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Brewing a sustainable future: a firm-level analysis of sustainability initiatives in the coffee sector

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Abstract
The coffee industry has long relied on third-party certification as their approach to sustainability, driven by customer demand and changing consumer behavior. Today, multiple forms of sustainability engagement have developed in the industry. This study uses a machine learning approach to analyze the engagement in sustainability initiatives of 100 firms active in the German market. Results reveal that company size and value chain position influence choice and engagement intensity in sustainability initiatives. A complementary literature analysis on policy recommendations to promote sustainability engagement in the coffee industry revealed a fragmented and insufficiently granular picture to address the diverse needs of stakeholders. While company characteristics significantly influence their choice of sustainability initiatives, policymakers often adopt generic approaches that do not reflect these nuances. Future research could extend this approach to deepen understanding or validate findings of policies for sustainable transformation in the coffee sector to other critical crops.

Keywords Sustainable coffee value chains · Sustainability initiatives · Sustainability policy · Web crawling · Machine learning

1 Introduction

Coffee is undergoing a sustainability crisis (Panhuysen and Pierrot 2020; Barreto Peixoto et al. 2023) due to the weak economic, social, and environmental practices of the industry, leading to problems, such as low and volatile prices, child labor, inadequate living conditions, lack of access to education, nutrition, sanitation, water, health services, and deforestation (Pinstrup-Andersen and Cheng 2007; Hadiyan 2021; SSC et al 2019; Bager and Lambin 2020). Moreover, climate change will progressively impact the yield in the future (Gebhart 2018; Wagner et al. 2021). Governments and industry players have sensed the situation's urgency and begun to implement countermeasures, such as policies that hold value chain actors accountable for their environmental and social impacts in the coffee sector (van Zanten and van Tulder 2018), e.g., the EU deforestation regulation (EUDR; European Union 2023; European Commission 2023), the EU Corporate Sustainability Due Diligence Directive (CS3D; European Commission 2024). Further, regulations on sustainability reporting, such as the Corporate Sustainability Reporting Directive (CSRD) and the EU Taxonomy, will make transparent and detailed disclosures mandatory for larger companies (European Union 2022). The EU is postponing the implementation of the CRSD and CSDDD to ease the compliance burden on companies, especially small and medium size enterprises, by giving time to adjust to the rules and requirements. The changes proposed in the so-called "omnibus package" aim to simplify requirements, reduce reporting scope and companies

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affected significantly and to finalize updated sustainability reporting standards (European Commission 2025).

Customers are increasingly aware of and willing to pay for sustainability features in coffee for different reasons (van Loo et al. 2015; Ut-tha et al. 2021; Valenciano-Salazar et al. 2021; Fuller et al. 2022). Therefore, the private sector heavily invests in sustainability initiatives, with certification and verification constituting the largest share, approximately 60% (Steemers 2016). In 2022, approximately 55% (not adjusted for multiple certifications) of global coffee production was certified (CBI 2021). However, due to limited demand, only about a quarter of certified coffee is marketed as such, limiting the benefits to producers and especially smallholder farmers (CBI 2021; Bitzer et al. 2008; Bager and Lambin 2020; Panhuysen and Pierrot 2020). Furthermore, industry actors and scientists raise concerns about whether third-party certification increases sustainable practices in the coffee sector. Consequently, industry players have redefined what sustainability means to them and their stakeholders through innovative governance approaches and beyond rule-based approaches (Grabs 2017; Thorlakson et al. 2018; Grabs and Garrett 2023).

During this phase of realignment in the sector, goal-based governance initiatives (e.g., *science-based targets initiative* (Grabs and Garrett 2023)) and firm-led initiatives (e.g., projects within local communities) have gained popularity (Grabs 2017). Researchers have warned against solely focusing on higher quality and premium segments and recommend policymakers to shape markets. Thus, it is essential to critically study both the developments and shortcomings in this area (Grabs 2017; Bozzola et al. 2021).

This paper aims to fill that gap by providing an in-depth characterization of the sustainability initiatives applied in the coffee value chain, focusing on traceability (Sun et al. 2017; Gaspar et al. 2022; Zhou et al. 2022).

It targets two main research questions:

- RQ 1: Which sustainability initiatives are applied within the coffee value chain, and how do company characteristics influence these choices?
- RQ 2: Which policy recommendations can be derived for different types of companies?

This paper's contributions are threefold. First, it analyzes the application of private and third-sector sustainability initiatives in the coffee sector at the firm level. Second, it derives policy recommendations for different company sizes and roles (Exporter, Trader, Roaster). Third, it applies an innovative methodological approach to data collection and processing through combining web crawling, content analysis, and machine learning. The focus is on a sample of companies operating in Germany, which ranks fifth in global coffee revenues with an annual turnover of € 21 billion (Statista 2024).

2 Methods

2.1 Research procedure

The research procedure followed an iterative approach in five steps. First, we located sustainability initiatives and their stakeholders in the coffee value chain. It provided the basis for the machine learning approach conducted for research question 1. In the second step, a structured literature review following the PRISMA logic (Page et al. 2021) was conducted to identify measures and programs relevant for policymakers aiming to support the advancement of sustainability initiatives in the coffee value chain with target-group specific approaches in response to research question 2 (Fig. 1).

2.2 Machine learning approach

The machine learning approach extracted information from publicly available data (cf. Sect. 2.1). Since companies communicate their sustainability initiatives through publicly available resources, such as reports and websites (Bager and Lambin 2020), web crawling was selected as a practical and innovative approach to gathering information. It allows the extraction of information from the Web for analysis (Khalil and Fakir 2017) and can process multi-modal inputs (Ceri et al. 2013). Initiated by parsing the content of an initial uniform resource locator (URL), further linked URLs were subsequently processed to gather their contents (Manning et al. 2009). The maximum number of links from the initial URL that the crawler included was set to 15, according to empirical research and practitioners' rule of thumb (Bozzola et al. 2021; Amazon Web Services 2023).

A total of 107 companies, 86 of which were exporters, 11 traders, and 28 roasters, were sampled, focusing on the German coffee end-consumer market. In addition to the described web crawling using the tool Sitesucker (Version 5.1.7), we manually extracted company characteristics and downloadable reports.

All inputs were merged into one document per company and analyzed. An unsupervised machine learning algorithm was employed to cluster the company data into groups. The implementation followed a four-step process combined with two common ML implementation approaches, depicted in Fig. 2.

