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Governance and trust in sustainability-based agri-food value chains. A comparative analysis of five cases in Germany

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Value chains that generate an increased willingness to pay among consumers by offering enhanced levels of sustainability are widely discussed as an important strategy for creating new business opportunities and fostering food system transformation. Previous research has highlighted the importance of governance arrangements to secure the trust necessary for the establishment of sustainability-based value chains. However, how different coordination designs by private and public actors along the value chain affect trust formation is not well understood. To address this question, this paper combines the concepts of hybrid governance and multidimensional trust to guide a comparative analysis of five sustainability-based agri-food value chains in Germany as exemplary case studies. The findings show that different types of governance activities are necessary to build the capacity to address four different sources of trust: dispositional, affinitive, rational and procedural trust. Building trust capacities facilitates coordination of activities along the value chain and reliable delivery of sustainability-related value propositions. In all five cases, governance arrangements and building of trust capacities were geared towards increasing willingness to pay. Sustainability-based agri-food value chains have therefore limited potential to internalize the agri-food sector's substantial negative externalities.

KEYWORDS

credence goods, information asymmetries, hybrid governance, trust, coordination, external effects, food systems, transformation

1. Introduction

Value chains built on special sustainability merits such as high levels of biodiversity protection, animal welfare, water protection or good labor conditions are currently discussed as an important strategy to transform agricultural and food systems towards more sustainability while maintaining or even increasing farm income (Ruben et al., 2021). Increasing both sustainability and farm income at the same time, however, will in most cases require a higher willingness by consumers to pay for the products (Nuppenau, 2019), which is typically generated by value propositions that pair claims to product quality and sustainability benefits. To deliver on such complex value propositions, coordination is required along the entire value chain (Carbone, 2017).

Encompassing a broad range of activities needed to transfer a good or service from production to consumption (Porter, 1985), value chains constitute “complex systems comprising networks of interdependent actors that cooperate and create value” (de Vries et al., 2022). Forming and maintaining value chains entails various challenges, which depend, *inter alia*, on product types, market conditions, stakeholder structure and environmental factors (Peterson, 2009). Sustainability-based agri-food value chains must not only solve problems in production modes, management practices, technological innovations, and consumer behavior (Pérez-Mesa et al., 2019) and acquire capacities in leadership, innovation, entrepreneurship, knowledge and learning (Peterson, 2009; Braun et al., 2022); similarly important is overcoming information asymmetries which arise from the sustainability claims at the core of the value proposition. The sustainability attributes refer to process characteristics which cannot be verified by customers through sensory experience of the product at the point of sale; this is a general characteristic of credence goods (Gachukia, 2015). The ensuing information asymmetry enables fraud and can lead to a collapse of markets or prevent their development in the first place (Akerlof, 1970). It generates a problem of trust which occurs along the entire value chain. Governance arrangements are needed to assure buyers at each stage of the value chain that the sustainability claims can be trusted (Anania and Nisticò, 2004).

Consequently, the interplay of governance and trust in agri-food value chains has been identified as a major challenge for research and practice (Pilbeam et al., 2012; Ingram et al., 2018; van Bers et al., 2019; Fielke et al., 2020; Assis et al., 2022; de Vries et al., 2022). Value chain governance typically comprises various modes of steering, for example, hierarchical or market coordination (Pilbeam et al., 2012; Ingram et al., 2018; Kataike and Gellynck, 2018). The governance of agri-food value chains is closely linked to food regulation and often involves a “hybrid” interplay of actors from the public, private and civil society sectors (Marsden et al., 2009; Verbruggen and Havinga, 2018). From the perspective of the value chain actors, the main purpose of value chain governance is coordination of activities to create business opportunities, while public and civil society actors are typically more interested in food safety and health, consumer protection and sustainability. Trust in product safety and the reliability of sustainability claims links both sets of interests. Suitable governance arrangements are a precondition to create and preserve trust.

This paper addresses the question how governance arrangements generate and maintain trust in sustainability-based agri-food value chains. For this purpose, we combine a hybrid governance perspective with a multidimensional concept of trust (Stern and Coleman, 2015; de Vries et al., 2019). We aim to understand how governance arrangements in agri-food value chains address different sources of trust and which capacities the value chain actors deploy for this end. We develop a conceptual framework on the relationship between value chain governance, trust formation and value chain capacities and conduct a comparative analysis of five agri-food value chains in Germany. We thereby aim to contribute conceptually and empirically to current discussions on hybrid governance (Verbruggen and Havinga, 2018) and the role of trust in value chains built on special sustainability claims (de Vries et al., 2022), with a view to understanding the role of such value chains in the sustainability transition of the agri-food sector (Marsden, 2013; Brunori et al., 2016; Ruben et al., 2021).

The remainder of this paper proceeds as follows. Section 2 sets out the conceptual framework to analyze the links between agri-food value chain governance and trust formation in agri-food systems. Section 3 describes the methodological approach of the comparative case analysis. Section 4 presents the findings from five agri-food value chains in Germany, in particular the impact of governance arrangements on trust formation, and on the required trust capacities. Section 5 contextualizes the results with current discussions on (hybrid) governance of the transformation in agri-food systems.

2. Conceptual framework

2.1. External effects in agri-food value chains

Agri-food value chains have been conceptualized in different ways (Donovan et al., 2015): first, based on Porter (1985), as the various activities to produce, process, trade and consume an agricultural product (Theuvsen and Spiller, 2007); second, as a set of actors connected through interactions (Riisgaard and Ponte, 2011); third, as networks of actors (da Silva and de Souza Filho, 2007). These conceptualizations are complementary since the activities are carried out by actors who are connected in networks (Donovan et al., 2015). Consequently, de Vries et al. (2022) define agri-food value chains as

“complex systems comprising a network of interdependent actors that cooperate to capture and create value by responding to consumer demand through a wide range of practices [...] including production, harvesting, bulking, processing, trading, packaging, and retailing of food.” (de Vries et al., 2022, p. 176)

Agri-food value chains are embedded in natural and institutional environments, that is, the broader agri-food system (Hospes and Brons, 2016), where they might create external effects, describing costs or benefits which are not reflected in the price of the products (Eriksen, 2008). These can be either positive, such as provision of food security, ecosystem services or regional development (Ingram et al., 2018), or negative, for example, through resource depletion or pollution. The market failure induced by these external effects is the main rationale underlying calls for a transformation of the governance of agri-food value chains (Ingram, 2011) and food systems more broadly (Ruben et al., 2021).

