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Value chain structures for deforestation-risk commodities shape private conservation governance and its outcomes across the tropics

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Abstract. Hundreds of firms have pledged to eliminate deforestation from their supply chains. Yet little is known about how supply chain structures interact with the design and implementation of forest-focused supply chain policies (FSPs) to influence their effectiveness and equity. We present a pan-tropical comparative analysis that explores how the design, implementation, and outcomes of FSPs shape, and are shaped by, supply chain structures. We conducted 173 stakeholder interviews and focus groups across four cases involving commodities that account for over half of agriculture-driven tropical deforestation: Brazilian cattle and soy, Indonesian palm oil, and West African cocoa. Drawing on Global Value Chain analysis, we propose an interpretive middle-range theory connecting supply chain structures with FSPs' outcomes. We find that the governance of deforestation-free production is influenced by the extent of FSP adoption and codification, and producers' capabilities to comply. These governance factors shape supply chains' vertical structures (firm–supplier linkages) and horizontal structures (collective market share of firms with FSPs), which in turn shape FSPs' outcomes. When FSPs are highly codified, producers have high capabilities, and market share is high, firms can implement FSPs through structures involving less explicit coordination. This makes effectiveness–equity synergies more likely. When codification, producers' capabilities, and market share are low, firms coordinate deforestation-free production directly. This increases control but risks excluding noncompliant producers, while low market share enables leakage. A more transformative approach would therefore see firms collaborating to promote widespread adoption of highly codified FSPs while building producers' compliance capabilities across their supply bases.

1.0 Introduction

Tropical deforestation contributes to climate change, biodiversity loss, and the erosion of forest-based livelihoods (IPBES, 2019). A quarter of tropical deforestation can be attributed to international demand for only a few agricultural commodities including cattle, palm oil, soy, and cocoa (Pendrill et al., 2019). This has led to the proliferation of "forest-focused supply

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chain policies" (FSPs): policies by firms to eliminate deforestation from their supply chains, alongside social safeguards and livelihood targets (Garrett et al., 2021).

FSPs include sectoral standards through which firms collectively apply incentives or sanctions to discourage deforestation (Lambin et al., 2018). For example, firms that signed the Amazon Soy Moratorium agreed not to buy soy from deforested properties in the Brazilian Amazon (Gibbs et al., 2015a). FSPs also include unilateral pledges, such as Indonesian palm oil firms' "No Deforestation, no Peat, no Exploitation" (NDPE) commitments (Grabs and Garrett, 2023). Other FSPs involve public actors; the *Termo de Ajustamento de Conduta* (Terms of Adjustment of Conduct, TAC) is a state-enforced policy requiring slaughterhouses in the Brazilian Amazon to sign commitments to avoid sourcing cattle from properties with illegal deforestation (Cammelli et al., 2022). The TAC is complemented by the *Compromisso Público da Pecuária* (Public Livestock Commitment, or G4), a commitment by Brazil's four largest meatpacking firms to exclude cattle from properties with any deforestation whatsoever. In West Africa, the Cocoa and Forests Initiative (CFI) is a public-private partnership between the governments of Côte d'Ivoire and Ghana and 35 firms to end deforestation while promoting productivity and social inclusion in cocoa supply chains (Carodenuto and Buluran, 2021). Each of these FSPs – whether collective, public-private, state-led, or private – has been characterized by the adoption of individual policies by participating firms. Some importing jurisdictions are also now introducing regulations that harden FSPs in public law, such as the European Union Deforestation Regulation (EUDR) (Berning and Sotirov, 2023). The EUDR requires firms to prove that commodities placed on the EU market were not sourced from land that was deforested after 2020.

Extensive research has analyzed FSPs' effectiveness within supply chains and at regional scales (Alix-Garcia and Gibbs, 2017; Garrett et al., 2021; Gibbs et al., 2015b; Gollnow et al., 2022; Heilmayr et al., 2020; Stigler et al., 2026). Researchers have also investigated FSPs' social equity, including their recognition of pre-existing political, economic, and social conditions (recognitional equity); opportunities for producers to participate in policy design (procedural equity); and distribution of costs and benefits (distributive equity) (Addoah et al., 2025; Lyons-White et al., 2025; McDermott et al., 2013). Exclusion from deforestation-free supply chains is a particular concern for smallholder farmers whose livelihoods depend on forest-risk commodities, and equity in market access has therefore become a prominent focus of FSP scholarship (Grabs et al., 2021).

The effectiveness and equity of FSPs are likely to be significantly affected by the structures of commodity supply chains. If lead firms – those that adopt FSPs and drive implementation – are located far from production, implementation must be delegated along complex supply chains with many intermediaries (Grabs and Carodenuto, 2021). As forest-risk commodities are produced in disparate regions by diverse groups of actors and involve different production, processing, and manufacturing activities, the structures of their supply chains can be expected to vary substantially. Yet despite their potential impacts, little is known about how different supply chain structures shape FSPs' design, implementation, and outcomes across different commodities and regions. Previous research remains limited to commodity- and region-specific insights about trade flows (zu Ermgassen et al., 2020), complexity (Lyons-White and Knight, 2018), and the roles played by firms at different supply chain tiers (Carodenuto and Buluran, 2021; Marschner et al., 2025).

Many multinational food companies with FSPs operate across different commodities and countries, while import regulations like the EUDR de facto affect all regulated commodities across the many regions in which they are produced. Better understanding of how supply chain structures influence the effectiveness of FSPs would allow policymakers to proactively to mitigate challenges across these diverse production contexts. Inadequate accommodation of this heterogeneity is also a limitation of best practice frameworks such as the Accountability Framework Initiative (https://accountability-framework.org), Science-Based Targets Initiative (https://sciencebasedtargets.org), and Science-Based Targets Network

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(https://sciencebasedtargetsnetwork.org). These frameworks provide generic guidance but do not address structural variations in buyers' ability to control production, which is potentially relevant to how policies should be designed.

Here, we present a pan-tropical, cross-commodity comparative analysis that explores how different supply chain structures influence firms' governance of deforestation-free production using FSPs and its outcomes. We define governance as the steps taken by firms to coordinate and control deforestation-free production in their supply chains (Gereffi et al., 2005), including the adoption, design, and implementation of FSPs. Our aim is to develop a "middle-range" theory of deforestation-free value chain governance. Middle-range theories propose mechanisms to connect well-bounded sets of phenomena; they aim to be more generalizable than *ad hoc* explanations of individual cases, but more specific than universal systems theories (Meyfroidt et al., 2018). Although comparative analyses permit weaker causal inferences than experimental or statistical studies, they are well-suited to developing middle-range theories through the interpretation of small numbers of cases (Della Porta, 2008). By comparing multiple commodities and regions, we seek to identify the mechanisms through which supply chain structures shape deforestation-free governance and develop a framework that can be tested and refined with further cases. This could inform understanding about FSPs and market approaches to agricultural sustainability more generally.