Our approach builds upon CRISP-ML (Visengeriyeva et al. n.d.). Since the CRISP-ML does not contain a sampling step, it was added from the SEMMA method (Brocklebank et al. 1998) to form the complete process. The sampling was conducted using snowball sampling,

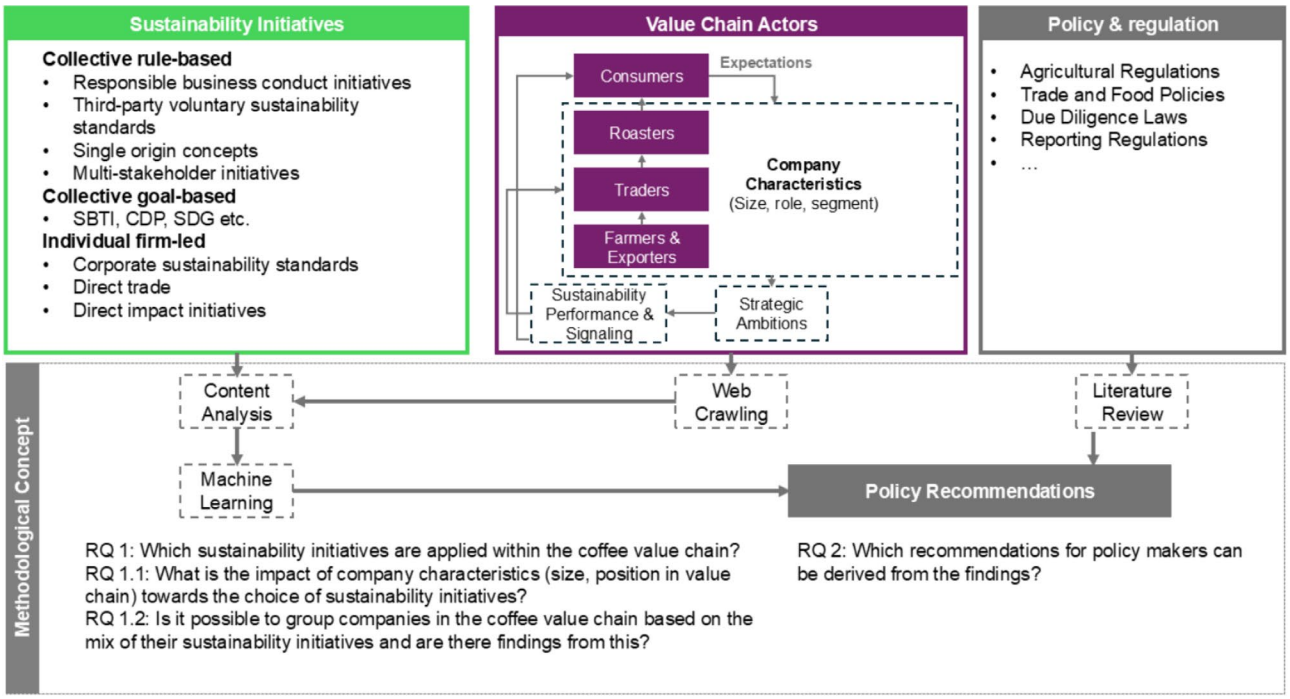


Fig. 1 Research procedure

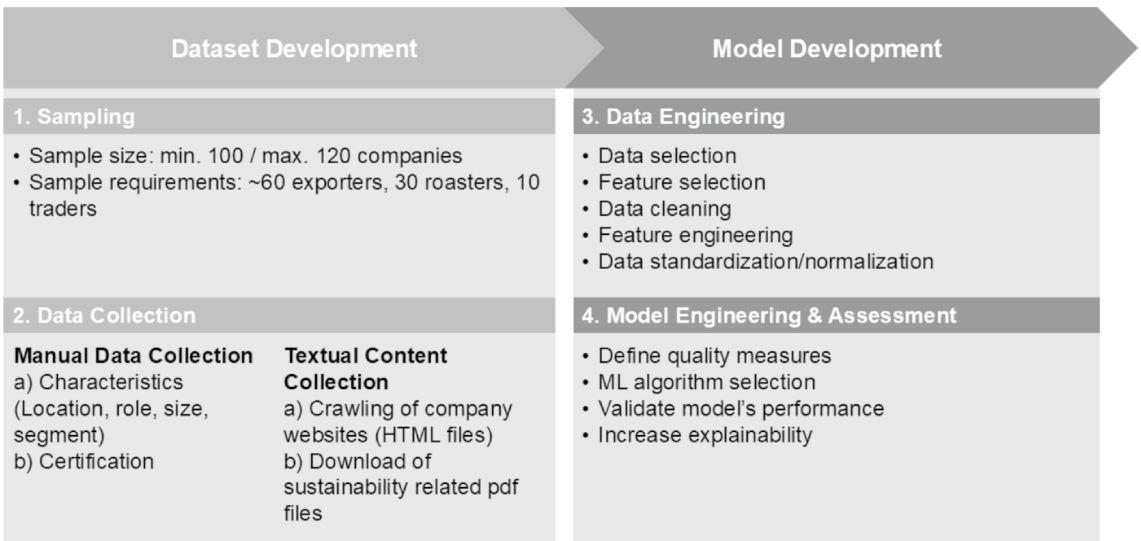


Fig. 2 Implementation procedure

among roasters and traders listed in industry and scientific publications (Ferro and Groothuis 2024; Hutz-Adams and Muerlebach 2020; Grabs and Carodenuto 2021). Exporting companies, national and international coffee organizations, NGOs, and other sector-specific organizations and media were identified using another snowballing approach, analogous to Bager and Lambin (2020). Packaging companies, equipment sellers, and local producers without exporting businesses were excluded; the main company represented subsidiaries. The main part of the sampling was performed in June 2023. Data engineering includes selecting features, data cleaning, and feature engineering (Visengeriyeva et al. n.d.). The term "feature" in the context of machine learning refers to "an attribute plus its value (e.g. mileage = 15.000)" (Geron 2019). Features were defined through keywords to detect features within the textual content

through analysis. The overview of feature and related key words is provided in the annex (Fig. 5). The web crawling application yielded a pandas DataFrame, describing the distribution of features in the sample.

To facilitate the exertion of the machine learning algorithm, data were scaled through consecutive normalization and standardization. We performed unsupervised clustering, which finds a structure in the data without a prior definition of classes. *K*-means clustering was chosen to allow for higher degrees of freedom in the model and a closer projection of the model structure to the data (Geron 2019; Jain et al. 1999) and as it is preferential to ensure a high degree of homogeneity within the clusters (Halkidi et al. 2001). The "elbow-method" was employed to determine the optimal number of clusters, resulting in four clusters (Kaloyanova 2021).

2.3 Literature review

The literature review followed a structured approach guided by predefined research questions. It addresses the second research question, which aims to elucidate how policy interventions can be more effectively tailored to specific groups of stakeholders within the coffee value chain. Three search strings (c.f. Fig. 3) were developed and validated for their efficacy in identifying relevant studies. The search strings were then subsequently applied in three different databases, *Google Scholar*, *Scopus*, and *DuckDuckGo*.

Results were checked for duplicates and the relevance of the article title and abstract. The eligibility criteria required the articles to be written in English and focus on a globally oriented geographical scope, i.e., they must not deal solely with a niche market or stakeholders not participating in global trade. The article was also required to make explicit recommendations to private or public decision-makers in the coffee value chain. In addition, it should be possible to derive specific policy recommendations for different actors in the coffee value chain, company sizes, sustainability initiatives, and traceability for at least one of the secondary research questions on policy recommendations. Evaluating criteria was subject to collaborative discussion among the authors when necessary, ensuring inter-rater reliability. Of the 39 papers initially reviewed, 24 met the inclusion criteria and were subjected to in-depth analysis. The selected publications were systematically analyzed against the backdrop of our research questions, employing a predefined analytical framework.

3 Results

The following sections address the research questions regarding the types of sustainability initiatives, the influence of company characteristics on the choice of a sustainability initiative, and whether clusters of companies can be built. The findings delineate sustainability initiatives within the coffee sector and how company characteristics influence their adoption and intensity. Further, findings from the literature review on sustainability policies in the coffee sector are presented.