Many external effects of agri-food value chains originate from the fact that agricultural systems provide not only private but also public goods (Meuwissen et al., 2019). While there are markets for the former, the latter, for example attractive and diverse landscapes, have long been taken for granted as by-products of farming (Ebert, 1998). Many agricultural activities, however, have detrimental effects on the condition of public goods such as climate, biodiversity, water quality and landscape amenity. Public policies have attempted to reduce negative externalities through regulation and financial remuneration of less damaging practices (Nuppenau, 2019), for example through the integration of environmental objectives and instruments in the Common Agricultural Policy (CAP) of the European Union (Feindt, 2010; Grohmann and Feindt, 2023). In parallel, markets have developed where some consumers are willing to pay higher prices for products with higher positive externalities and/or lower negative

externalities, organic products being a prime example. Many of the sustainability claims in these value chains directly address the provision of public goods or reduced negative externalities. Increasing interest and willingness to pay for goods produced with increased sustainability benefits has been observed if the benefits are credibly communicated (Hemmerling et al., 2015).

However, the sustainability claims made by producers, processors and sellers can usually not be verified at the point of sale. The “sustainable” products are credence goods, which means that individual consumers cannot check the attributes which are decisive for the purchasing decision and the higher willingness to pay without incurring prohibitively high costs (Anania and Nisticò, 2004). The ensuing information asymmetry between the value chain actors (Shen et al., 2019; Vosooghizajji et al., 2020) inhibits the development of markets for such goods (Akerlof, 1970) unless suitable governance mechanisms create trust in the reliability of claims (Gachukia, 2015).

2.2. Coordination activities in agri-food value chain governance

Governance in agri-food chains entails the multiple steering mechanisms that coordinate the activities among the value chain actors (based on: Havinga et al., 2015; Ingram et al., 2018). Coordination is normally enabled through rules that codify expectations and obligations. While simple value chains with low levels of risk involved and patterns of frequent interaction might work based on informal rules, coordination in more complex value chains usually requires formal rules. Generally, coordination activities in agri-food value chains must fulfill five essential functions (Abbot and Snidal, 2009; Havinga, 2015; see Table 1): *Rule-making* involves agenda setting, defining goals, as well as negotiating and formulating concrete rules. If the political, social or economic environment changes, the objectives and rules may need revision or reformulation. The second and third coordination activity are *adoption* and *implementation* of the rules. This typically involves a formal process that obliges suppliers and customers to comply with the rules, and instigating the measures necessary for compliance. *Monitoring* the rules generally requires the periodic conduct of tests, inspections, and audits, the certification of products, and the ongoing documentation of the measures or product

characteristics specified by the rules in order to be able to track misconduct. *Enforcement* of the rules includes various forms of internal sanctions, such as warnings, contractual penalties or withdrawal of certification, but also legal sanctions that must be enforced in court. The sanctions must be defined in the rule system to be behaviorally effective and generate legitimacy.

The increasing complexity and internationalization of contemporary food value chains is mirrored by a proliferation of governance activities that complement national public regulations, such as private and international standards and regulatory systems, a process that has been described as “hybridization of food governance” (Verbruggen and Havinga, 2018). Hybrid governance arrangements imply an interplay of private and public actors within each of the coordination activities and between two or more activities (Verbruggen and Havinga, 2015). An example of the former is the joint development of standards by government institutions and farmers’ associations; an example of the latter would be the delegation of monitoring of government standards to private institutes. Importantly, while the five functions of coordination activities logically build upon each other, in practice the activities are often overlapping or cyclical.

2.3. Trust in sustainability-based agri-food value chains

The five functions and coordination activities in hybrid food governance create conditions that enable collaboration by reducing the risk of investing in activities that create benefits only if the expected behaviors of others are fulfilled – for example, if the wholesaler pays the expected higher price for sustainably produced crops. All five functions are therefore directly relevant for the creation and maintenance of trust along the value chain. While trust has been studied by many disciplines, the basic conceptualization is “not so different at all” (Rousseau et al., 1998). The notion of trust mostly refers to a willingness to accept vulnerability regarding the outcomes of an interaction, based on positive expectations about the intentions or behavior of others (Mayer et al., 1995; Bauer, 2021). From a systems theoretical perspective, trust reduces complexity in social interactions, as does distrust, but with different outcomes (Luhmann, 1988).

The *functions* of trust in agri-food value chains have been widely discussed. Trust is seen as a prerequisite for interactions and commercial success (Troy et al., 2016), an enabler of collaboration (Mankad et al., 2017; Dania et al., 2018) that also helps to reduce transaction costs (Bair, 2008; Martino, 2011), and a facilitator of the sustainability performance in agri-food value chains (Chen et al., 2017). However, few connections have been made to the literature on the *formation* of trust. Mayer et al. (1995) focus on personal characteristics, including the ability, benevolence and integrity of an actor. De Vries et al. (2019) distinguish between trust based on personal relationships (“trusting the people”) and trust based on perceptions of the institutional frameworks as reliable (“trusting the system”). Stern and Coleman (2015) differentiate even four possible sources of trust (see Table 2): (1) Dispositional trust describes the propensity of individuals to trust institutions, organizations, office holders, or other people. (2) Affinitive trust is based on shared experiences, values, identities or networks. (3) Rational trust is built on a calculation of expected benefits and risks based on the information available at the time and on fulfilled or disappointed

TABLE 1 Functions and coordination activities in agri-food chains.

Function	Coordination activity
Rule making	Agenda setting Determining the objectives Negotiating and drafting concrete rules
Adoption	Adopting the rules Imposing the rules on value chain actors
Implementation	Implementing the rules and measures
Monitoring	Testing, inspecting, auditing Certifying Documenting Tracing non-compliance
Enforcement	Internal sanctioning Legal sanctioning

Own representation based on Havinga (2015, p. 32).

TABLE 2 Types and sources of trust.

Type	Sources
Dispositional trust	Institutions and organisations Positions People
Affinitive trust	Shared experiences Shared values and identities Shared networks
Rational trust	Information on expected benefits and costs Fulfilled expectations in the past
Procedural trust	Procedural legitimacy Transparency Fairness

Own representation based on Stern and Coleman (2015, p. 122).

expectations in the past. (4) Procedural trust refers to the perceived legitimacy, transparency and fairness of procedures and processes that allow reliable predictions to be made about the behavior of others.

Research on trust in agri-food value chains has focused on consumers' trust (Macready et al., 2020), particularly in single actors along the food chain, for example, farmers (Moore, 2006), manufacturers (James, 2006) or retailers (Rampl et al., 2012). Previous studies on the relationship between trust and governance in agri-food value chains have concentrated particularly on the potential of market, hierarchical or hybrid governance to reduce transaction costs (Martino, 2011), whereas limited attention was given to the differentiation of individual governance activities (for a recent exception, see: Weber and Wiek, 2021) or to different types of trust.

3. Materials and methods

To address the research question of how governance arrangements generate and maintain trust in sustainability-based agri-food value chains, we have conducted a comparative analysis of five cases in Germany, based on a qualitative analysis of documents and in-depth expert interviews. Such a research design is well established in studies of trust in agri-food value chains (de Vries et al., 2022). Comparative analyses allow for a systematic comparison of specific phenomena (Chen et al., 2021; Michel et al., 2022), while considering their concrete contexts in order to contribute to a better understanding of the phenomena under investigation (Yin, 2017). They permit to generate new insights for the further development of conceptual considerations on the basis of empirical findings (Flyvbjerg, 2006).