We ask: 1) what are the characteristics of the supply chains in which prominent FSPs have been implemented? 2) How do supply chain structures shape firms' governance of deforestation-free production? And 3) how do supply chain structures shape FSPs' outcomes, specifically their effectiveness and equity? We examine effectiveness in terms of the additional impacts of FSPs on deforestation at regional scales. We examine equity in terms of market access for both smallholder farmers and larger producers, as this is a particular concern for FSPs (Grabs et al., 2021).

We begin by introducing our theoretical framework and methods, before presenting our findings for each commodity. We then compare our findings across the commodities before developing a middle-range theory of deforestation-free value chain governance and, finally, presenting our conclusions and policy recommendations.

2.0 Theoretical framework

We adopted a Global Value Chain (GVC) perspective, which extends beyond describing the movement of commodities through a supply chain to examine the series of stages involved with producing and adding value to a product (Antràs, 2020; World Bank, 2020). By adopting a GVC perspective, it thus becomes possible to explore how lead firms govern the production of goods for global markets, including the coordination and control of deforestation-free production.

Several frameworks exist to analyze how lead firms govern GVCs and the related concept of global production networks (Coe and Yeung, 2015; Ponte et al., 2019). To examine the relationship between value chain structures and governance, we developed upon Gereffi et al.'s (2005) theoretical framework, which specifies the linkage types that firms use to govern production.

Our framework is designed to facilitate a stepwise analysis connecting the variables that determine value chain governance structures to observed FSP outcomes. Accordingly, we present it as a series of steps, which are set out below and illustrated in **Fig.1** with definitions of key terms. We retained the concept of "supply chains" to characterize the sequence of actors (e.g., farmers, traders, manufacturers) involved in each chain, while using the GVC framework to analyse the governance relationships between them.

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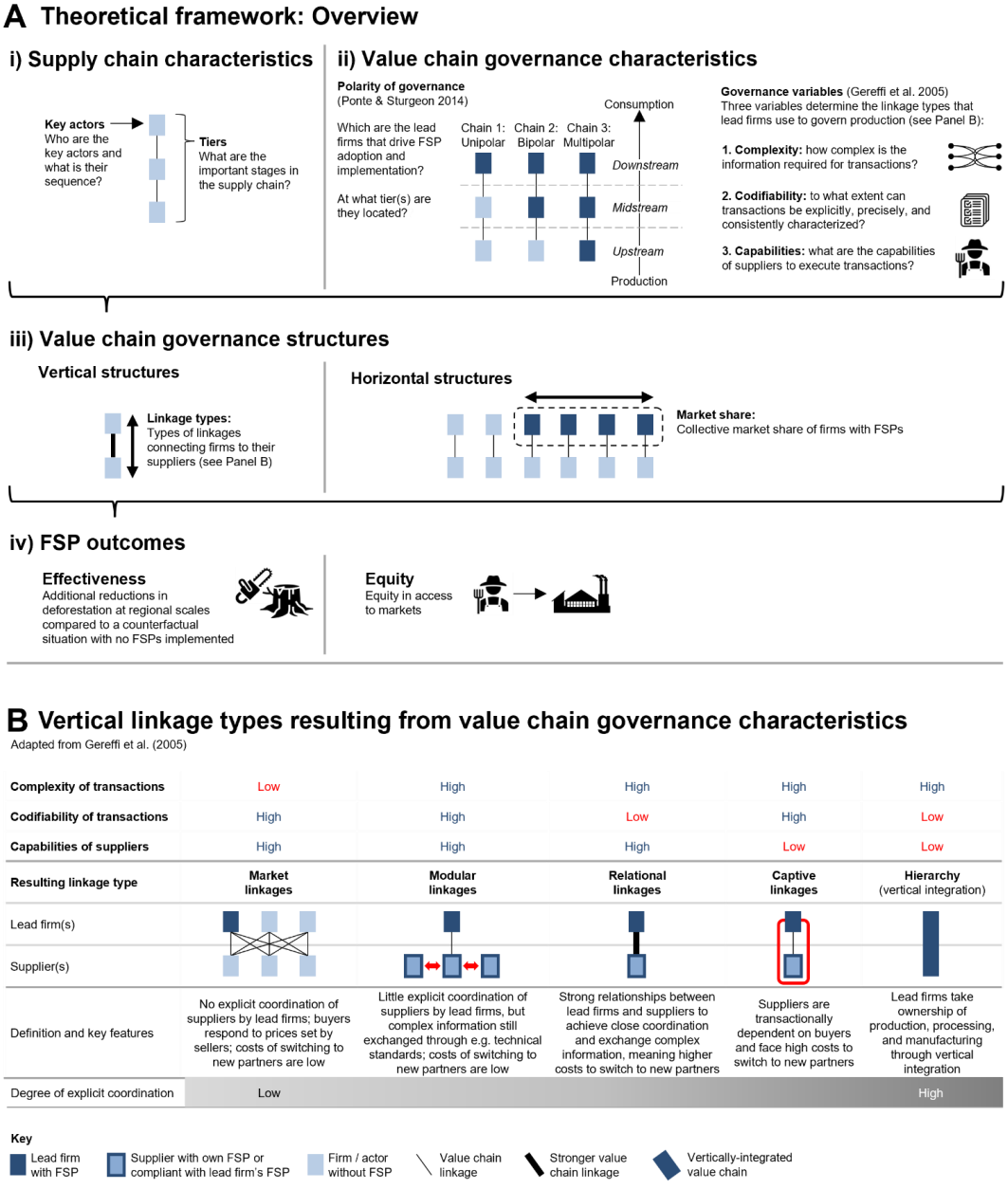

Figure 1. Overview of theoretical framework and key terms. Panel A: Supply chain characteristics **(i)** and value chain governance characteristics **(ii)** shape horizontal and vertical value chain governance structures **(iii)**. In this study, we examine how these characteristics and structures might shape FSP outcomes **(iv)** in terms of their regional effectiveness and market access equity. **Panel B** (adapted from Gereffi et al., 2005): Vertical value chain governance structures, defined here as the types of linkages between lead firms and their suppliers, are determined by the values (high or low) taken by three value chain governance variables: the complexity of transactions, codifiability of transactions, and capabilities of suppliers to execute transactions. In practice, low complexity is not found with low codifiability or low supplier capabilities.

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2.1 Step 1. Supply chain characteristics

For each case, we first described the supply chain in terms of the sequence of actors between which commodities are transferred and the tiers – i.e., supply chain stages – they occupy (**Fig. 1.A.i**).

2.2 Step 2. Value chain governance characteristics

We then identified the polarity of governance in each value chain – i.e., the tier(s) at which lead firms with FSPs are located – and the values taken by the three governance variables that, according to Gereffi et al. (2005), determine the types of linkages that firms use to coordinate and control production (**Fig. 1.A.ii**).