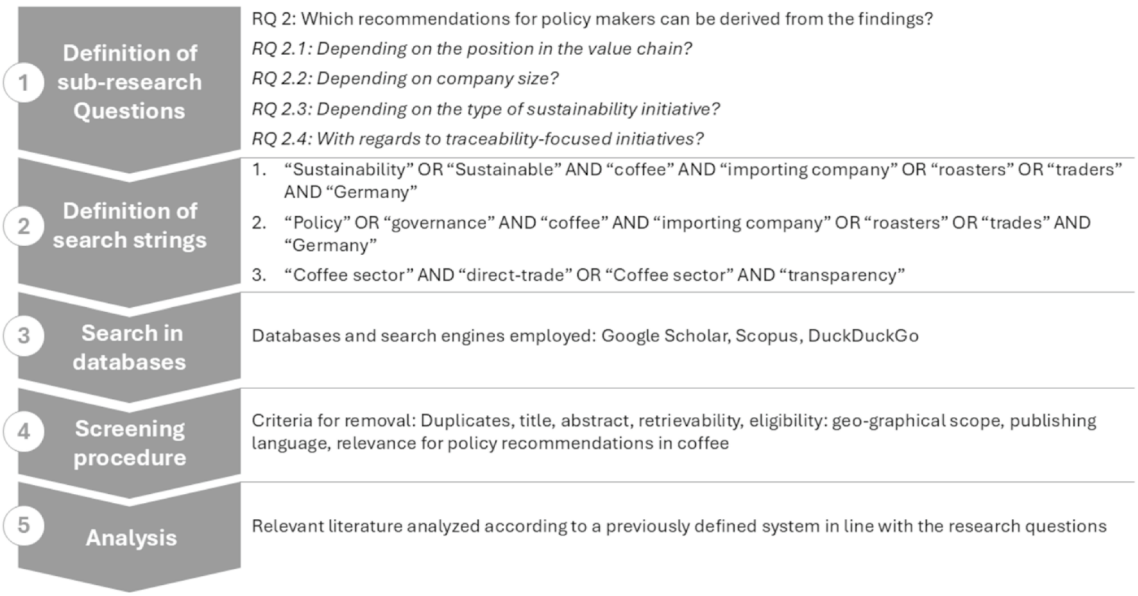


Fig. 3 Literature research process

3.1 Coverage and intensity of sustainability initiatives

Table 1 summarizes the types and prevalence of different sustainability initiatives as identified by analyzing companies' communication. Coverage of engagement was determined as the percentage of companies actively (at least once) communicating in a certain field of a sustainability initiative.

Results show that *Third-Party Certification* dominates, followed closely by *Multi-stakeholder Initiatives*. The rather young concept of *(Collective) Goal-based Initiatives* shows promise and *Single-Origin Concepts* and *Direct Trade* are still exotic among the initiatives.

Among the Direct Impact Initiatives identified, economic and social initiatives like *Economic Support* and *Access to Finance* are less represented, while ecological initiatives like *Good Agricultural Practices & Extension Services* and *Diversification & Ecosystem* have a high coverage. A full overview of the features and keywords can be found in the appendix (Fig. 5).

3.2 Influence of companies' characteristics

To determine the influence of company size (S, M, L, XL, XXL) and position in the value chain (Exporter, Trader, Roaster) on the intensity of engagement in sustainability initiatives, normalized data of 107 companies were mapped against each type of initiative. This includes 68 exporters from nine origin countries, 11 traders, and 28 roasters worldwide (c.f. Fig. 4). Except for Olam, whose headquarters are in Singapore, all sampled traders have their headquarters in Europe.

Most roasters are headquartered in Germany, with few based in Italy, the US, The Netherlands, and Switzerland. The sample characteristics are summarized in Table 2.

Third-party Certification and *Multi-stakeholder Initiatives* are widely adopted across all company sizes. Larger firms tend to intensify their engagement with *Third-party Certification*, possibly due to their diverse producer networks and capacity to manage multiple certification schemes. Similarly, as company size increases, there is a trend toward greater participation in *Multi-stakeholder Initiatives*, likely attributed to larger firms having the resources for active engagement. *Goal-based Initiatives* are applied almost exclusively by very large firms with the management capacities needed to prepare for (future) non-financial sustainability reporting requirements. *Direct Impact Initiatives* are found across all firm sizes, with a stronger focus on environmental aspects. Still, *Direct Impact Initiative* in the category of business and economic support gets the highest attention of companies sized XL or XXL. Roasters exhibit a strong commitment to all sustainability aspects along the supply chain, which is more intense toward the consumer-facing end of the supply chain. Traders demonstrate a comparably high involvement, especially in *Traceability* and *Third-Party Certification*, which is among their main duties as supply chain connectors. Exporters display low engagement in sustainability initiatives overall, with exceptions in *Third-Party Certification* and *Traceability*.

3.3 Clustering results

The clustering was performed to investigate patterns among companies that could be addressed jointly and yielded four distinct typologies of companies based on their different intensity of engagement in the 16 sustainability initiatives. *Direct Trade* and *Corporate Certification* show a low intensity in all clusters. For the remaining features, the intensity is mixed throughout the groups. Cluster 2 has the highest intensity of all features, whereas Cluster 4 has the lowest intensity. Cluster 1 and 3 are in the middle, each with prioritized topics.

Cluster 1: "Traceability Elite" ($N = 33$): Dominated by 79% exporters, 18% roasters and 3% traders, of which a share of 42% are small companies. Half of the companies are selling specialty coffee only. The focus is on *Traceability*.

Cluster 2: "Conventional Giants" ($N = 14$): Comprising almost exclusively very large companies (93%), particularly roasters (72%), engaging extensively across sustainability initiatives, especially *collective goal-based* approaches but also third-party certification. Only a minor share of 14% of the companies are selling specialty coffee or organic coffee, conventional produce is the priority.

Cluster 3: "Mixed Engagers" ($N = 14$): Balanced mix of companies in terms of role, with a dominance of large and very large companies and a moderate engagement in sustainability initiatives, yet similarly high engagement in *Third-party Certification* as Cluster 2. 61 % of companies in this group offer both, conventional and organic coffee.

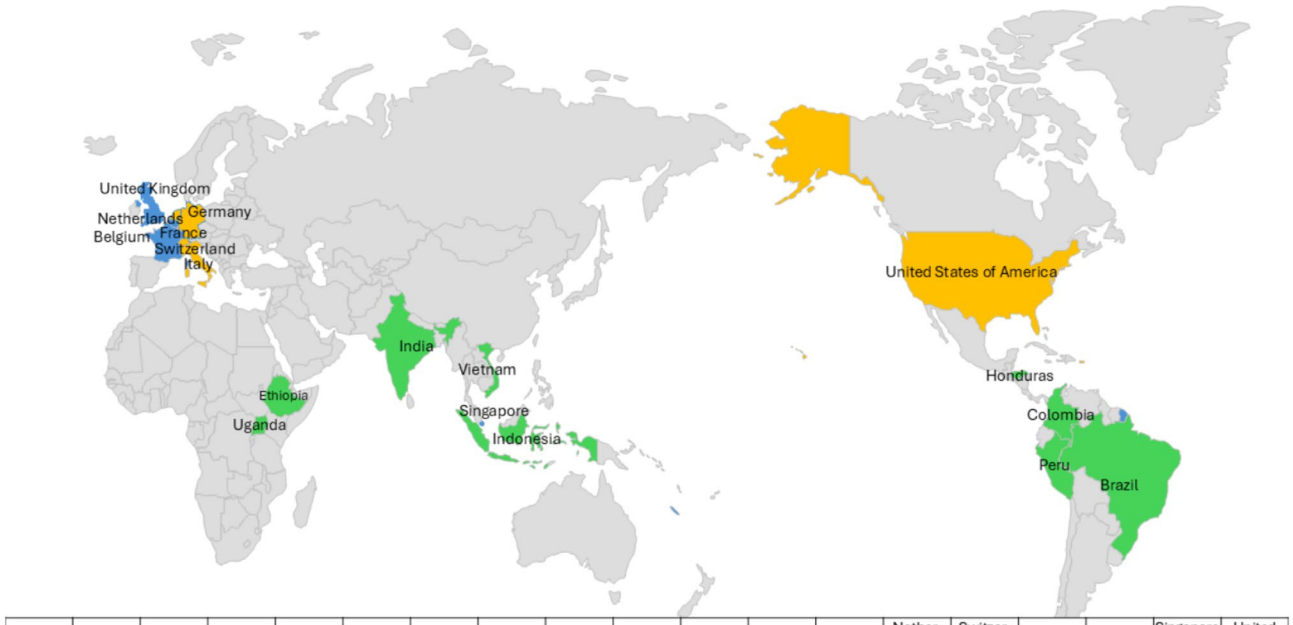
Cluster 4: "VSS (Voluntary Sustainability Standards) Base" ($N = 42$): Largest cluster with a high share of exporters and small companies. The focus is on *Third-party Certification*, showing a second strategy pathway of exporters, as an alternative to *Traceability* for specialty coffee as in Cluster 1.