3.1. Case selection

The selection of the five cases of sustainability-based agri-food chains followed a systematic approach. As a first step, we conducted a desk research and compiled a database of 50 projects, brands, initiatives and companies in Germany that claim to commercialize agricultural products with special sustainable characteristics (see Supplementary material A). Only agri-food chains in Germany were included to ensure similar market conditions as well as economic and institutional frameworks across cases. Economically, Germany

provides relatively favorable conditions due to relatively high demand and willingness to pay for sustainably produced food. The institutional framework is shaped by the EU's CAP, which provides income support for farms that is made conditional to compliance with basic environmental, health and animal welfare requirements as well as financial remuneration of more sustainable farming practices, for example, support of organic farming or agri-environmental and climate measures. Despite the inclusion of many sustainability-related goals and instruments in the CAP, negative externalities of agriculture in the EU have not been effectively internalized (Pe'er et al., 2019). This persisting market failure allows products from unsustainable production systems to dominate the market and thereby provides the space and rationale for sustainability-based agri-food chains.

Five characteristics were recorded for each of the 50 agri-food chains included in the database: product type, sales channel, sustainability claim, number of different groups of value chain actors (for example producers, processors, retail) and coordinator. The recorded examples showed very different combinations of characteristics. We selected five cases following the principle of contrast (sampling of extreme cases) which means the aim was to achieve the greatest possible dissimilarity with regard to the characteristics (Silverman, 2017, p. 268) and to include different forms of sustainability-based value chains. One of the authors pre-selected 10 possible cases from the 50 recorded examples, with value chains representing a broad range of different product types, sustainability benefits (according to self-representation of the initiatives) and governance arrangements (sales channels, number of different value chain actor groups and coordinators). The pre-selected cases were discussed by the entire project team and five cases were selected which present the strongest possible contrast along the characteristics. The result of the case selection is summarized in Table 3 which shows the five cases and their characteristics.

3.2. Description of the cases

The first case, *Wasserschutzbrot* ("water protection bread"), is a project of the district government of Lower Franconia (South Germany) that started in 2014 as part of the overall strategy on groundwater protection by the Bavarian state government (Regierung von Unterfranken, 2021). The overarching goal of this strategy was to enhance the quality of drinking water across Bavaria by reducing nitrate pollution from intensive fertilization in the regional farming sector. The project successfully developed an agri-food value chain: Participating growers of baking wheat – numbering 35 at the time of the study – must skip the last nitrogen application before harvest, which can reduce nitrate leakage into groundwater by 25%–75%, depending on weather conditions. However, omitting the so-called "quality fertilization" reduces the protein level of the wheat by up to 1.5 percentage points to around 11%, which would normally result in lower sales prices. At the first stage of processing, the mills are contractually obliged to pay participating farmers the regular market price, which is normally reserved for quality wheat with a protein level of about 13%. Additionally, mills are required to store and grind the grain on separate processing rails. At the retail level, 36 artisan bakeries participated when the study was conducted. They must process and bake the flour separately and can then market the bread under the brand *Wasserschutzbrot*. A sufficient number of customers have been

TABLE 3 Case selection for the comparative analysis.

Case name	Product type	Sales channel	Sustainability claim	Number of actor groups	Coordination
Wasserschutzbrot	Pastry and bakery products	Artisan bakeries	Water protection	Five	Regional government
Landwirtschaft für Artenvielfalt	Various	Food retailers	Biodiversity protection	Five	Civil society organization
Waldgarten	Vegetables fruit eggs sheep products	Direct marketing	Various (e.g., biodiversity protection, animal welfare)	Two	Producer
Du bist hier der Chef	Milk	Food retailers	Animal welfare	Five	Private company and civil society organization
MoorFutures	Carbon certificates	Private certificate market	Climate protection	Four	State government

willing to pay a higher price for this product. Apart from protecting drinking water, the project also aims to raise awareness among producers and consumers and to promote regional development.

The second case, *Landwirtschaft für Artenvielfalt* (“farming for biodiversity”) is a project jointly initiated by the nature and environmental protection organization World Wide Fund for Nature (WWF), the German organic farming association Biopark e.V., and EDEKA, one of the four leading food retailers in Germany. The Leibniz Center for Agricultural Landscape Research (ZALF) provides scientific advice. As part of the project, the scientists from ZALF developed a catalog of conservation measures intended to increase the diversity of wild species on areas of organically managed farms (Gottwald and Stein-Bachinger, 2018). At the time of our study, 60 organic farms in Germany were participating. The implementation of this conservation measures that are presented in the catalog as particularly effective in addressing biodiversity benefits was in some cases associated with higher costs compared to standard organic farming practices. The farms receive an additional certification that enables them to receive a higher price when selling their products through the sale channels of the established value chain. The retailer EDEKA guarantees the purchase of the various products of the participating farms and offers products for sale using a special logo.

The third case, *Waldgarten*, represents an organic farm located in the Prignitz region of Brandenburg in Northeast Germany (SoLaWi Waldgarten, 2021) that operates a community-supported agriculture (CSA) finance and marketing model (Fomina et al., 2022). The farm exists since the mid-1990s and is run as a CSA since 2012. Since then, an increasing part of the products (e.g., vegetables, fruit, chicken, and sheep products) is marketed through the CSA structure. In addition, other channels such as direct marketing are also used, although their share is steadily decreasing. Under the CSA structure, the farmer and the members of the CSA group jointly determine the budget for the upcoming year at an annual plenary meeting. Membership is obtained by purchasing one or more shares of the harvest per year. In anonymous bidding rounds, the members are increasing their offers until the necessary budget has been secured. This mechanism results in different prices being paid per share, which is considered as an expression of solidarity among the group members. At the same time, upfront financing hedges the risks of agricultural production, for example yield losses due to calamities, or widely fluctuating producer prices. The members’ advance payments provide also a secure remuneration of the

agricultural labor in exchange for a guaranteed share of the harvest. At the time of the study, one share cost 92 euros per month on average and included a weekly delivery of harvested products to nine self-managed pick-up points in the cities of Berlin and Potsdam. The production system combines arable farming and grassland (with mowing and grazing areas), and trees and shrubs (following the principles of permaculture). On this basis, *Waldgarten* claims to provide multiple sustainability benefits in addition to food production, for example, contributing to biodiversity protection through the abandonment of chemical-synthetic methods of crop protection, soil protection and increased water retention capacity through enhanced humus formation, or animal welfare through extensive grazing.