Lead firms may be located upstream (close to producers); downstream (near the end users of products); or midstream (in the middle). Governance is defined as being unipolar, bipolar, or multipolar depending on whether lead firms are located at one, two, or many tiers (Ponte and Sturgeon, 2014).

Gereffi et al. (2005) observed that firms' abilities to govern production are influenced not only by the costs and risks associated with investing in specific transactions, but also firms' relationships, networks, and competencies, and those of their suppliers. This led them to identify three variables that determine the value chain linkages firms use to govern production: 1) the complexity of information required for transactions (here, evidence that commodities were produced without deforestation); 2) the extent to which that information can be codified (i.e., characterized explicitly, precisely, and consistently) and therefore replicated, for example by using a standard; and 3) suppliers' capabilities to execute those transactions (i.e., demonstrate FSP compliance) (Gereffi et al., 2005). Each variable can take a value of either "high" or "low".

2.3 Step 3. Value chain governance structures

2.3.1 Vertical structures

According to Gereffi et al. (2005), the values taken by the three governance variables produce five observable types of "vertical" linkages that connect firms to their suppliers: market, modular, relational, captive, and hierarchical (**Fig. 1.A.iii, Fig. 1.B**). These linkages range along a spectrum from low to high levels of explicit coordination. At the low end of the spectrum, firms make no attempt to coordinate production and exert little control over suppliers, buying commodities from whoever offers the lowest price through market linkages. This can be seen when firms purchase commodities on a spot market. At the high end, firms directly coordinate and control production through vertically integrated hierarchical value chains. For example, some large palm oil firms undertake all production, processing, manufacturing, and marketing activities themselves. By examining the complexity and codifiability of FSPs, and suppliers' capabilities for compliance, it should thus be possible to identify the types of vertical linkages through which firms govern deforestation-free production. These linkages are potentially important for FSPs' additionality. Firms sourcing commodities through captive or hierarchical linkages are likely to be able to control land use directly, whereas firms using market linkages may have little control over their suppliers' land-use practices.

2.3.2 Horizontal structures

While identifying vertical linkages should provide insights about how lead firms govern deforestation-free production on an individual basis, it is insufficient for understanding the collective impacts of FSPs across multiple firms at the same value chain tiers. Many FSPs share common goals or are collective initiatives that target regional outcomes (Garrett et al., 2019;

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Lambin et al., 2018). These factors make it important to consider not only how value chains are structured vertically between firms and suppliers, but also "horizontally" across multiple firms at the same tiers (**Fig. 1.A.iii**) (Gereffi and Lee, 2016). With respect to deforestation-free governance, horizontal structure can be considered in terms of the alignment between firms with FSPs and their collective market share. High collective market share can reduce environmental externalities when it enables firms to limit production to drive up prices (Asker et al., 2024; Buchanan, 1969) or, in the case of FSPs, govern a larger share of the supply base (Garrett et al., 2019; Levy et al., 2023). It may also reduce the opportunities for supplier switching or firms sourcing commodities "indirectly" through intermediaries, which can produce leakage and undermine FSPs' effectiveness (zu Ermgassen et al., 2022).

From a social perspective, concentrated markets can provide less-capable producers with access to services and more stable relationships (Maertens et al., 2011; Minten et al., 2009). However, they can also enable firms to depress prices, dispossess smallholders, or exclude producers (Amanor, 2012; Antràs, 2020; Swinnen and Vandeplas, 2010). For FSPs, higher market share could increase the exclusion of noncompliant farmers (Grabs et al., 2021; Levy et al., 2023).

2.4 Step 4. From value chain governance structures to FSP outcomes

This theoretical framework allows us to propose several hypotheses about FSP outcomes. FSPs often involve complex requirements to demonstrate compliance, including mapping farms and applying technocratic forest definitions. Consequently, we expect FSPs to increase the complexity of transactions and thus limit the number of market linkages in value chains with high collective market share. Where market share is high, we also expect to observe less leakage and higher regional effectiveness. We expect that value chains with more capable suppliers will exhibit higher market access equity, because suppliers will retain access to FSP markets and lead firms can coordinate deforestation-free production without using coercive captive or hierarchical linkages. Taken together, we expect to observe the most effective and equitable FSPs in value chains with highly codified FSPs, highly capable suppliers, and high collective market share. We expect lower effectiveness and equity in value chains combining low collective market share with less-capable suppliers. In these chains, firms would need to coordinate deforestation-free production through coercive linkages and exclude noncompliant suppliers, but noncompliant production could still be diverted to non-FSP buyers.

3.0 Methods

3.1 Study design

We adopted a qualitative comparative case design based on semi-structured interviews and focus groups. We used complementary insights from existing literature to inform aspects of the analysis which could not be reliably established by interviews alone (namely FSPs' market share and effectiveness) or about which knowledge already exists (primarily polarity of governance, which is partially influenced by the manner in which FSPs originated).

3.2 Cases

We examined the most prominent FSPs associated with the four most important forest-risk commodities, which collectively account for over half of agriculture-driven tropical deforestation (Pendrill et al., 2022). These were the Amazon Soy Moratorium (ASM) and cattle slaughterhouses' TAC agreements in the Brazilian Amazon; the policies of cocoa firms that

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signed the CFI in West Africa (Côte d'Ivoire and Ghana); and palm oil firms' NDPE policies in Indonesia (**Fig. 2**). Each commodity-FSP-region combination was considered a case. Design features of the FSP in each case are presented in **Table 1**.

Studies of each individual case have been published previously, examining different aspects of FSP adoption and implementation but not the role of value chain structures (Addoah et al., 2025; Brandão et al., 2025; Cammelli et al., 2022; Chandra et al., 2026b; Grabs and Garrett, 2023; Kouakou et al., 2026). Here, we drew on data collected across this research programme to provide a novel comparative analysis of the influence of value chain structures on deforestation-free governance.

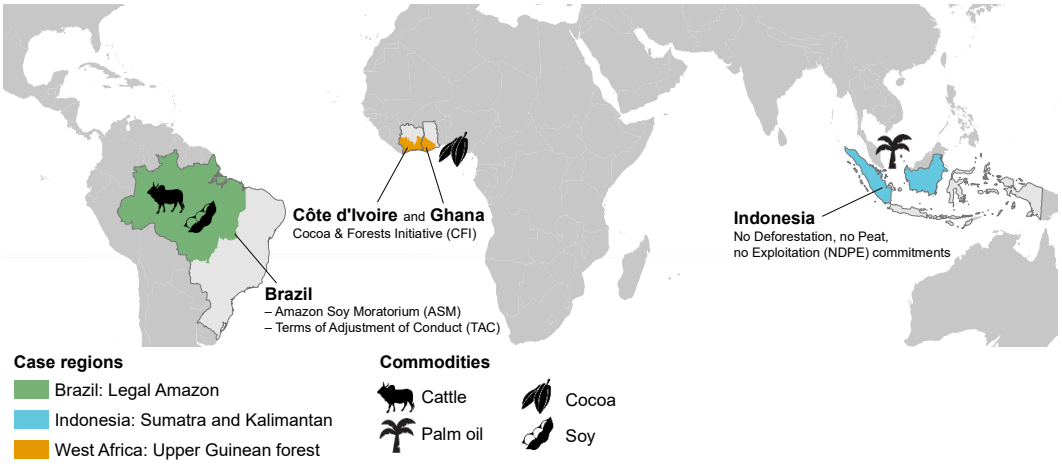

Figure 2. Major forest-focused supply chain policy (FSP) cases examined in this study. Coloured map regions indicate the principal regions in which the four agricultural commodities associated with the most tropical deforestation are produced (Goldman and Weiss, 2024), where the selected FSPs have been implemented.