3.4 Policy recommendations for the coffee sector

Out of 39 papers reviewed, 24 provided explicit recommendations for public and private policies in the coffee sector. Specific recommendations regarding certain positions in the supply chain, company size, and type of sustainability initiative were rarely mentioned; thus, recommendations were derived in the "Discussion" section. Table 4 in "Annex" provides a summary of the studies. Seven main themes were identified among the papers mentioning explicit policy

Table 1 Overview on types of sustainability initiatives and their prevalence

Type	Definition	Prevalence (%)	Examples
Third-Party Certification	Third-party certification schemes aim to regulate production through a common set of rules, methods, and norms (Cashore et al. 2004; Dietz et al. 2018a; Grabs 2017; Grabs et al. 2016)	71.0	Fairtrade, Rainforest Alliance, 4C, Organic
Multi-stakeholder Initiatives	Collaborative approaches between private and third-sector actors that facilitate cross-sectoral dialogue and engagement in the form of common standards (Grabs 2017; Grabs and Carodenuto 2021)	67.3	Global coffee platform, an initiative for coffee and climate, sustainable coffee challenge
Responsible Business Conduct	Responsible business conduct initiatives can be seen as a baseline requirement regarding sustainable development supported by companies. They are also referred to as 'principle-based initiatives' (Decker 2018; GRI, Compact UG, WBCSD 2015)	16.8	United Nations Global Compact (UNGC)
(Collective) Goal-Based Initiatives	Frameworks for companies for voluntary alignment with forward-looking objectives, (Grabs and Garrett 2023). The goal setting-process is inclusive, the goals are non-binding and it relies on weak institutional arrangements (Biermann et al. 2017)	19.6	Science-Based Target Initiative (SBTi), Carbon Disclosure Project (CDP)
Corporate Certification Initiatives	Voluntary self-obligation schemes followed by individual companies, sometimes co-developed by independent third parties, e.g., the Starbucks C.A.F.E. Program	10.3	AAA, C.A.F.E.
Single-Origin Concepts	Single-origin coffee comes from either a country, a specific region, or a farm and is sold as a pure product (Teuber 2010)	13.1	Geographical indication, protected geographical indication (PGI)
Direct Trade	Mostly applied in the specialty coffee segment, when (mostly) small roasters buy their coffee directly from producers without involving intermediaries (Bozzola et al. 2021)	24.3	Relationship coffee, direct trade initiatives
Direct Impact Initiatives, e.g.	Direct impact initiatives consist of on-the-ground projects that follow different objectives. Projects are mostly executed by third-party companies and can be for or not-for-profit (Steemers 2016)	*Percentages for direct impact initiatives in the following*	Can include various categories of engagement
GHG Emissions		43.0%	
Traceability		54.2%	
Charity		57.0%	
Disaster Relief		46.7%	
Waste-Management and By-products		40.2%	
Economic Support and Empowerment		26.2%	
Access to Finance		13.1%	
Good Agricultural Practices and Extension Services		73.8%	
Diversification and Ecosystem		75.7%	



Country	Brazil	Vietnam	Columbia	Peru	India	Ethiopia	Uganda	Indonesia	Honduras	Germany	Italy	USA	Nether-lands	Switzer-land	Belgium	France	Singapore / Europe	United Kingdom
Exporter	22	13	6	5	5	5	5	4	3	-	-	-	-	-	-	-	-	-
Trader	-	-	-	-	-	-	-	-	-	4	-	-	1	1	1	2	1	1
Roaster	-	-	-	-	-	-	-	-	-	22	3	1	1	1				

Fig. 4 Supply Chain Positions: number of companies in sample

Table 2 Company cluster typologies

Cluster	No. of companies in cluster	Company type composition	Dominating company size	Characteristics
1	33	79% Exporters, 18% roasters and 3% traders	42% Small companies	Focus on specialty coffee and traceability
2	14	72% Roasters, 21% traders, 7% exporters	93% Very large companies	Conventional produce is dominating, focus on collective goal-based initiatives
3	14	Balanced across all types	77% (Very) large companies	Majority of companies offer conventional and organic coffee, focus on third-party certification
4	42	79% Exporters, 19% roasters, 2% traders	52% Small companies	Focus on specialty coffee and third-party certification

recommendations, which structure the presentation of key findings in the following. The following Table 3 gives an overview of the literature that underpins each of the main themes.

Regulations and standards While regulations are mandatory within national contexts, standards address sectors voluntarily from a global perspective. Evidence shows that considering national contexts in standard setting is equally important, as standards are often developed from an importing country's perspective for diverse origin countries (Manning et al. 2012). Successful change is enabled by a joint vision of the political direction, shared benefits, and a balance of power between stakeholder groups (Vos et al. 2022). VSS and other private regulations are considered bridge builders between public regulations in the absence of intergovernmental agreements and the second best alternative to public policy (Reinecke et al. 2012; Marx et al. 2024). Private standards support existing public regulations and promote accountable certification systems, while public ones encourage the search for more sustainable practices (Raynolds et al. 2007). Several factors need to be assured to advance sustainability in origin countries, including clear and transparent requirements, effective and accessible participation structures, and hybrid forms of relational and hybrid

Table 3 Overview on main themes identified for policy recommendations

Main theme	References
Regulations and standards	Manning et al. (2012), Vos et al. (2022), Reinecke et al. (2012), Marx et al. (2024), Raynolds et al. (2007), Giovannucci and Ponte (2005), and Navarrete-Cruz and Birkenberg (2024)
Sustainable sourcing and supply chain management	Cordes et al. (2021) and Duşmăneanu and Jeschke (2024)
Public–private partnerships and multi-stakeholder collaboration	Reinecke et al. (2012), Giovannucci et al. (2008), Schuster and Mossig (2024), Giovannucci and Ponte (2005), and de Alba Verduzco et al. (2024)
Data for impact assessment and transparency	Giovannucci et al. (2008), Samper and Quinones-Ruiz (2017), Duşmăneanu and Jeschke (2024), Giovannucci and Ponte (2005), Dietz et al. (2018a), Millard (2017), and Rubio-Jovel et al. (2023)
Global and national sustainability strategies	Manning et al. (2012) and Marx et al. (2024)
Infrastructure and capacity building in origin countries	Cordes et al. (2021) and Sachs et al (2019)
Innovation and technology	Lachenmeier et al. (2024)

contracts (Giovannucci and Ponte 2005; Navarrete-Cruz and Birkenberg 2024). Compensation and incentive structures could go two ways: simply rewarding producers for meeting the standards' requirements or using complex, multidimensional incentive structures to motivate implementation of sustainability approaches (Giovannucci and Ponte 2005; Navarrete-Cruz and Birkenberg 2024).