The fourth case, *Du bist hier der Chef* (“You are the boss here”), is a brand aiming to “give control over their food back to consumers” (Du bist hier der Chef, 2021). The brand describes itself as a “consumer initiative”,¹ as it develops, produces and markets agricultural products on the basis of votes by consumers. The initiative acts as a broker. Through an internet-based consultation tool, interested members of the public (prospective customers) “vote” on specific production conditions of pre-selected agricultural products (e.g., the type of feed, standards for animal husbandry, price to be paid to the farmer), which are explained with indicative costs. Based on the results, the broker determines a product profile with criteria and prices (producer price and final sales price) and looks for agricultural producers, processors and retailers willing to produce, process and market the conceived product. Between the launch of the initiative in Germany in June 2019 and the time of our study, characteristics of one product (milk) were determined, which subsequently went on sale under the initiative’s brand logo in various outlets of several food retail chains. With the selected characteristics for fresh milk, the initiative claims to contribute to more animal welfare as the cows are fed predominantly with fresh fodder, spend more than 4 months on pasture, and have increased opportunities for physical movement and social contact compared to legal standards. At the time of the interviews, the initiative planned to add more agri-food products (such as eggs and potatoes) to the portfolio.

1 The idea of the initiative originated in France, where consumer-created products have been successfully marketed in food retail under the consumer brand “C’est. qui le patron?!” since the end of 2016.

The fifth case, *MoorFutures*, represents a brand for carbon certificates offered on the voluntary carbon certificate market. The project was developed by what was then the Ministry of Agriculture and Environment in the German state of Mecklenburg-Vorpommern in collaboration with the University of Greifswald ([Ministerium für Landwirtschaft und Umwelt Mecklenburg-Vorpommern, 2017](#)). The project was implemented by the public settlement company of the state of Mecklenburg-Vorpommern (Landgesellschaft Mecklenburg-Vorpommern mbH). The general goal of the project is to harness the potential of rewetted peatlands to reduce CO₂ emissions. Revenue from the sale of *MoorFutures* is used to fund projects to rewet peatlands that have been drained for agricultural or forestry use. In addition to emission reduction, the regeneration of peatlands is expected to contribute to the protection of further ecosystem services, for example, in the field of water regulation and biodiversity protection ([Joosten et al., 2013](#)). Since the brand was established in 2011, three rewetting projects have been implemented in the state of Mecklenburg-Vorpommern (Polder Klieve, Kamerunwiese, Gelliner Bucht). In addition, the federal states of Brandenburg (in 2012, project Rehewiese), Schleswig-Holstein (in 2014, project Königsmoor) and Lower Saxony (in 2020, pilot project Seemoorwiesen) acquired licenses to use the brand. At the time of writing, *MoorFutures* projects covered an area of 130 hectare. The projects are accompanied by research projects from regional scientific institutions, which carry out the monitoring, for example, evaluating the emission reductions. Certificates can be purchased by individuals, companies or institutions to voluntarily offset emissions. The price is based on the costs required to avoid one ton of CO₂, which includes the costs for project planning and approval procedures, possible compensation to land owners, construction and monitoring of the climate impact.

3.3. Data collection and analysis

To complement the findings from the desk research, we conducted two sets of semi-structured interviews: with the persons identified as the coordinator in each of the five cases, and with six experts on sustainable agri-food value chains. The five coordinator interviews were carried out by two of the authors between 17th September and 11th October 2020. They lasted between 50 and 110 minutes. The aim of the interviews was to corroborate the information obtained in the desk research. A special focus was set on the governance arrangements in the respective value chain and trust-building mechanisms. The interview guideline was structured along four thematic focal sections (for a translated version of the interview guideline, see [Supplementary material B1](#)). First, we asked for general information about the history of the project, initiative or brand, its functioning, and the actors involved. The second section addressed the sustainability claims made and the measures implemented in order to deliver them. Based on the conceptual considerations on governance activities and trust, sections three and four of the interview guideline focused on the design of coordination activities and the strategies used in the respective value chain to build trust. The interviews were recorded and fully transcribed. The raw data were analyzed by two of the authors, using a computer-assisted qualitative data and text analysis program (MAXQDA) along a unified coding system that included both deductive and inductive codes (for a translated version of the coding system, see: [Supplementary material B2](#)). In the first

round of coding, information on the value chain and claimed sustainability attributes was identified. The second round of coding focused on statements regarding coordination activities. This procedure made it possible to extract the key statements from the five interviews into a uniform system and then compare them. For the comparative analysis, we assigned each of the identified coordination activities in the five cases to the different sources of trust (see Section 2). The results of the data analysis were iteratively discussed and interpreted among the team.

The six interviews with scientists and experts from administration were conducted by two of the authors in order to discuss and validate the results of the comparative case analysis. They took place between 14th December 2020 and 11th January 2021 and lasted between 60 and 100 min. A second semi-structured interview guideline was developed to ensure that the earlier findings from the project were systematically discussed and that the experts had sufficient opportunity to express their own considerations. The guideline included three main thematic blocks: sustainability in agri-food chains; trust-building governance arrangements and activities; and policy interventions (for a translated version of the interview guideline, see: [Supplementary material B3](#)). Transcripts of the full interviews were analyzed by two of the authors, using MAXQDA along a uniform code system (for a translated version of the coding system, see: [Supplementary material B4](#)). In a first round of coding, the statements on sustainability-based value chains were evaluated in order to arrive at a consolidated definition of the concept. The second round focused on the responses to our findings regarding trust-building governance activities. In the third round, the experts' statements about necessary support and assistance were evaluated. This procedure allowed us to extract the relevant statements of the six experts into a uniform system. As with the first set of interviews, the results of the data analysis were iteratively discussed and interpreted among the members of the team.

4. Findings

4.1. Design of the coordination activities

In the first case, *Wasserschutzbrot*, the initiative for establishing the sustainability-based agri-food value chain originated from the Bavarian state government. In order to implement the measures decided at the state level, the district government of Lower Franconia, a subordinate authority of the federal state of Bavaria, appointed an administrator as project coordinator. The selected coordinator had professional experience in the agricultural administration and was well connected in the region. To initiate the project, the coordinator approached selected farms, mills and bakeries known from other professional and personal contexts to explore their interest in participating in the new value chain and to discuss the conditions for a possible cooperation. Further participants were acquired through the establishment of personal contacts by the project coordinator and already participating farms, mills and bakeries. The rules were developed and formulated during a participatory workshop facilitated by the project coordinator, resulting in four criteria for each stage of the value chain, now available online ([Regierung von Unterfranken, 2021](#)). All project partners commit to the implementation of these rules by signing a declaration. The coordinator serves as a networking and coordination hub. Network meetings are organized twice a year,

often combined with a visit to a participating mill or farm. The project coordination also carries out educational work with schools and centers for adult education (for example, providing learning materials and organizing informational events and excursions). A professional communication service provider designs information material, for example signboards for display at participating farmers' fields, flyers and commercials for the sales outlets. Participating value chain actors have specific documentation obligations, for example on processing quantities. These are controlled by the independent Research Institute for Organic Farming (FiBL) which also provides technical advice for the project coordination. If a violation of the established criteria is detected, the project coordination issues a written warning. The sanction for repeated violations is exclusion from the project and the value chain, and any project-related information materials (field boards, flyers, displays) must be returned.