Table 1. Design features of the FSPs investigated in each case. FSP types were identified from Lambin et al. (2018). Design feature categories were identified from criteria for effective and equitable FSPs developed by Garrett et al. (2019), Grabs et al. (2021), and Addoah et al. (2025). Only those design features deemed most important for understanding a policy's overall design and implementation are presented.

Commodity and region	Cattle, Brazilian Amazon	Cocoa, West Africa	Palm oil, Indonesia	Soy, Brazilian Amazon
FSP investigated	Terms of Adjustment of Conduct (TAC) agreements signed by slaughterhouses	Cocoa and Forests Initiative (CFI) and signatory firms' sustainability programmes	No Deforestation, no Peat, no Exploitation (NDPE) commitments adopted by firms	Amazon Soy Moratorium (ASM)
Policy adoption date	July 2009[1]	March 2017[2]	From 2010	July 2006[3]
Type	Sanction-based sectoral standard: state-led standard based on market exclusion of noncompliant producers	Collective aspiration / public-private partnership and individual company pledges	Individual company pledges	Sanction-based sectoral standard: sectoral agreement based on market exclusion of noncompliant producers
Scope: actors	Cattle producers, although TAC agreements are signed by slaughterhouses	Smallholder cocoa farmers, cooperatives, and traders; initially, direct suppliers only	Firm's own plantations and independent palm oil producers and suppliers	Soy producers
Scope: region or biome	Cattle-producing Amazon states incl. Pará, Acre, Rondônia, Amazonas, Mato Grosso[1]	Côte d'Ivoire and Ghana	NDPE policies cover the entire (global) supply chains of committed companies	Legal Amazon
Deforestation reduction target and/or definition	Zero illegal deforestation	In theory, zero gross deforestation (no HCV or HCS, no sourcing from protected areas)[4]; in practice, zero illegal deforestation	Zero gross deforestation: no conversion of forests identified as High Conservation Value (HCV) or High Carbon Stock (HCS)	Zero gross deforestation
Cut-off date	22 July 2008[1,3]	Ghana: 1 Jan 2018 (National Parks), 31 Dec 2019 (Category 1 Forest Reserves);[2] Côte d'Ivoire: 31 Dec 2018 (National Parks and Reserves);[4] firms mostly 2025 or 2030[5]	Dates vary by firm, type of forest assessment (HCV or HCS), and application to firms' own or suppliers' operations	22 July 2008[3]
Monitoring approach	Deforestation monitored using the National Space Agency's (INPE) PRODES satellite monitoring system and property boundaries in Rural Environmental Registry (CAR)	Deforestation risk assessment and satellite monitoring by individual firms; national satellite monitoring systems being developed by each country	Deforestation risk assessment and satellite monitoring by individual firms; collective investments in forest disturbance alert system (Radar for Detecting Deforestation, RADD)[6]	Deforestation monitored within property boundaries using PRODES and CAR
Traceability approach	Cattle purchase documents including Animal Transport Permits (GTA), CAR certificates, environmental production licenses (LAR)†	Mapping of individual farms by firms; certification (mostly Rainforest Alliance or Fairtrade); national traceability systems in development	Use of supplier and mill lists and supply sheds; extensive mapping of plantations but limited mapping of smallholder farms by firms; RSPO or ISCC certification	Property-level identification of soy producers
Enforcement approach	Exclusion of non-compliant direct suppliers by slaughterhouses, enforced using state audits of slaughterhouses' purchase documents[7]	Exclusion of farmers with farms in protected areas and surrounding buffer zones, as identified by individual firms and cooperatives through risk assessments	Implementation of HCV and HCS approaches in firms' own plantations; grievance, engagement, and suspension or exclusion procedures with suppliers	Exclusion of noncompliant farms based on list published annually by Soy Moratorium Working Group (GTS)[3]
Benefit sharing and/or capability building by firms	Limited and company-specific, e.g. JBS' Green Offices initiative	Mass sensitization programmes by firms on environmental conservation, agroforestry, productivity, and livelihoods, but only to farmers within firms' value chains	Some capability building with scheme (contract) smallholder farmers by individual firms; some firm-to-firm capability building; sharing of certification premiums	Capability building undertaken by GTS to educate producers about the ASM[8]
Coordination with public and private actors	TAC developed and enforced by the Brazilian Federal Prosecutor's Office (MPF)	CFI is a public-private partnership between 35 firms and the Governments of Côte d'Ivoire and Ghana	Some private coordination through e.g., Consumer Goods Forum, Palm Oil Collaboration Group, Palm Oil Innovation Group, and HCS Approach Steering Group,[6] and jurisdictional or landscape approaches	Government and NGOs were members of GTS[3]

1. Gibbs et al. (2015b); 2. Republic of Ghana (2018); 3. Heilmayr et al. (2020); 4. République de Côte d'Ivoire (2018); 5. Addoah et al. (2025); 6. Grabs and Garrett (2023); 7. Levy et al. (2023); 8. Brannstrom et al. (2012).
Definitions (Portuguese initialisms defined in English): ASM, Amazon Soy Moratorium; CAR, Rural Environmental Registry; CFI, Cocoa & Forests Initiative; GTA, Animal Transport Permit; GTS, Soy Moratorium Working Group; HCS, High Carbon Stock; HCV, High Conservation Value; ISCC, International Sustainability & Carbon Certification; LAR, Rural Environmental Licence; MPF, Brazilian Federal Prosecutor's Office; NDPE, No Deforestation, no Peat, no Exploitation; RSPO, Roundtable on Sustainable Palm Oil. † Larger properties in Pará only.

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3.3 Interviews and interview guides

We conducted semi-structured interviews with actors along each value chain from producers to manufacturers (**Table 2**). We also conducted interviews with farmers and organizations involved with conservation and/or economic development, including government agencies and non-government organizations (NGOs). In Indonesia and West Africa, where smallholders account for a substantial proportion of production, we also conducted focus groups as we expected farmers would be more willing to disclose information in an unfamiliar research setting when among peers (Guest et al., 2017).