Sustainable sourcing and supply chain management are central for advancing sustainability efforts, directly impacting coffee farmers' living conditions and farming practices. Responsible sourcing encompasses interventions on prices and premiums, business practices, and direct support for producers; however, it must be tailored to the context to be truly beneficial (Cordes et al. 2021). Investments in physical and non-physical infrastructure are needed to ensure efficient business execution (Duşmăneanu and Jeschke 2024).

Public–private partnerships and multi-stakeholder collaboration are vital for sustainability, as they can fill gaps in public regulations or advance sustainability ambitions beyond the regulatory minimum (Reinecke et al. 2012). Collaborative approaches adapt more easily to market dynamics, potentially resulting in higher efficiency than traditional "command and control" policies (Giovannucci et al. 2008). However, except for the organic regulation, private standards commonly remain independent from public regulations. Competition among private labels arises from overlaps and redundancies between standards, which need to be managed (Reinecke et al. 2012). Critics highlight the "soft law" character of private standards and their non-binding nature, however, the voluntary character of such initiatives brings together like-minded people or those sharing similar goals and challenges (Schuster and Mossig 2024). Both voluntary and public policies could focus on transparency regarding standards and requirements, involving stakeholders from origin countries in the decision-making process, improving access to information and supplies, and lowering costs for participation of small farmers. Support systems for producers, including provision of financing and guidance to better production and farm management are needed to ensure long-term viability (Giovannucci and Ponte 2005; de Alba Verduzco et al. 2024).

Data for impact assessment and transparency are essential for trusted supply chains. Policy measures could encourage open data sharing via platform solutions and ensure their accessibility from farmer to consumer (Giovannucci et al. 2008; Samper and Quinones-Ruiz 2017). Such approaches serve the threefold purpose of allowing farmers to monitor and improve their production, share knowledge, and support traceability efforts (Duşmăneanu and Jeschke 2024; Giovannucci and Ponte 2005). Besides traceability, also SDG KPIs can be tracked and made available for reporting purposes (Samper and Quinones-Ruiz 2017) or ease certification. On a higher level, data generated throughout the value chain allows for impact assessments at business and landscape level (Dietz et al. 2018a; Millard 2017) and to evaluate and compare sustainability initiatives, guide policy design, and set standards for private sustainability initiatives. Research indicates that VSS is insufficient to foster a transition to more sustainable coffee production, as trade-offs between different SDGs bias the perceived vs. the overall impact (Rubio-Jovel et al. 2023).

Global and national sustainability strategies need close alignment to effectively promote private standards and facilitate multi-stakeholder processes. This includes anchoring key stakeholders, such as buyers, roasters, and development agencies (Manning et al. 2012). As VSS are considered the second-best alternative without other strong private or public regulations, policymakers could provide infrastructure and security to enable VSS to thrive by complementing or advancing the requirements of public regulations (Marx et al. 2024).

The integration of region-specific requirements and multiple perspectives into policy analysis and design (Raynolds 2009) can enhance the efficiency in targeting global SDGs at

the national or even local level and help support other quality standards, e.g., geographic indication of origin (Samper and Quinones-Ruiz 2017).

Infrastructure and capacity building in origin countries are two key areas to be addressed by policymakers. Cross-national policy design, flanked by institutional and physical infrastructure as a basis for further measures, offers viable opportunities to increase sustainability along the entire value chain (Cordes et al. 2021). For example, Sachs et al (2019) propose National Coffee Sustainability Plans (NCSPs) individualized for each coffee-origin country's goals, funded through a Global Coffee Fund supported by industry, donors, national budgets, and private investments.

Innovation and technology are critical enablers for achieving sustainability goals, and policymakers could review regulations to promote circularity approaches and product innovation. For example, the EU's novel food regulations limit utilizing coffee by-products, avoiding the larger-scale utilization of novel ingredients (Lachenmeier et al. 2024).

4 Discussion

The results of this study for Germany, as one important coffee market, provide information regarding applied sustainability initiatives. However, the literature review yielded only generic insights regarding policy recommendations for specific types of companies. In the following, we discuss the findings.

4.1 Diverse initiatives, shared goals

Our analysis showed *Third-Party Certification* and *Multi-Stakeholder Initiatives* dominate sustainability efforts across all company sizes, however, increasing company size tends to relate with intensified engagement. Company size can thus be considered an important influence on sustainability engagement, suggesting that increased resources and capacity lead to more comprehensive sustainability efforts. Corporate certification initiatives are common for large and very large players and subject to company organization (Bager and Lambin 2020). Such initiatives could be monitored for consistency in standards, and holistically addressing the entire value chain (Alvarez et al. 2010). Collective rule-based initiatives are usually represented as *Multi-stakeholder Initiatives* and could focus on involving a majority stakeholders from different supply chain areas. Besides supporting farmers within their supplier networks, companies could consider pre-competitive contributions to public goods benefiting a broad range of farmers, such as research for new varieties. In contrast, *Goal-based Initiatives* are promising but still niche and almost exclusively applied by very large firms, that possess the necessary management capacities and are preparing for (future) non-financial sustainability reporting requirements. *Goal-based Initiatives* can thus be considered size-dependent and possibly indicate a gap in sustainability practices between large and smaller companies. *Direct Trade Initiatives* are also younger initiatives but still niche while *Single-Origin Initiatives* remain exotic. *Direct Impact Initiatives* show a varied focus across firm sizes, with a stronger focus on environmental aspects. However, policies are required that push for even stronger efforts, e.g., increasing GHG emissions or waste and by-product efforts. The largest companies give the greatest attention to business and economic support within *Direct Impact Initiatives*, suggesting a more comprehensive approach by bigger players.

4.2 From smallholders to giants: customizing policies

Depending on the company size companies face different challenges and their effect on the individual entity but have a common base of root causes that policymakers could address. Small companies lack the (financial) power and leverage to make changes independently. They could build partnerships and cooperations to strengthen their position, facilitate knowledge sharing, and reduce power imbalances (Duşmăneanu and Jeschke 2024; Marx et al. 2024). Setting up (digital) platforms to facilitate the building of trade relationships and knowledge sharing is another means to empower small companies across different physical locations (Samper and Quinones-Ruiz 2017; Lachenmeier et al. 2024). Medium-sized companies might appear to be "stuck in the middle", yet their position offers a good vantage point for developing a targeted positioning and niche offering due to their flexibility to work both upstream and downstream. This highlights the importance of sustainability-driven business model innovation to help companies overcome such stalemate (Lachenmeier et al. 2024). Particularly in the field of Direct Impact Initiatives, partnering with larger and very large companies allows medium-sized players to excel in their individual outreach and overcome limitations (Bager and Lambin 2020). Large and very large companies are dominating the coffee value chain through their size and financial capacity (Cordes et al. 2021) and have, therefore, the strongest lever to trigger changes (Giovannucci and Ponte 2005; Venus et al. 2024). Public policy could continue bailing large and very large companies in for the sustainable transformation of their supply chain. Research is needed on incentivizing firms to adopt these practices (Marx et al. 2024).