The project *Landwirtschaft für Artenvielfalt* was initiated by the then director of the organic farming association Biopark e.V., who approached representatives of WWF and EDEKA to jointly develop the project framework and objectives. Using his personal contacts, he also recruited a number of organic farms to participate in the early stages of project development and to give feedback on the outlined project. To date, a prerequisite for participation in the project on the part of the farmers is membership in an organic farming association. To secure scientific expertise in nature conservation, the Leibniz-Center for Agricultural Landscape Research (ZALF) was included, especially advising on the constantly evolving rules for conversation and land management practices. Participating farmers receive advice in selecting and implementing nature conservation measures tailored to their farm and natural conditions. As part of the project, 12 advisors were specifically trained for this purpose. Cooperation of the value chain actors is facilitated by a coordination framework and individual cooperation agreements. An important component of the project is the communication of the conservation measures by means of a project website, a product logo, QR code tracking tools on the products and farm signboards and posters for direct marketing. Compliance with the criteria and implementation of the measures is verified during the annual inspection by the organic farming associations. Subsequently, each farm receives follow-up consultation during which the conservation measures are jointly reviewed and optimized. In case of violations of the rules, a farm can be excluded from the project, thereby losing the possibility to market their products with the project logo and through the project's sales channels.

Waldgarten was initiated by a farm manager in search of new marketing channels. He established a CSA structure for parts of the farm's products with the aim to develop a producer-consumer community, building on existing contacts with consumers from direct marketing. Objectives and concrete rules are formulated in an ongoing process between the producer and the members of the CSA, which comprises various formats, in particular an annual plenary meeting (which includes the bidding round for next season's shares), continuous thematic working groups and three to four joint farm visits per year. The agreed framework conditions of the producer-consumer community are laid down in a 10-point plan, which, along with the specified monetary contribution and the acquired share of the harvest, becomes the subject of an annual contract between the farmer and each individual member. The 10-point plan sets out general commitments among the CSA members that can be adapted during the annual plenary meetings. The CSA is based on the farm's

operation in accordance with the requirements of an organic farming association, which is verified by the organic farming inspection body (organic certification). In addition, members of the CSA can convince themselves of the farm's compliance through direct exchange with the producer within the mentioned formats.

In the case of *Du bist hier der Chef*, the value chain is coordinated by a company and an association registered in Germany. The association is responsible for overseeing the consumer initiative and serves as a platform for networking. Responsibility for product development, contracting partners and marketing lies with the company. Any person can become a member of the association for a symbolic fee of 1 euro. In the example of the milk product, possible criteria and prices were developed by the company, involving potentially cooperating farmers and dairies. The final decision on production conditions was made by online voting, organized by the association. The rules for the milk include, *inter alia*, organic production, animals grazing on pastures, a producer price of 0.58 euros per liter (fixed for 3 years), and sustainable packaging that is climate-neutral through emissions-offsetting (*Du bist hier der Chef*, 2021). The selected criteria are stipulated in a product brief (*Pflichtenheft*) which forms the basis for the contractual agreements of the company with the farms, dairies and food retailers and must be implemented by all contractual partners. Compliance is monitored by an external auditing institute based on documentation of quantity flows and prices (for example, delivery bills). In addition, farm and dairy visits are offered to association members. At the time of this study, all 15 participating farms were members of an organic farming association, which entails annual controls under the framework of the organic farming regulation. The sanction mechanism in case of non-compliance with the specified criteria is non-payment.

In the fifth case, *MoorFutures*, the initiating and coordinating Ministry of Agriculture and Environment in the German federal state Mecklenburg-Vorpommern could build on positive experiences with a previous reforestation project. The Ministry aimed to create emission certificates for rewetted peatlands. For this purpose, the University of Greifswald developed a standard which is based on the internationally used Verified Carbon Standard. Besides this standard, the planning procedures foreseen under water protection legislation provide the legal basis for the rules formulated during the development of the trademark (*Ministerium für Landwirtschaft und Umwelt Mecklenburg-Vorpommern*, 2017). The implementation of the projects in the state of Mecklenburg-Vorpommern is coordinated by the state-owned public settlement company and includes the contract negotiation with land owners (land register entry of the water level to be tolerated) as well as the implementation of the construction measures by the state-owned construction companies. There are also awareness-raising measures, for example, information events and publications conducted by the Academy for Sustainable Development in Mecklenburg-Vorpommern and the Greifswald Mire Centre. Knowledge exchange between projects is supported by a cross-state project working group. The projects are subject to scientific monitoring by academic institutions in the respective federal states to ensure that the intended emission reductions have actually been realized (*Couwenberg and Michaelis*, 2015). If the emission reduction promised with the sale of the certificate is not achieved (which has not occurred so far), the shortfall has to be matched by purchasing carbon credits from other sources.

4.2. Formation of trust through the design of the coordination activities

The comparative analysis of the five cases has found considerable differences in the coordination activities regarding rule making, adoption, implementation, monitoring and enforcement. We now turn to the effects of the coordination activities on the formation of trust. As Table 4 shows, the coordination activities address the four types and sources of trust distinguished in Section 2.3 in different ways.

In *rule making* (agenda setting, defining the goals, and negotiating and formulating the concrete rules), trust was primarily established through the involvement of governmental institutions, scientific

advice and civil society actors. These strategies addressed *dispositional trust*. In addition, participatory procedures either in criteria development or in decision-making on production and processing strengthened procedural legitimacy and thus *procedural trust*. Furthermore, personal contacts and recourse to shared values, identities and networks served to build on and further establish *affinitive trust* between the various actors involved. The coordinating actors had great importance in creating trust among all members of the value chain. In the five cases, the coordinating role was filled by a person who acted on behalf of a company or a government agency. In all cases, personal credibility and networking abilities were decisive for the establishment and maintenance of trust within the value chain

TABLE 4 Comparative analysis of coordination activities and the addressed sources of trust.