We developed interview guides for the main actor groups in each case to reflect differences in their positions and roles in the value chain (Adams, 2015). Details of the methods used to develop the guides, their contents, and the guides themselves are presented in the **Supplementary Information** (**SI**).

3.4 Sampling

We adopted a purposive sampling design to include actors identified through stakeholder mapping in each case (further details in the SI). We invited actors using email, LinkedIn, and/or personal connections. As data collection proceeded, we applied snowball and opportunistic sampling to take advantage of introductions by gatekeepers and encounters with relevant actors. We continued sampling in each case until all identified firms had been invited or thematic saturation (monitored using field journals) was attained (Saunders et al., 2018).

3.5 Fieldwork and data collection

We undertook fieldwork in Brazil, Côte d'Ivoire, Ghana, and Indonesia between 2019–2022 (details in **SI**), conducting 165 interviews and 8 focus groups. For Indonesian palm oil, West African cocoa, and Brazilian soy, we audio recorded interviews, subject to participants' consent, and made detailed fieldnotes. For Brazilian cattle, audio recording was not possible due to the topic's sensitivity; fieldnotes were taken instead. All participants freely agreed to a prior informed consent form and interviews were conducted under condition of anonymity (ethical approvals described in **SI**).

Table 2. Number of interviews and focus groups (FGs) with actor groups in each case. N show the numbers of interviews and FGs but not necessarily the number of organizations interviewed. For example, in West African cocoa, representatives of the same firms were interviewed in both Ghana and Côte d'Ivoire. Capitalized abbreviations define the pseudonyms used to identify interviews and focus groups in the results, framework matrix (Table S1) and audit trail (Table S3), e.g., IPO3-TRA = Indonesian palm oil, interview 3, trader; CIV-FG01-FAR = Côte d'Ivoire cocoa, focus group 1, smallholder farmers.

			West African cocoa							
	Brazilian cattle (BRC)	**N**	**Côte d'Ivoire (CIV)**	**N**	**Ghana (GHA)**	**N**	**Indonesian palm oil (IPO)**	**N**	**Brazilian soy (BRS)**	**N**
Consumer goods manufacturers (CGM)			Chocolate manufacturers (CGM)	5	Chocolate manufacturers (CGM)	7	Consumer goods manufacturers (CGM)	5		
Traders, exporters, processors	Slaughterhouses and meatpackers (SLA)	8	Traders / exporters / grinders* (TRA)	5	Traders / exporters / grinders* (TRA)	6	Traders / processors (TRA)	4	Traders / exporters (TRA)	4
					Licensed Buying Companies (LBC)	2	Large integrated supply chain companies (LISCs)	6	Industry associations (IND)	4
Producers	Producers: fatteners / finishers (FAT)	13	Corporate growers (GRO)	1			Corporate growers (GRO)	5	Corporate growers (GRO)	1
	Producers: calvers (CAL)	15	Smallholder farmers, focus groups (FG-FAR)	5	Smallholder farmers (FAR)	4	Smallholder farmer organizations (SHO)	2	Producers' associations (PRO)	1
					Smallholder farmers, focus groups (FG-FAR)	1	Farmer cooperatives, focus groups (FG-COP)	2		
			Farmer cooperatives (COP)	5	Farmer cooperatives (COP)	3				
Government (GOV)	Government departments / agencies (GOV)	5	Government departments / agencies (GOV)	6	Government departments / agencies (GOV)	7	Government departments/ agencies (GOV)	1	Government departments / agencies (GOV)	1
Non-government organisations (NGOs)			Environmental and / or social NGOs (NGO)	4	Environmental and / or social NGOs (NGO)	4	Environmental and / or social NGOs (NGO)	6	Environmental and / or social NGOs (NGO)	9
Supporting organizations and industry experts	Meat industry union (UNI)	2	Technical Support Organizations / consultancies / researchers (TSO)	1	Technical Support Organizations / consultancies / researchers (TSO)	1	Technical Support Organizations / consultancies / researchers (TSO)	4	Technical Support Organizations / consultancies / researchers (TSO)	5
			Certification scheme (CER)	1	Certification scheme (CER)	1				
			Intergovernmental organization or foreign development agency (IGO)	2						
Total		**43**		**35**		**36**		**35**		**25**

* Some firms fulfilled both trading/exporting and grinding functions. Numbers shown in each row indicate numbers of semi-structured interviews unless focus groups are explicitly stated.

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3.6 Analysis

Analysis involved coding, charting, and interpreting interview data (Ritchie and Spencer, 1994) to generate initial findings for each case, before scoring the GVC governance variables and FSP outcomes using a pre-defined rubric and, finally, comparing findings across the cases. Each step is described below. Where necessary and possible, we integrated complementary insights from previous literature in the charting and interpretation phases. **Table 3** summarizes whether interview data or previous literature primarily informed our findings for each variable.

Table 3. Primary evidence sources (interview data or previous literature) used to inform findings for each variable. Where an X is indicated in both the interview data and literature columns for a given case, evidence from both sources contributed equally.

		Cattle, Brazilian Amazon		Cocoa, West Africa		Palm oil, Indonesia		Soy, Brazilian Amazon	
		Interview data	Literature	Interview data	Literature	Interview data	Literature	Interview data	Literature
Supply chain characteristics	**Supply chain structure**	X	X	X		X	X		X
Value chain governance characteristics	**Polarity of governance**		X	X		X		X	
	Complexity of FSPs	X		X		X			X
	Codification of FSPs	X		X		X			X
	Capabilities in the supply base	X		X		X		X	X
Vertical governance structure	**Value chain linkages**	X		X		X		X	
Horizontal governance structure	**Market share**		X		X		X		X
FSP outcomes	**Effectiveness**		X	X	X		X		X
	Market access equity	X		X		X		X	

3.6.1 Coding

We coded interview transcripts and notes in NVivo (QSR International, 2022). We developed a coding framework deductively using themes from the GVC governance framework (Gereffi et al., 2005), namely polarity of governance; complexity and codifiability of FSPs; suppliers' compliance capabilities; and evidence of market, modular, relational, captive, or hierarchical linkages. To examine FSPs' complexity, we included codes based on criteria for analyzing FSPs' design (Garrett et al., 2019; Grabs et al., 2021). To assess FSPs' outcomes, we included codes for effectiveness (additionality, permanence, and leakage) and equity (market access/exclusion). We refined the coding framework throughout the coding process by inductively identifying themes emerging from the data.

3.6.2 Charting and interpretation

Once coding was complete, a subset of codes (themes) judged as being most relevant to the research questions was selected for further analysis. These included all themes relating to the GVC framework, plus those on effectiveness and equity. We charted the coded data in a framework matrix (**Table S1**), which cross-tabulated the selected themes with the four commodities. The matrix was populated with written summaries of coded data and exemplary quotations. Summaries and quotations were linked to interviews using pseudonyms (defined in **Table 2**). We also incorporated insights from the

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previous literature to complement our findings about: 1) polarity of governance, 2) FSPs' collective market share, and 3) FSPs' effectiveness.