4.3 From farm to roaster: role-based policy solutions

Depending on the position in the value chain, policy measures need to address the obstacles preventing companies from intensifying their sustainability engagement. *At farm level*, encouraging implementation of best management practices, both in business and agriculture, could increase efficiency and

productivity. By that, land use change can be avoided, and the sovereignty of farmers increases (Millard 2017). Farmers usually attempt to comply with different standards on the market to align their production with multiple consumer preferences, but should keep a sensitive trade-off between business opportunity and certification cost in mind due to consumers' increasing "label fatigue" (Dietz et al. 2018b). Standards that have a strong democratic base and are coordinated through NGOs, e.g., Fairtrade, should be preferred over corporate certifications, e.g., Nespresso AAA, that reflect buyers' interests (Raynolds et al. 2007). Public policy could focus on setting frameworks that foster equitable participation of farms of all sizes in key decisions over standard setting and monitoring procedures (Giovannucci and Ponte 2005), ensure sufficient financial means to drive sustainable transformation, considering minimum prices or public–private partnerships (Sachs et al 2019; de Alba Verduzco et al. 2024), and foster adoption of innovation and technology for supply chain transparency (Bager and Lambin 2020; Marx et al. 2024). Third-party certifications and multi-stakeholder initiatives are suited to accommodate this across all company sizes, while direct impact approaches can address specific requirements complementarily and context-specific. *Exporters* display the lowest engagement intensity in sustainability initiatives, focusing only on the minimum requirements set by third-party certification and traceability. Traders show a slightly higher intensity of engagement. Both groups have the most proximity to the origin of coffee production. Therefore, they could partner with other players along the supply chain to promote sustainable sourcing practices, emphasizing transparency and traceability (Cordes et al. 2021). This includes rethinking the governance structures that are imposed to ensure farmers' interests are reflected through equal representation (Raynolds 2009) and ensuring better understanding and buy-in into self-imposed goals, allowing the adaptation of global targets to local realities (Schuster and Mossig 2024). *Roasters* are the value chain link often getting the most attention through their immediate interaction with consumers through brands. Therefore, their high involvement in sustainability is a logical consequence. However, roasters often lack the direct link upstream until the farm level, which impedes credible storytelling about their initiative and assessment of the overall impact. Focusing on sustainability initiatives that allow for physical traceability of products, engagement in direct impact initiatives, and conducting impact assessments to ensure holistic changes, together with consumer education, are key to strengthening the role of roasters in the coffee value chain (Raynolds et al. 2007; Reinecke et al. 2012). Positioning brands through origin-centric approaches, rather than standard-focused, can create real opportunities for authentic differentiation for all, as they are more scalable than, e.g., direct trade approaches and can co-exist with other forms of certification (Samper and Quinones-Ruiz 2017). To summarize, the key focus for all value chain players should be on strengthening collaboration and building partnerships, making governance more inclusive with shared responsibilities and participation, and reducing barriers to research, innovation, and technology.

4.4 The promise of clustering for policy design

Clustering of companies with similar sustainability engagement typologies may allow efficient yet, tailored policy recommendations to advance sustainability efforts. For example, for Traceability-focused exporters (Cluster 1), digital tools are essential for enhancing sustainability and origin approaches. Conventional Giants/Roasters (Cluster 2) should align innovations with sustainability goals, with public policies applying pressure for change. Mixed Engagers (Cluster 3) need effective certification schemes to encourage larger companies to commit to fair pricing. Lastly, VSS Finest, smaller companies prioritizing premiums for farmers, require collaboration and investment with producers, larger firms, and public entities to advance sustainability.

5 Conclusion

The findings of our study reveal a structural gap between the current global policy landscape and the heterogeneous needs of actors in the coffee sector. While sustainability initiatives are growing, they often lack the granularity to manage the complexity related to differences in company size, resources, and strategic priorities. This misalignment currently constitutes an obstacle to adoption and effectiveness, but at the same time presents an opportunity for renovation of the industry. The evolving interplay between public and private standards, combined with advances in traceability and transparency technologies, offers a promising foundation for more targeted and impactful measures. Our work provides a practical basis for differentiated policy design, by identifying distinct company clusters with shared preferences for sustainability approaches. Tailoring the offering of sustainability initiatives to companies' needs bears the potential to enhance engagement and outcomes, compared to imposing a one-size-fits-all approach. Beyond the coffee sector, this analytical approach could be applied to other agricultural commodities with complex global value chains, where sector-wide goals often struggle to account for on-the-ground diversity, such as cocoa or exotic fruits. Future research could build on these findings by validating cluster patterns with richer datasets, incorporating economic performance indicators, and triangulating with empirical evidence to assess policy outcomes. Such efforts would not only strengthen the evidence base for sustainability governance in coffee but also contribute to broader debates on how to align global frameworks with the diverse realities of industry actors, ultimately advancing both equity and effectiveness in sustainable commodity trade in coffee and beyond.

Appendix

See Fig. 5 and Table 4.

Sustainability initiatives (Features) and key word mapping									
Features	**(1) Responsible business conduct initiatives**	**(2) Single origin concepts**	**(3) Multi-Stakeholder initiatives and industry associations**	**(4) Goal-based initiatives**	**(5) Corporate certification**	**(6) Direct trade initiatives**			
Key words	'global compact', 'ungc', 'guidelines for multinational enterprises', 'oecd guidelines'	geographical indication', 'protected geographical indication', 'pgi'	sustainable coffee challenge', 'multi-stakeholder initiative', 'global coffee platform', 'international coffee partner', 'association', 'sustainable agriculture network', 'coalition for coffee communities', 'initiative for coffee and climate', 'sustainable agriculture initiative'	'cdp', 'carbon disclosure project', 'science-based target', 'science based target', 'sbti'	'aaa', 'c.a.f.e.'	'direct trade', 'direct-trade', 'relationship coffee'			
Direct impact categories (Features) and key word mapping									
Features	**(a) Business & economic support**	**(b) Access to finance**	**(c) Good agricultural practices & agricultural extension services**	**(d) Diversification & ecosystem**	**(e) Traceability**	**(f) Charity initiatives**	**(g) Disaster relief**	**(h) GHG emissions**	**(i) Waste management & by-product valorization**
Key words	'living wage', 'living-wage', 'living income', 'living-income', 'women empowerment',	'pre-finance', 'pre financing', 'growers liquidity', 'farmers liquidity', 'producers liquidity', 'farmer pension'	'training', 'agricultural extension services', 'integrated pest management', 'good agricultural practices', 'extension services', 'better farming', 'water resources', 'water management', 'water footprint'	'diversification', 'habitat', 'biodiversity', 'agroforest', 'agro forest', 'agro-forest', 'soil fertility', 'restoration', 'ecosystem', 'regulation services', 'ecosystem services'	'blockchain', 'traceability'	'education fund', 'donation', 'foundation', 'charity', 'school'	'disaster relief', 'climate-smart', 'climate smart', 'climate resilience', 'drought-tolerant varieties', 'water storage', 'rainwater', 'water management', 'water footprint', 'water resources', 'climate change'	'scope 3', 'emissions', 'net-zero', 'net zero', 'carbon-neutral', 'climate neutral', 'offsetting', 'solar power', 'photovoltaic'	'biodigester', 'water treatment', 'composting', 'by-product', 'biogas'