	Wasserschutzbrot	Landwirtschaft für Artenvielfalt	Waldgarten	Du bist hier der Chef	MoorFutures
COORDINATION ACTIVITIES					
Rule making					
Agenda Setting	Governmental institution	Private actor (farming association)	Private actor (farmer)	Private actor/civil society	Governmental institution
Determining the objectives	Governmental institution	Various value chain actors	Participatory (producer-consumer)	Private actor/civil society	Governmental institution
Negotiating/drafting rules	Participatory (value chain actors)	Research institute	Participatory (producer-consumer)	Participatory (consumers)	Research institute
Adoption					
Adopting the rules	Contractual obligation	Contractual obligation	Contractual obligation	Contractual obligation	Contractual obligation
Imposing the rules	Networking, public relations	Public relations, research	Networking	Public relations	Public relations, research
Implementation					
Implementing measures	Training and qualification	Training and qualification	Networking	Networking	Networking
Monitoring					
Testing, inspecting, auditing	Research institute	Organic inspection, advisors	Networking, organic inspection	Organic inspection, networking	Research institute
Certifying		State seal, private certification	State seal and private certification	State seal and private certification	
Documenting	Research institute, governmental institution		Participatory (producer-consumer)	Private actor/civil society	Research institute, governmental institution
Enforcement					
Sanctioning	Written warning, exclusion	Withdrawal of certification, exclusion	Leaving/exclusion of the community	Consequences of non-fulfilment of contracts (e.g. non-payment)	Compensation
SOURCES OF TRUST					
Rule making					
Agenda Setting	Trust in institutions	Shared values and identities	Trust in people	Trust in institutions	Trust in institutions
Determining the objectives	Trust in institutions	Trust in institutions	Shared values, identities, networks	Procedural legitimacy	Trust in institutions
Negotiating/drafting rules	Procedural legitimacy	Trust in institutions	Procedural legitimacy	Procedural legitimacy	Trust in institutions

(Continued)

TABLE 4 (Continued)

	Wasserschutzbrot	Landwirtschaft für Artenvielfalt	Waldgarten	Du bist hier der Chef	MoorFutures
Adoption					
Adopting the rules	Procedural legitimacy, transparency	Procedural legitimacy, transparency	Procedural legitimacy, transparency	Procedural legitimacy, transparency	Procedural legitimacy, transparency
Imposing the rules	Shared experiences, networks	Information on expected benefits	Shared experiences, networks	Information on expected benefits	Information on expected benefits
Implementation					
Implementing measures	Shared values	Shared values	Shared experiences, networks	Shared experiences, networks	Shared experiences, networks
Monitoring					
Testing, inspecting, auditing	Information on expected benefits	Trust in institutions	Shared experiences	Shared experiences	Information on expected benefits
Certifying	Trust in institutions	Information on expected benefits	Trust in institutions	Information on expected benefits	Trust in institutions
Documenting			Shared experiences, networks	Trust in institutions	
Enforcement					
Sanctioning	Procedural legitimacy, fairness	Procedural legitimacy, fairness	Procedural legitimacy, fairness	Procedural legitimacy, fairness	Procedural legitimacy, fairness

relationships. Dispositional and procedural trust were important mainly for outside credibility towards customers and the public, while affinitive trust was significant for relationships inside the value chain, supported by procedural trust to reassure participants that they would be treated fairly.

For *rule adoption and implementation* in the value chain, contracting was the most important strategy to build trust in the procedures and processes, primarily addressing *procedural trust*. Value chain actors in all five cases made great efforts to provide and disclose information, for example, on the rules and criteria (for example, catalogue of services and criteria, specifications, 10-point plan). In addition, other types of trust were addressed through various adoption and implementation activities. For example, meetings and farm or processing plant visits aimed to build networks and to create shared experiences as dimensions of *affinitive trust*. Education and training measures such as additional conservation qualification or consulting services as well as public relation activities were carried out in order to facilitate the development of shared norms and values, primarily addressing the formation of *affinitive trust*. Finally, the strong emphasis in two cases on accompanying research and scientific advice in providing information on the expected benefits can support the activation of *rational trust*.

The value chain designs varied greatly with regard to the *monitoring* of the adopted rules. On the one hand, building on well-established control and certification systems or scientific monitoring facilitated the provision of information about the realization of expected benefits, which in turn allowed to communicate the value proposition credibly. These activities addressed *rational trust*, supported by *dispositional trust* in established control institutions. The importance of scientific monitoring, especially in the development of criteria and their monitoring is associated with two key challenges: first, the measurement of sustainability-related value chain features,

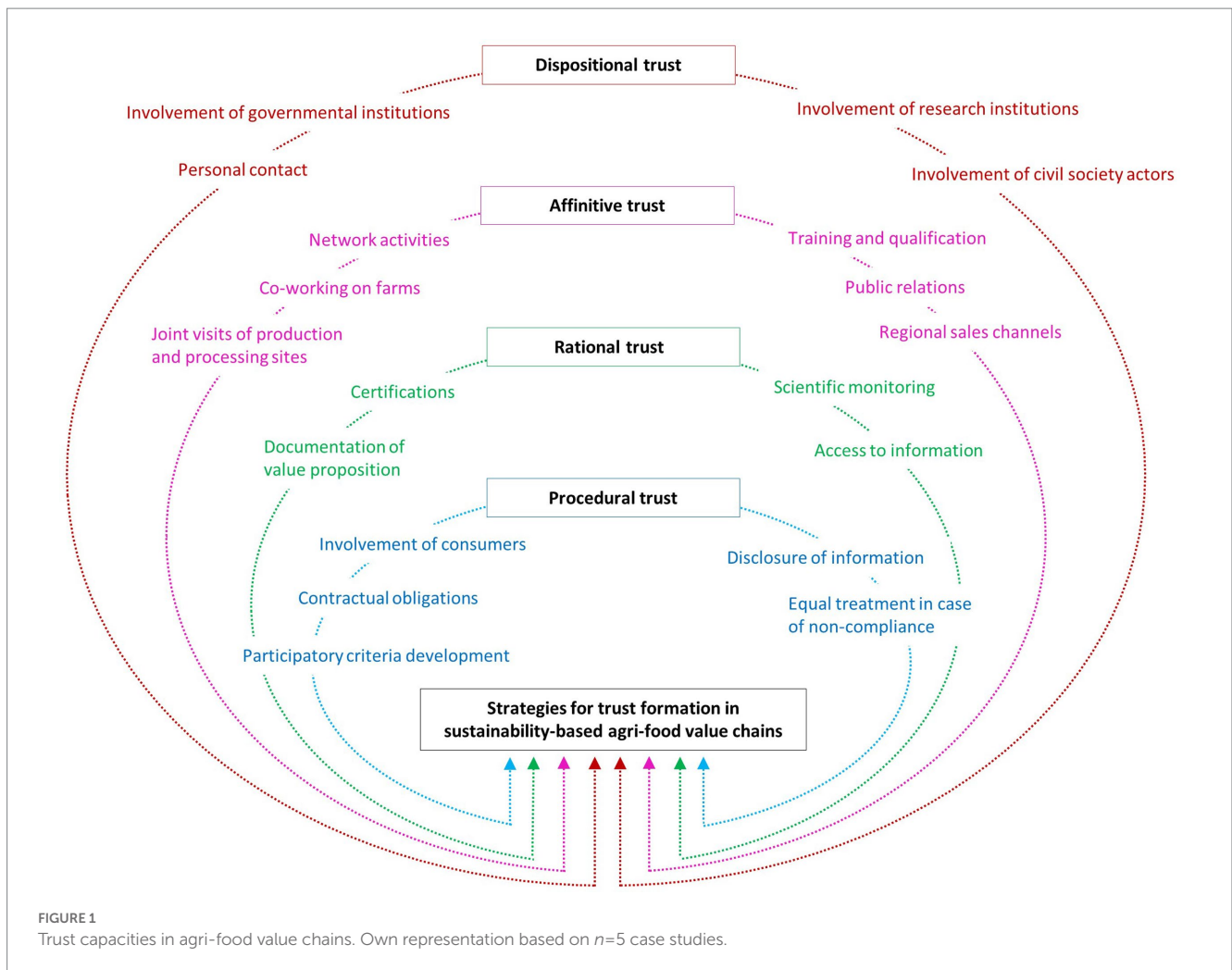
which is often discussed controversially, and second, communication of the monitoring results. Furthermore, various activities in the five cases aimed to strengthen compliance through shared experiences, for example visits to farms and processing sites. Such opportunities for personal inspection appeal to *rational trust* while the interaction could also contribute to *affinitive trust*.