We developed our initial findings by interpreting evidence in the framework matrix, referring to additional themes where further insights were required (e.g., on capability building).

3.6.3 Scoring

We assessed the values of the GVC governance variables and FSP outcomes using a set of pre-defined criteria (**Table S2**), which we developed by augmenting variable definitions from Gereffi et al.'s (2005) original GVC framework with criteria for assessing FSPs' effectiveness and equity (Garrett et al., 2019; Grabs et al., 2021). Noting the diversity of actors, FSPs, and outcomes across commodities and within value chains, we allowed each variable to take an intermediate value as well as "high" or "low". Values (i.e., scores) were initially assigned to variables by the first author before being validated by co-authors with expertise in each case. Disagreements were resolved through discussion. This led to four initial scores being revised. **Table S3** provides an audit trail from the original data to the final score assigned to each variable. It summarizes key evidence from the framework matrix; specifies the source(s) used (interviews or literature) with citations; and provides the initial variable assessments and scores assigned by the lead author, validation comments by co-authors, and final assessments and scores.

3.6.4 Comparison

Finally, we compared our findings across the four cases to draft a narrative description of the similarities and differences between key variables (Della Porta, 2008) – including polarity of governance, FSPs' complexity and codification, suppliers' capabilities, vertical linkages, and market share – and their associations with FSPs' regional effectiveness and market access equity.

4.0 Results

We present our findings as a narrative synthesis for each case, structured in alignment with our theoretical framework: 1) supply chain characteristics; 2) value chain governance characteristics, including polarity of governance, complexity and codifiability of FSPs, and suppliers' capabilities; 3) value chain governance structures, including vertical structures (linkages) and horizontal structures (market share); and 4) FSP outcomes. Implications for the design, adoption, and implementation of FSPs are discussed throughout. All statements are based on interview data unless a literature reference is cited. Supporting quotations are linked to interviews using pseudonyms (**Table 2**). Existing literature is used to provide complementary insights about polarity of governance, market share, and effectiveness, but also cited when interview data echoed established knowledge that supports comprehension in each case. **Fig. 3** and **Table 4** provide an overview of our findings with scores assigned to key variables. After each case is presented individually, we compare our findings to examine how different value chain governance structures shape firms' governance of deforestation-free production across countries and commodities.

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4.1 Cattle in the Brazilian Amazon

Supply chain characteristics: Cattle value chains in the Brazilian Amazon involve many producers who manage and trade cattle through one or more lifecycle stages of calving, rearing, and fattening/finishing. Producers sell cattle to slaughterhouses or meatpackers, sometimes through informal intermediary traders.

Value chain governance characteristics: The TAC's design was negotiated between the Public Prosecutor's Office (Portuguese initialism MPF), the Association of Brazilian Cattle Exporters (ABIEC), and the four largest meatpacking firms, JBS, Marfrig, Minerva, and Bertin (Cammelli et al., 2022), signifying unipolar midstream governance.

To fulfil TAC agreements, slaughterhouses require producers to provide complex but highly codified evidence of compliance. This includes an Animal Transport Permit (GTA), Rural Environmental Registry (CAR) certificate and, for larger properties in Pará, an environmental production license (LAR). Slaughterhouses use these documents together with the Brazilian National Space Agency's (INPE) PRODES satellite monitoring system, embargo lists, polygons of Indigenous lands and protected areas, and productivity indices to verify that no illegal deforestation has taken place. Some slaughterhouses reported initially having limited capabilities to implement these procedures, even if they ultimately completed monitoring: "*We don't have the structure to deal with the public prosecutor's office, that's the truth... TAC is a headache*" (BRC44-SLA). Producers have varying capabilities to execute TAC-compliant transactions. While larger finishers found requirements expensive but feasible, a government official (BRC03-GOV) noted low farm management capabilities among smallholders.

Vertical structures: In keeping with the TAC's high complexity and low capabilities among many producers, we observed some hierarchical linkages. For example, four producers had vertically integrated value chains involving "full cycle" management covering the entire bovine lifecycle. Among slaughterhouses, few had integrated cattle production into their operations. Instead, slaughterhouses that had signed TACs described the importance of developing strong relationships with suppliers, signaling that TACs are implemented through relational linkages. We found market linkages between producers and non-TAC signatory slaughterhouses, between which price and timely payment – rather than relationships or environmental criteria – determined sales.

Horizontal structures: In addition to signing TAC agreements, JBS, Marfrig, Minerva, and Bertin signed the G4 agreement in October 2009 under pressure from Greenpeace (Cammelli et al., 2022). Due to these firms' substantial market share, the TAC and G4 came to cover 75% of slaughterhouses' cattle purchases in Pará, Rondônia and Mato Grosso by 2018, of which 26% was accounted for by the TAC alone (Levy et al., 2023). This ensured broad alignment on FSP content and moderate market share. Nonetheless, many individual slaughterhouses remained without TAC agreements as only those with a record of sourcing from illegally deforested properties had to sign one. In addition, high demand for cattle in the study region entailed that seven of the eight slaughterhouses we interviewed were unable to meet their processing capacities. This meant producers were able to sell cattle to local butchers or non-TAC slaughterhouses without having to prove TAC compliance. A meatpackers' union official described the problem of implementing the TAC in this situation: "*It's like trying to separate beans and rice, it's difficult. You discard the beans, and then someone else comes along and eats the rice and beans as well as your beans*" (BRC07-UNI).

FSP outcomes: Early analyses of the TAC and G4 found no impact on forests in areas surrounding slaughterhouses (Alix-Garcia and Gibbs, 2017). However, the G4 was later found to have reduced cattle-driven deforestation by 15% in Pará, Rondônia, and Mato Grosso between 2010–2018 (Levy et al., 2023). The TAC was also found to have reduced deforestation

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on farms in Pará by 0.57% per year between 2009–2018, although this impact declined by 89% due to deregulation under the Bolsonaro administration (Brandão et al., in review). Producers and slaughterhouses claimed, "*TAC is succeeding*" (BRC39-SLA) by limiting where producers can clear.

From the perspective of market access equity, smaller producers with lower capabilities were excluded from selling to TAC slaughterhouses but did not lose market access altogether due to the availability of non-signatory buyers. Most small- and medium-sized producers we interviewed were not even aware of the TAC; only two of 15 reported that their buyers had environmental requirements. Still, as TAC implementation ramped-up against a background trend of land concentration, participants were concerned that small producers risked being pushed out of the market: "*If we continue at the current pace, in 10 years the medium and small businesses will be extinct*" (BRC10-FAT).