Fig. 5 Features and key word mapping

Table 4 Overview on literature reviewed for policy recommendations

Count	Title	Author(s)	Year	General policy recommendations
1	Responsible Coffee Sourcing: Toward a Living Income for Producers	Cordes, Kaitlin Y.; Sagan, Margaret; Kennedy, Solina	2021	* Adapt sourcing practices to help close the living income gap. * Broader sustainability investments by roasters and retailers. * Interventions within supply chains on: prices and premiums; changes in business practices; producer support; and traceability. * Policy interventions by governments (in both producing and consuming countries, as well as sector-level initiatives, are also needed. * Strengthen physical and institutional infrastructure in producing countries and improve efficiencies at the farm and farm-group levels and within supply chains, helping economically non-viable producers to exit coffee and to benefit from other livelihood options
2	The Voluntary Coffee Standard Index (VOCSI)	Dietz, Thomas; Auffenberg, Jennie; Estrella Chong, Andrea; Grabs, Janina; Kilian, Bernard	2018	* Develop structured indices to assess impact of VSS on regulatory topics in the four main regulatory areas of sustainable development: environmental, economic and social sustainability and compliance enforcement. * Aggregating the subindices into the "Voluntary Coffee Standards Index" (VOCSI)
3	Transparency and Traceability in the Supply Chains of Coffee and Cocoa	Duşmăneanu, B. and Jeschke, M.	2024	* Establish regulatory frameworks regarding farmer documentation and supply chain traceability in producing countries to support the traceability efforts of downstream actors * Encourage collaboration to establish comprehensive systems that deliver complete information to the consumers
4	Seeking Sustainability: COSA Preliminary Analysis of Sustainability Initiatives in the Coffee Sector	Daniele Giovannucci and Jason Potts with B. Killian, C. Wunderlich, G. Soto, S. Schuller, F. Pinard, K. Schroeder, I. Vagneron	2008	* Focus on market-based policy to promote static and dynamic efficiency in the market place, as market-based measures are considered more effective than traditional "command and control" policy. * Develop an open access data base on sustainability initiatives for policy-makers and producers to enable strategic business, risk and quality management, adoption of sustainable practices and collaboration between farmer groups and local institutions
5	Still Brewing: Fostering Sustainable Coffee Production	Millard, E.	2017	* Employ landscape approaches across regions, connecting land users with community leaders and policy-makers to tackle the root causes of the environmental degradation. * Market approach to sustainable coffee production requires parallel commitments from governments and donor agencies to achieve equitable social participation and environmental conservation. * Impact studies, which presently focus on standards and certification, should consider a wider range of market approaches

Table 4 (continued)

Count	Title	Author(s)	Year	General policy recommendations
6	Mainstreaming Fair Trade Coffee	Raynolds, L. T.	2009	* (Re)design policy analysis to explore "driving," "coordinating," and "normalizing" relations within "global value chains" simultaneously
Count	Title	Author(s)	Year	Explicit general policy recommendations
7	Regulating Sustainability in the Coffee Sector: A Comparative Analysis of Third-Party Environmental and Social Certification Initiatives	Raynolds, L. T., Murray, D. and Heller, A.	2007	* Private regulations should work hand in hand with public regulations to foster emerging certifications that seek to raise ecological and social standards rather than maintaining the status quo, as private regulations cannot replace public regulations but only complement them * The complementary aims of private and public regulations are that private ones advance sustainability through support of existing public sustainability regulation and the implementation of democratic and accountable certification systems. Meanwhile, public ones are focusing on advancing the search for more sustainable practices and defending existing regulations
8	The Emergence of a Standards Market: Multiplicity of Sustainability Standards in the Global Coffee Industry	Reinecke, Juliane; Manning, Stephan; von Hagen, Oliver	2012	* Voluntary standards are means to bridge regulatory gaps in the absence of intergovernmental regulations regarding sustainability, as the absence creates a regulatory vacuum. * One of the biggest challenges that needs to be addressed is the multiple overlapping standards, developed by both social movement organizations and firms, that co-exist and compete for adopters in the same sector despite being similar in design, content and intentions to regulate the transnational arena. * Even in the case of organic, the only standard that has been turned into public regulation in multiple countries, multiple labels exist in parallel. Reduction of redundancies and overlaps can be achieved through the installation of an overarching authority and definition of the object or quality to be standardized as the absence of the two elements creates the regulatory vacuum

Table 4 (continued)

Count	Title	Author(s)	Year	General policy recommendations
9	Ensuring Economic Viability and Sustainability of Coffee Production	Sachs, Jeffrey; Cordes, Kaitlin Y.; Rising, James; Toledano, Perrine; Maennling, Nicolas	2019	* Each coffee-producing country should develop a National Coffee Sustainability Plan (NCSP), that accounts for differentiated needs, challenges, and opportunities within the country's coffee sector. At their core, NCSPs would offer clear strategic plans for supporting producers, promoting sustainable coffee production, and aligning producing regions with the SDGs. * A Global Coffee Fund Underpinned by a Multi-stakeholder Approach, i.e., financed by the main coffee industry actors and used to leverage additional public sector funding, would enable stakeholders to implement activities under the NCSPs. The GCF would be a key pre-competitive initiative of the coffee sector to fill critical financing gaps for sustainability investments in coffee-producing regions
10	Toward a Balanced Sustainability Vision for the Coffee Industry	Samper, L. F. and Quiñones-Ruiz, X. F.	2017	* Develop new sustainability models that adapt to region-specific requirements and KPIs that reflect global sustainability priorities locally. * Identify ways to practically obtain farmer input. * Establish a data sharing and communication platform for SDG matters. * Encourage sustainability programs for specific geographical originals, focusing on consistency and continuity, rather than a pass/fail approach
11	Innovation and Networks in the Bioeconomy: A Case Study from the German Coffee Value Chain	Venus, T. E., Beale, C. and Villalba, R.	2023	* Remove inconsistencies in waste regulations. * Revise the primary regulatory frameworks for waste (e.g., German Recycling Act) to clarify how to classify food residues, their disposal structures and broaden their use streams. * Incorporate downstream activities into the sustainability discussion in the coffee chain
12	National Contexts Matter: The Co-evolution of Sustainability Standards in Global Value Chains	Manning, Stephan; Boons, Frank; von Hagen, Oliver; Reinecke, Juliane	2012	* Anchoring key stakeholders such as roasters, producers and development agencies in economic and institutional context within national contexts supports the development and effective implementation of VSS. * Co-existence of multiple standards is not necessarily problematic, provided that the diversity of standards allows different countries to participate in the process and create feedback loops. * Governments and governmental agencies maintain a central role in promoting private standard regimes, facilitating and moderating multi-stakeholder processes

Table 4 (continued)