In *rule enforcement*, the most important strategy for trust-building in all cases was ensuring perceived legitimacy and equal treatment in case of infringement. Non-compliance with the adopted rules regularly led to exclusion from the value chain, sometimes after written warnings. One case (MoorFutures) contained rules about compensation in case of insufficient performance. These activities addressed primarily *procedural trust*. The sanctions are important to reassure all participants as well as potential customers and the public that delivery of the value proposition is taken seriously. Even in smaller value chains, where compliance might be supported by social control and feelings of social connectivity, formalized systems of rule enforcement are necessary to ensure transparency, participation and fair treatment as dimensions of *procedural trust*.

4.3. Developing trust capacities

The analysis of trust formation through coordination activities found that the design of governance arrangements considerably affects the formation of trust along all stages of the agri-food value chains. Based on the comparative analysis of the five case studies, we mapped the various resources used by the value chain actors onto the sources of trust types (see Figure 1).

Addressing each of the sources of trust requires different capacities. In the five cases studied, building *dispositional trust* involved pre-existing personal contacts with relevant actors in the



value chain and the ability to involve government institutions, scientific institutions and civil society actors. Associated challenges are the availability of well-connected persons with relevant networks, and access to institutions with epistemic or institutional authority. Building *affinitive trust* required the capacity of value chain actors, in particular the coordinator, to tap into the social connectedness of actors along the value chain, potential customers and the public. Whereas public relations activities might go some way, the five case studies found numerous collaborative activities which also served to strengthen affinitive trust by building shared values and experiences. While significant financial and personnel resources might be needed to secure affinitive trust, reputation, that is, the perceived integrity and benevolence of individuals, is an indispensable resource that cannot be substituted by financial means. Addressing *rational trust* required the capacity to credibly communicate expected costs and benefits. This often involved recourse to the capacities of third parties, for example through independent certification or external monitoring. New technologies such as QR codes can facilitate access to relevant information, thereby strengthening transparency. However, establishing such systems can incur high costs for the technology and the certification. Addressing *procedural trust* required cognitive and organizational capacities to plan and coordinate the various activities along the value chain. Analytical and social capacities were needed to co-develop rules and procedures which ensure fairness and transparency. Legal skills were required to formalize them in a reliable

way. At a more abstract level, specific personnel resources are necessary which can be acquired if financial resources are available. Overall, the analysis shows that a broad range of different capacities was required in each case to ensure the trust needed at different levels to enable value chains based on sustainability claims.

5. Discussion

In this paper, we have analyzed the design of coordination mechanisms in five sustainability-based agri-food value chains in Germany to understand how their governance arrangements address the formation of trust. The selected cases were agri-food value chains based on claims that they contribute to sustainability merits, for example, the protection of biodiversity or environmental resources. Since such process claims cannot be verified by the consumer at the point of sale or by intermediate actors along the value chain, the ensuing information asymmetries are constitutive for credence goods. As a consequence, governance arrangements are required that enable trust in the veracity of the sustainability claims along the entire value chain. The selection of agri-food chains in Germany implies that their activities were embedded in institutional, political and cultural context conditions with relatively high levels of generalized trust (*World Values Survey, 2022*). Keeping in mind these limitations, four reflections emerge from our results that can contribute to broader discussions on

the governance of agri-food value chains and their possible contribution to transforming food systems towards more sustainability.

First, our analysis of agri-food value chains based on sustainability claims found that the actors involved in the coordination activities, including the making, adoption, implementation, monitoring and enforcement of rules, had backgrounds in the private, public and civil society sector. This finding resonates with the emerging research on “hybrid governance” arrangements in agri-food value chains (Verbruggen and Havinga, 2015), which are characterized by an interplay between private, public and civil society actors within the governance function (for example, participatory approaches in rule making or the delegation of monitoring to external control bodies or research institutes). Our results also confirm previous studies that have highlighted the importance of private standards in combination with third-party certification (Fulponi, 2006; Maloni and Brown, 2006), particularly to address negative externalities such as environmental degradation (Oosterveer, 2015). We also found support for claims that civil society actors are increasingly involved in the development of private standards since they can enhance the legitimacy of various claims (Raynolds, 2012).

Second, the results of the comparative case analysis show that the design of governance arrangements considerably affects the formation of trust along all stages of the agri-food value chains. Our findings indicate that a broad range of governance activities is used to activate different sources of trust. This observation is in line with earlier studies which emphasize the multidimensionality of trust (Stern and Coleman, 2015). Demonstrating the importance of all four different sources of trust in agri-food value chains – dispositional, affinitive, rational and procedural trust – provides a more nuanced account of the role of trust in such settings, particularly in connection with sustainability claims. While previous studies distinguished between different objects of trust as either interpersonal or institutional trust (Kjærnes, 2006; de Vries et al., 2019), or between different functions of trust as prerequisite for cooperation and coordination (Hanf and Dautzenberg, 2006; Mankad et al., 2017; Dania et al., 2018), our approach emphasizes the formation and importance of various sources of trust. This perspective embraces the relevance of the specific trust context and its dynamic (de Vries et al., 2022). While these contexts have often been understood primarily in geographical terms (either local or global), our findings suggest that the context can also be analyzed through the lens of the specific design of the governance arrangements and how it relates to sources of trust as part of the context of the value chain.

Third, the findings regarding the variegated governance activities with their impact on trust formation point to an important link between the development and maintenance of sustainability-based agri-food value chains and actors’ capacities. Addressing each of the sources of trust requires different capacities. The analysis of the five cases found that different strategies were used to build these capacities, including the involvement of trustworthy individuals and institutions, creation of social connectedness, independent monitoring and certification as well as process organization. We use the term “trust capacities” to describe the cognitive, normative, material and social resources that can be used to form and maintain trust. These trust capacities are essential for the development of transformative food value chains since they facilitate the coordination of activities and the delivery on sustainability-related value propositions, thereby enhancing income and sustainability. The five cases presented here emphasize the crucial role of the actor with the coordinating function in the value chain. This observation resonates with previous studies

which have highlighted the importance of leadership, entrepreneurship, innovation, knowledge and learning capacities on the development of sustainability-based agri-food value chains (Peterson, 2009). Lack of such capacities among value chain actors may be compensated by specialized consultants (“value chain developers”) who act as “facilitators who support collaboration among value chain partners” (Braun et al., 2022). Our findings show that in hybrid governance arrangements, value chain developers can emerge from either the private, public or civil society sector.