4.2 Cocoa in West Africa

Supply chain characteristics: Smallholders account for the majority of cocoa production in Côte d'Ivoire and Ghana. In Côte d'Ivoire, farmers sell cocoa beans to cooperatives, or to middlemen (pisteurs) who sell to local buyers (traitants) or cooperatives. Cooperatives and traitants sell beans to traders. In Ghana, the parastatal cocoa board, Cocobod, licenses "Licensed Buying Companies" (LBCs) to buy beans from farmers. LBCs sell beans to Cocobod's Cocoa Marketing Company, which sells to traders. In both countries, cocoa traders and grinders sell cocoa beans and products to chocolate manufacturers.

Value chain governance characteristics: The CFI was adopted in 2017 by cocoa traders and grinders, chocolate manufacturers, and the Ghanaian and Ivorian governments (CFI, 2017), suggesting that within the bounds of the value chain, governance is bipolar. However, traders explained that FSP adoption and design were primarily driven by manufacturers, suggesting governance is weighted towards the downstream: "*We represent* [them] *on the ground to implement their sustainability ambitions and commitments*" (GHA20-TRA).

Cocoa firms' FSPs are complex, covering forest conservation, agricultural productivity, and social safeguards, and were described by one manufacturer as akin to "*development packages*" (CIV27-CGM). Implementation activities include farmer training and farm mapping. FSPs are moderately codified. While many firms implement policies using Fairtrade or Rainforest Alliance certification, manufacturers usually require additional activities to differentiate their brands. These are specified by in-house sustainability programmes (e.g., Mondelēz's Cocoa Life, Nestlé's Cocoa Plan). Large, highly capable traders match manufacturers' requirements to their own programmes (e.g., Cargill's Cocoa Promise, Barry Callebaut's Cocoa Horizons). LBCs' and cooperatives' capabilities vary, while farmers' capabilities to comply with FSPs independently are low. Farmers we interviewed generally knew farming in protected areas was prohibited – "[cooperatives] *don't take cocoa from the classified forest*" (CIV-FG02-FAR) – but NGOs and cooperatives described the challenge of building capacity and supporting them to become certified. This has led to capability-building and implementation initiatives by government, NGOs, and firms.

Vertical structures: When traders' and manufacturers' FSPs align, or certification is used, this enables firms to trade FSP-compliant cocoa through modular linkages. When manufacturers' requirements exceed available offerings, traders offer tailored activities and relational linkages emerge. Manufacturers and traders also form relational linkages with highly capable cooperatives and LBCs to implement FSPs with farmers. Less-capable suppliers are controlled more closely. In Côte d'Ivoire, some traders reported installing their own staff in cooperatives, revealing captive linkages. In Ghana, Barry Callebaut, Cargill,

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Ecom, and Olam vertically integrated their value chains by acquiring or establishing LBCs, often explicitly to coordinate FSP implementation (Barry Callebaut, 2015).

Despite farmers' low capabilities, it is challenging for firms to establish captive or hierarchical linkages with them. High demand for beans means farmers can often choose between several buyers, to which they can sell beans through market linkages. Implementing FSPs therefore requires firms to develop relational linkages by building farmers' capabilities and promoting loyalty. To do this, firms offer advance payments, price premiums, and training on good agricultural practices, agroforestry, and conservation.

Horizontal structures: Despite aligning different firms' FSPs through common reporting requirements, the CFI initially only required firms to implement policies in their direct value chains (CFI, 2019). Continued indirect sourcing of conventional cocoa has led to low market share. While CFI signatories account for 85% of global cocoa usage, and Côte d'Ivoire and Ghana produce ~60% of global supply, the focus on direct sourcing means just 26% of globally traded cocoa is covered by an FSP (Parra-Paitan et al., 2023).

Consequently, separate value chain streams for FSP-compliant and conventional beans have emerged. As cooperatives and LBCs often source FSP-compliant and conventional beans for different clients and farmers can mix beans from different plots, beans from deforested areas are easily commingled into FSP-compliant streams. This means beans cannot be traced to a single plot: "*Anyone tells you they can attest to that, they're lying. It's impossible. There is always going to be the farmer with a dozen different plots... There's no way you can know exactly, 100%, that your cocoa didn't come from a classified forest*" (CIV15-TRA). Meanwhile, capability building is also undermined by firms only engaging their direct suppliers, and a lack of coordination between firms leads to duplicated efforts: "*When it happens like that, you are not able to achieve impact at the landscape scale. Impact becomes sporadic and scattered and it's a matter of time that you have rollback*" (GHA26-TSO).

FSP outcomes: In Ghana, FSPs have been associated with small reductions in cocoa-driven deforestation inside and outside forest reserves, but these are undermined by additional food crop deforestation in reserves (Addoah et al., 2026; Renier et al., 2025). Some manufacturers, traders, and cooperatives were positive about FSPs' impacts on forests, as they claimed farmers in protected areas were being excluded from FSP value chains, but this was disputed by other private, public, and civil society participants.

Published evidence on the equity of cocoa FSPs is limited. In Ghana, one household survey found ~4% of cocoa households had experienced market exclusion under FSPs (Addoah et al., in review), while the number rises to 13% in Côte d'Ivoire (Garrett et al., in prep). One group of farmers in a "buffer zone" around an Ivorian classified forest described being excluded from their cooperative: "*It hurts, it hurts, we cried every day… When we were in the cooperative we managed well... But since that day, we've lost out*" (CIV-FG01-FAR).

4.3 Palm oil in Indonesia

Supply chain characteristics: Indonesian palm oil supply chains are long and complex (Lyons-White and Knight, 2018). Independent producers, mills, refiners, traders, and consumer goods manufacturers represent major tiers. Smallholder farmers

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account for 36% of Indonesia's planted oil palm area (Gaveau et al., 2022). Large integrated supply chain companies (LISCs) with growing, milling, refining, trading, and manufacturing operations account for a substantial proportion of trade.

Value chain governance characteristics: Nestlé, a consumer goods manufacturer, became the first firm to adopt a zero-deforestation policy in 2010 following pressure from Greenpeace (Grabs and Garrett, 2023). NGOs and manufacturers also pressured LISCs and traders to adopt policies, such as Wilmar's NDPE policy and Golden Agri Resources' Forest Conservation Policy. In turn, LISCs and traders encouraged NDPE adoption by mills and growers upstream. Thus, while NDPE governance was initially driven by manufacturers downstream, bipolar governance emerged and LISCs at the midstream became "*the leader*[s] *in NDPE implementation*" (IPO25-TSO).

NDPE policies require suppliers to satisfy complex criteria, including proving that forests identified as High Conservation Value (HCV) or High Carbon Stock (HCS) have been conserved. Roundtable on Sustainable Palm Oil (RSPO) certification provides some codification, but cannot satisfy the needs of all downstream firms with specific brand requirements: "*Not all of these buyers are satisfied with RSPO… Every large consumer goods manufacturer will want things his own way… We have, further downstream, a bit of a mass of different requests as to what is acceptable*" (IPO20-LISC). Some firms' NDPE policies thus go beyond RSPO, although traders claimed different firms' policies are broadly similar. Codification had reportedly been increased by NDPE alignment initiatives such as the Implementation Reporting Framework.