Count	Title	Author(s)	Year	General policy recommendations
13	Sustainability Strategies by Companies in the Global Coffee Sector	Bager, Simon L.; Lambin, Eric F.	2020	* Mainstreaming of sustainability should be targeted through deployment of new information technologies creating transparency on market players' different approaches. * Mainstreaming of sustainability should also include a holistic coverage of different aspects of sustainability, such as climate change and deforestation instead of focus setting on specific aspects
14	Nestlé Nespresso AAA Sustainable Quality Program: An Investigation into the Governance Dynamics in a Multi-stakeholder Supply Chain Network	Alvarez, G., Pilbeam, C. and Wilding, R.	2010	* Treat governance mechanisms not as a fixed variable but adapt the coordination mechanisms to the external and internal context of the relationships and characteristics of the task at hand. * By understanding the variables underlying a relationship, organizations can adjust their governance to support objectives, which may also evolve as relationships develop. * Network relationships can be both, resources and biases
15	Standards as a New Form of Social Contract? Sustainability Initiatives in the Coffee Industry	Giovannucci, D. and Ponte, S.	2005	* Three factors must be assured for standards to work for developing countries: (1) transparency and clarity of the standards and their requirements; (2) effective participation by developing country producers in key decisions over standard setting and monitoring procedures; (3) reasonable access; and (4) just compensation for the efforts required of producers to meet and monitor elevated standards. * Public–private partnerships with balanced input from all stakeholders can make a strong case for setting minimum prices and facilitation of communication in sustainability initiatives. * The role of governments is to ensure a basic level of fairness and security
16	Institutions, Interests, Ideas and Networks in Three Cases of Policy Reform	Shearer, Jessica C.; Abelson, Julia; Kouyaté, Bocar; Lavis, John N.; Walt, Gill	2016	* Changes in network structures are an important step in policy evolution, but not the initiating change. * Change is often initiated by changes in donor rules, affecting the composition and structure of actors in then networks
17	The Political Economy of Reforming Agricultural Support Policies	Vos, Rob; Martin, Will; Resnick, Danielle	2022	* Political–economic constraints are most important limitations to successful change. * Three interrelated factors cause resistance to policy reform: ideas (preconceived notions about policies), interests (opportunities to secure individual benefits), and institutions (power imbalance between stakeholder groups)
18	Shaping the Future of Coffee: Climate Resilience, Liberica's Rise, and By-product Innovation: Highlights from the International Coffee Convention 2023 (ICC2023)	Lachenmeier, Dirk W.; Weller, Philipp; Farah, Adriana; Lagman, Ma Carmen Ablan; Fabian, Massimiliano; Del Castillo, Maria Dolores; Schwarz, Steffen	2024	* Critiquing the EU's novel food regulation, arguing that it poses a significant trade barrier to coffee by-products. * Advocated for a revision of the regulation to allow for a rapid and flexible introduction of novel foods, including traditional foods from third countries, to uphold food security and sustainability in the EU

Table 4 (continued)

Count	Title	Author(s)	Year	General policy recommendations
19	SDGs Trade-offs Associated with Voluntary Sustainability Standards: A Case Study from the Coffee Sector in Costa Rica	Rubio-Jovel, Karla; Sellare, Jorge; Damm, Yannic; Dietz, Thomas	2023	* Statistical analysis performed for the study suggest that VSSs alone are not enough to promote a transition to a more sustainable coffee production, due to trade-offs between the contributions of VSSs and different SDGs. * Evidence of impact is scattered and inconsistent although VSS are often promoted as tools for sustainable transformation in regions with weak national governance. * Collaborative approaches and empirically systematic and independent evaluations are necessary to ensure the ongoing improvement in VSSs' effectiveness as governance instruments
20	Multi-stakeholder Initiatives and Sustainability? A Governance Analysis using the German Initiative on Sustainable Cocoa (GISCO) as a Case Study	Schuster, Daniel; Mossig, Ivo	2024	* Critics of multi-stakeholder initiatives point out that such a collaboration does not necessarily ensure constructive and solution-oriented cooperation and due to its voluntary character, decisions made generally do not have any legally binding effect and are therefore referred to as "soft law regulation". * Dialog as an opportunity to meaningfully complement regulations through legally non-binding collaboration, due to the cognitive closeness and common goals of members. * At working level, a revision of decision-making paths and strengthening of communication structures is advised to ensure early alignment between stakeholder groups and executive board
21	"Global Governance Through Voluntary Sustainability Standards: Developments, Trends and Challenges"	Marx, Axel; Depoorter, Charline; Fernandez de Cordoba, Santiago; Verma, Rupal; Araoz, Mercedes; Auld, Graeme; Bemelmans, Janne; Bennett, Elizabeth A.; Boonaert, Eva; Brandi, Clara; Dietz, Thomas; Fouilleux, Eve; Grabs, Janina; Gulbrandsen, Lars H.; Harrison, James; Heilmayr, Robert; Hernandez, Ariel; Hoekman, Bernard; Lambert, Siti Rubiah; Lambin, Eric; Li, Li; Maertens, Miet; Mortara Batistic, Paulo; Michida, Etsuyo; Nakagawa, Junji; Negi, Archna; Pérez-Pineda, Jorge A.; Ponte, Stefano; Rueda, Ximena; Schleifer, Philip; Thorstensen, Vera; van der Ven, Hamish	2024	* VSS are the second best alternative in the absence of strong private or public regulatory alternatives. * VSS can complement public policies in several ways, including as proof of compliance with regulatory requirements. In the advent of emerging due diligence measures, VSS should pay close attention to necessary changes in their theories of change in order to maintain their status and relevance. Alternatively, VSS could intentiously separate themselves from regulations in the future, by guaranteeing a standard level above the legal minimum. * Private–public cooperations should be intensified in innovative ways to increase the effectiveness of value chain initiatives. * VSS should not be promoted in an export-oriented strategy only, as they are also a way to make domestic markets more sustainable and increase consumer consciousness about sustainability

Table 4 (continued)

Count	Title	Author(s)	Year	General policy recommendations
22		Navarrete-Cruz, Angela; Birkenberg, Athena	2024	* For governance mechanisms between farmers and traders to advance sustainability goals and enhance resilience in AVCs four propositions were developed: (1) Hybrid forms based on relational contracts enhance resilience and adoption of sustainability approaches, while hybrid forms based on formal contracts contribute to the implementation of sustainable practices but may jeopardize resilience. (2) The effect of formal contracts on resilience could be lessened by the implementation of plural forms. (3) Sustainability standards foster collective action efforts among farmers and between farmers and midstream segments, while engaging different types of actors in the segment farmers-traders enhancing the resilience of AVCs. (4) Complex incentive structures that include ethical incentives to adopt sustainability practices could boost both the implementation of sustainability approaches and resilience in AVCs
23	How Do Governance Mechanisms Between Farmer and Traders Advance Sustainability Goals and Enhance the Resilience of Agricultural Value Chains?	Alba Verduzco, Javier Eugenio García de; Barbosa, Samuel Borges; Hernandez, Blanca Catalina Ramírez; Moro, Leila Dal; Rodríguez, Luis Enrique Lomelí; Brandli, Luciana Londero; Deggau, André Borchardt; Peixoto, Maria Gabriela Mendonça; Navarro, Angélica Isabel García; Sehnem, Simone; dos Guimarães Alvim Nunes, Viviane; Andrade Guerra, José Baltazar Salgueirinho Osório de	2024	* Policy recommendations for Latin American context. * Measures should be aimed at improving farms and farmers' skills in managing their businesses. * Policy should establish a support system for producers, including provision of financing and guidance to better production. * Regarding certification, the organization of farmers in cooperatives should be encouraged for improvement of production practices and access to supplies. * On managerial implications regarding certification standards, it is advised to maintain certification cost affordable to small family farmers and create public–private partnerships taking regional specifics into account in order to maximize impact
24	Proposal for a Social Certification Model for Agriculture in Latin America Aligned with the Sustainable Development Goals	Grunert, Klaus G.; Seo, Han-Seok; Di Fang; Hogan, Victoria J.; Nayga Jr., Rodolfo M.	2024	* Providers of sustainability information to consumers and policy-makers wanting to promote sustainable choices should keep in mind potential wear-off effects of the information and focus on ways to remain relevant for consumers. * Further research into the topic should be invested in to better understand how information supporting repeat choices should differ from information supporting first time choices

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