The final reflection concerns the potential of agri-food value chains that are based on sustainability claims to contribute to a transformation of food systems. While it was not the focus of this study to assess the contribution of the five cases to more sustainable agri-food value chains, the governance perspective points to their limitations. Sustainability problems in the agri-food system result from negative external effects, that is, the private costs of production, processing, transport, retail, consumption, and waste do not reflect the full economic costs. This is a systemic problem. Harnessing private willingness to pay a higher price for products with enhanced sustainability features will not be sufficient to fully address the externalities problem. Such products necessarily address prime niche markets against the background of standard products with (at least perceived) lower sustainability (Chiriaco et al., 2022). Even worse, there is a paradox: The lower the general perceived sustainability standards in the agri-food system, the higher the market potential for products based on sustainability claims (van Doorn et al., 2021). Hence, the emergence of such value chains depends on a perceived gap between the sustainability of standard products and “sustainability products”. Their success is as much an indicator of underlying sustainability problems in the broader food system as it might be a harbinger of a pending sustainability transformation. The latter would rather require a systematic internalization of negative externalities through a combination of regulatory and financial instruments (for example emission standards and carbon emission trading) along with a systematic remuneration of positive externalities through effective and efficient support policies (Pe'er et al., 2020; Feindt et al., 2022). It is unlikely that the externalities of agri-food chains will be fully internalized through consumer choices.

6. Conclusion

This study set out to examine how governance arrangements address the formation and maintenance of trust in agri-food value chains that are based on sustainability claims. Using a comparative analysis of five cases in Germany, we found that the design of governance arrangements was linked to the formation and maintenance of trust along all stages of the food value chains, and that variegated governance activities addressed different sources of trust: dispositional trust, affinitive, rational and procedural trust. Addressing each of these sources of trust required different capacities. These “trust capacities” are in general essential for the development of agri-food value chains since they enable actors along the value chain to coordinate their activities and to deliver on sustainability-related value propositions, thereby creating income and sustainability benefits. Whether such value chains can have transformative effects depends on the broader economic conditions. If sustainability claims mainly serve to activate higher willingness to pay, they rely on a relatively low level of perceived general sustainability of standard products.

This research contributes to a better understanding of trust development and its interrelationship with governance arrangements in value chains. Empirically, we add to the literature on the coordination and functioning of agri-food value chains built on special sustainability merits. The focus on the impact of governance arrangements on trust formation in sustainability-based agri-food chains contributes to a better understanding of the capacities of food systems to undergo a transformation towards sustainability.

The analysis of governance arrangements and trust capacities in agri-food value chains resonates with broader discussions on food systems, which highlight the need for developing their capacity to adapt and transform in response to environmental, social and economic threats in the 21st century (Erickson, 2008; Meuwissen et al., 2019, 2022; van Bers et al., 2019). Our study helps to understand how the design of governance arrangements may affect the formation of trust and which capacities are required in order to establish and maintain them. Various coordination mechanisms can generate a higher willingness to pay in sustainability-based agri-food value chains. These observations have important implications for governance practice. If we expect such value chains to become frontrunners of a sector transformation towards sustainability, policy strategies should be geared towards the creation of enabling frameworks. Policies such as the CAP of the EU should then pay more attention to agri-food chains, not only to the remuneration of producers for more sustainable farming practices. The CAP contains a number of instruments that are suitable for promoting agri-food value chains with enhanced sustainability, such as support for producer organizations, investments, information and knowledge transfer, European Innovation Partnerships, or advisory services (Linares Quero et al., 2022). However, the distribution of the budget among the CAP policy instruments and their concrete design betrays a focus on income support for agricultural producers (Feindt et al., 2022; Grohmann and Feindt, 2023). The EU Farm to Fork strategy provides some promising elements in this regard. However, only implementation will show whether its “game-changing potential” is will be realised (Schebesta and Candel, 2020). But while financial instruments that support the collaboration and formation of variegated capacities of the value chain actors are important, they cannot cover all trust capacities. Credibility, broad networks and access to actors and institution with independent epistemic authority are indispensable. Furthermore, since commercial success of value chains based on sustainability claims depends on a background of perceived general low sustainability, their function in a sustainability transformation of the agri-food sector appears both ambivalent and confined. Our study therefore also contributes to a better understanding of the limitations of sustainability-based value chains towards a food system transformation.

The results of this study are unavoidably limited by decisions of our research design, from which we derive three directions for further research. First, the study has an exploratory character, confining the case selection to sustainability-based agri-food chains in Germany. An analysis of further case studies from other contexts would be beneficial in order to corroborate the findings and to possibly identify additional challenges and coordination activities. An extension to more countries or transnational agri-food value chains may reveal other governance arrangements and other strategies of trust formation due to different context conditions in these regions. A further methodological limitation results from the restriction to the investigation of successful examples of sustainability-based value chains. An investigation of failed projects

in this area would be desirable. However, such cases are more difficult to identify and those affected are generally less willing to provide information than actors in successful projects. Second, the role of the state (including the EU) and its agricultural policies in supporting more sustainable agri-food value chains requires further research (Grant, 2022). In this context, linking the perspective of hybrid governance to the emerging literature on agricultural post-exceptionalism might be a promising line of inquiry (Daugbjerg and Feindt, 2017). An interesting point of departure would be the discussion of shifting power relations in post-exceptionalist policy arrangements (Attorp and McAreavey, 2020). Our study raises the question whether specific structural, economic or cultural factors enable some individuals or organizations to build trust capacities more easily than others. A third direction of further research points to the contribution of governance activities and trust capacity development on strengthening the resilience of agri-food value chains (Stone and Rahimifard, 2018). Further research should focus on the question of how the sustainability performance can be maintained when food prices are skyrocketing, squeezing out consumers' willingness to pay a premium for credence attributes. In times of accumulating risks and shocks, trust and trust capacities may contribute to ensuring robustness, adaptability and transformability of sustainability-based value chains.

Data availability statement

The original contributions presented in the study are included in the article/[Supplementary material](#), further inquiries can be directed to the corresponding author.

Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

PG: conceptualization, methodology, data collection, data analysis, writing—original draft, review and editing, and visualization. VD: conceptualization, methodology, data collection, data analysis, and writing—original draft, review and editing. CK and PF: conceptualization, methodology, data analysis, and writing—review and editing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fsufs.2023.1130895/full#supplementary-material>

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