries with laxer environmental standards, while the second hypothesis emphasizes that regulatory pressure can trigger innovation and efficiency. In the context of GCI, these findings indicate that green customs systems are not merely instruments of administrative control, but are part of a strategic arena that influences market behavior, trade flows, and cross-border economic adaptation.

Finally, the findings of the co-word analysis reveal that the conceptual map of the research is still dominated by general keywords such as environmental policy, commerce, sustainable development, international trade, and environmental regulation. This means that GCI research in an adaptive policy context currently still relies on the broader orbit of trade-environment relations, sustainability, and the green economy, but has not yet fully evolved into a highly specific discourse regarding green customs governance. Clusters on "Regulatory Enforcement and Trade–Environment Governance," "Sustainability Management and Adaptive Trade Decision-Making," and "Green Economy, Trade Openness, and Policy Transformation" show that this field of study is multidisciplinary and closely tied to the adaptive policy agenda. Theoretically, this affirms the relevance of the adaptive policy framework, which emphasizes institutional flexibility, continuous learning, and the ability to adjust policies to changes in risk and global context. Thus, this research indicates that the future of GCI studies needs to move from a still general macro-discourse toward more specific studies regarding customs institutions, cross-border enforcement mechanisms, inter-actor coordination, and institutional capacity in responding adaptively to green trade challenges.

The second and third clusters in the bibliographic coupling further deepen the understanding that GCI issues do not end at the macro-trade level but also reach the organizational level and theoretical policy foundations. The Compliance, Eco-Innovation, and Environmental Management cluster shows that compliance with environmental regulations is increasingly understood as an adaptive process that can yield innovation, efficiency, and

competitive advantage. This is supported by (Costantini & Mazzanti, 2012; Kammerer, 2009; Lo et al., 2006; May & Winter, 1999), who assert that policy pressure can drive organizations to develop eco-innovation and more mature environmental management practices. Meanwhile, the Theoretical Foundations of Trade and Environmental Policy cluster reveals that the field remains grounded in political-economic explanations regarding incentives, regulation, and actor behavior, as seen in (Copeland, 1994; Damania & Fredriksson, 2003; Ulph, 1996). Theoretically, these results are close to Institutional Theory and Ecological Modernization Theory, both of which explain that regulatory pressure produces not only formal compliance but also institutional transformation and continuous policy learning.

The co-word analysis findings ultimately show that the research conceptual map is still dominated by general keywords such as environmental policy, commerce, sustainable development, international trade, and environmental regulation. This means that research on the GCI within the context of adaptive policy currently still relies on the broad orbit of trade-environment relations, sustainability, and the green economy, but has not yet fully developed into a highly specific discourse on green customs governance. Clusters on Regulatory Enforcement and Trade–Environment Governance, Sustainability Management and Adaptive Trade Decision-Making, and Green Economy, Trade Openness, and Policy Transformation show that this field of study is multidisciplinary and very closely aligned with the adaptive policy agenda.

Theoretically, this affirms the relevance of the adaptive policy framework, which emphasizes institutional flexibility, continuous learning, and the ability to adjust policies to changes in risk and global context. Consequently, this research indicates that the future of GCI studies needs to move from a still-general macro-discourse toward more specific studies on customs institutions, cross-border enforcement mechanisms, inter-actor coordination, and institutional capacity in responding adaptively to green trade challenges.

4. STUDY IMPLICATIONS AND LIMITATION

Theoretical Implications

This research contributes theoretically by demonstrating that the GCI lacks a singular, consolidated theoretical core, evolving instead through the intersection of environmental policy, international trade, and adaptive governance. By utilizing co-authorship, bibliographic coupling, and co-word analysis, the study reveals GCI as a multidimensional governance issue—rather than a mere technical customs tool—that requires an adaptive policy framework to navigate the complexities and uncertainties of global trade and ecological risks. Furthermore,

the findings highlight that the intellectual landscape of GCI is shaped by social and institutional networks, where scientific influence is driven by collaborative centrality and institutional capacity, ultimately advocating for a more integrated conceptual framework that links adaptive governance with cross-border customs systems and environmental regulation.

Managerial Implications

The results of this research provide several vital implications for policymakers and customs authorities, emphasizing that environmental protection must no longer be a peripheral concern but a core component integrated into border management, risk assessment, and daily operational procedures. The study highlights that successful implementation of the GCI depends on robust cross-border collaboration and strategic knowledge exchange, urging developing nations to strengthen their organizational capacity to engage with dominant global research hubs. Furthermore, the focus on sustainability and adaptive decision-making underscores the need for a shift from rigid administrative routines to flexible, data-driven management practices, including scenario planning and continuous institutional learning, to effectively navigate the complexities of evolving ecological risks and global trade pressures.

This research has several limitations, starting with its reliance on a single database, Web of Science, which may not capture all relevant publications indexed in Scopus, Dimensions, or institutional reports, thereby representing an indexed scientific perspective rather than the entire GCI knowledge landscape. Additionally, bibliometric methods map structural patterns and intellectual connections but do not directly assess the substantive quality or practical effectiveness of the analyzed studies, meaning these results should be viewed as a structural overview rather than empirical evidence of policy implementation success. Finally, the visualization outcomes are sensitive to the chosen thresholds and keywords in VOSviewer, where different settings could yield varying thematic emphases, and the prevalence of general keywords suggests the field still orbits broad trade-environment discourses. Consequently, future research should combine multiple databases and integrate longitudinal bibliometric approaches with qualitative or empirical studies to achieve a more specific and contextualized understanding of green customs governance.

5. CONCLUSION

Research on the GCI within the context of adaptive policy is developing as a multidisciplinary field that remains strongly intersected with major themes such as environmental regulation, international trade, sustainability, and adaptive governance. The results of the co-authorship analysis show that the dominance of scientific actors is determined

more by the strength of collaboration networks than by the mere number of publications, while the country-level analysis highlights the central roles of China, the United States, and the United Kingdom in shaping the knowledge structure of this field. Furthermore, bibliographic coupling confirms that the primary intellectual foundations of GCI research rest upon the relationship between environmental regulation, trade, market response, compliance, and eco-innovation, while co-word analysis indicates that the direction of research themes still orbits the broader trade–environment discourse and has not yet fully crystallized into a highly specific domain for green customs. Overall, these findings underscore that the GCI must be understood not merely as a technical customs instrument, but as a component of adaptive governance that demands institutional capacity, cross-actor collaboration, and policy flexibility in responding to global trade dynamics and environmental sustainability requirements.

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