Suppliers' capabilities to comply with or implement NDPE policies vary. LISCs "*have full control*" (IPO13-NGO) to implement policies throughout their operations. Larger growers and traders are also often highly capable. However, independent smallholders generally have low capabilities to achieve RSPO certification: "*RSPO is pretty demanding. It costs a lot, especially in terms of labor… RSPO is incredibly complicated*" (IPO-FG01-COP). Similar challenges apply to even more stringent NDPE policies. Many smallholders have little knowledge of NDPE requirements, as one grower explained: "*Policies are up here, producers are down here*" (IPO03-GRO).

Vertical structures: Variations in producers' compliance capabilities have produced different linkages. LISCs implement policies in their vertically integrated chains through hierarchical linkages. If suppliers are highly capable (including certified smallholders), RSPO certification enables firms to buy NDPE-compliant oil through modular linkages. However, firm-specific policies demand closer engagement. We observed firms using relational linkages to encourage compliance by their more capable suppliers, attempting engagement before suspending or excluding suppliers that had breached NDPE requirements. We also found firms investing to build suppliers' capabilities. This may eventually produce modular linkages as suppliers' expanding capabilities give them access to new buyers: "[We] *were consistently supporting them in that transformation journey, but then, like a kid that grows up, they left us behind. They had better options*" (IPO21-TRA).

Despite the importance of relational linkages or vertical integration for implementing NDPE policies, growers, traders, and LISCs continue to source palm oil "indirectly" from independent smallholders and mills or intermediaries through market linkages, reportedly to minimize investment and logistical costs and to secure supply. Meanwhile, improved infrastructure, high demand for oil, and excess refining capacity have enabled mills (and, via intermediary traders, smallholders) to choose buyers that offer competitive prices and simple transactions, including domestic buyers without NDPE requirements.

Horizontal structures: Although participants reported differences between downstream firms' NDPE requirements, the Implementation Reporting Framework and earlier collective aspirations such as the Consumer Goods Forum's zero net deforestation pledge and Indonesia Palm Oil Pledge have ensured some alignment between firms' policies (Grabs and Garrett,

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2023). LISCs and large traders also applied NDPE policies across their entire value chains to secure access to markets as sustainability demands grew. This produced moderate market share, with 70% of firms and 89% of smallholders being covered by an NDPE policy by 2020 (Chandra et al., 2024). In practice, however, the rollout of NDPE policies among smallholders has lagged. As in Brazilian cattle and West African cocoa, FSP-compliant and conventional value chain streams have emerged.

FSP outcomes: RSPO certification reduced deforestation in Indonesian oil palm concessions by 33% between 2005–2015, although RSPO only required conservation of primary and HCV forests (not zero deforestation) during that time period (Carlson et al., 2017). Causal analysis of NDPE policies from 2018–2020 suggests they produced no additional impact (Stigler et al., 2026), as all palm oil concessions (whether linked to NDPE firms or not) reduced deforestation during a period when overall Indonesian forest loss fell by 69% (Angelsen et al., 2025). Still, growers, LISCs, and manufacturers lauded progress on deforestation in concessions, which they claimed is "*trending down*" while "*deforestation outside concessions is on the rise*" (IPO19-LISC). Deforestation outside concessions may be driven by wealthy medium-sized producers (petani berdasi) that are nominally considered "smallholders" even though each may hold hundreds or thousands of hectares in total. Collectively, this evidence suggests NDPE policies have been moderately effective, although inequity has been mitigated by access to conventional markets for noncompliant producers. Even within NDPE value chains, survey data have revealed that active exclusion of noncompliant smallholders is limited (Chandra et al., 2026a).

4.4 Soy in the Brazilian Amazon

Supply chain characteristics: By comparison to the other commodities, Brazilian soy supply chains have relatively few tiers. Farmers sell soybeans to traders, occasionally via intermediaries or cooperatives. Vertical integration is limited, with Brazilian trader Amaggi being an outlier in owning farms (Heron et al., 2018).

Value chain governance characteristics: The ASM emerged from pressure by Greenpeace on retailers and traders including McDonald's and Cargill. Both firms initially drove FSP adoption by seeking support from other companies; while McDonalds "*brought companies together*" downstream (BRS03-NGO), Cargill's dominance in the Brazilian Association of Vegetable Oil Industries (ABIOVE) gave it midstream influence. This suggests bipolar governance in the ASM's initial design. However, ABIOVE and Greenpeace subsequently established a Soy Moratorium Working Group (GTS) to implement the ASM which included traders, NGOs, and later the government. This signaled a shift towards unipolar midstream governance in implementation.

The ASM is highly codified: it involves precisely characterized and standardized technical requirements to ensure zero deforestation. From the point of view of implementation, it entails moderately complex transactions. Farmers must register their property boundaries on the CAR, and compliance is assessed by traders using deforestation data from PRODES and a list of noncompliant farms published annually by the GTS. However, as CAR registration is a legal requirement, complying with the ASM is no more complex for producers than meeting their statutory obligations.

Soy farmers generally have high capabilities for compliance. They are often well capitalized (Garrett and Rausch, 2016) and have become highly organized into a powerful national lobby, the Brazilian Association of Soy Producers (Aprosoja). Previous research has also shown that the availability of previously cleared cattle pastures in the Amazon (Macedo et al., 2012) made compliance relatively easy for producers seeking to expand soy cropland. Yet, to the extent that the ASM disincentivized new agribusinesses investment in the Amazon, it likely increased transaction and input costs for farmers compared to places where economies of scale had been achieved like Brazil's Cerrado savannah biome (Garrett et al., 2013): "*Although the cost of land*

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was lower in the Amazon, the costs of investment would make it unfeasible to start soy production in the Amazon" (BRS12-PRO).

Vertical structures: The ASM's moderate complexity, high codification, and farmers' high compliance capabilities, alongside the comparatively short value chain, produced modular linkages between producers and traders. One firm, Cargill, established captive linkages with producers through a near-monopsony around its Amazon River port of Santarém, before the ASM was established (Garrett et al., 2013). This enabled it to enforce the ASM directly among its suppliers. Elsewhere, producers were reportedly able to find non-ASM buyers despite the Moratorium's high market share (see below), but Aprosoja complained that farmers incurred high switching costs to sell to them: "*Aprosoja's argument was like this… You're taking away producer's income, because they say he sells, but he's forced to sell cheaper... Or those guys who specialized in sourcing blocked soya from the Moratorium, they already knew the producer had to sell, and they would drive the price down*" (BRS02-IND). This suggests that while the ASM was implemented through modular linkages, Aprosoja used the claim that it increased switching costs – a characteristic usually associated with relational or captive linkages (**Fig.1.B**) – as grounds to oppose it. Analyses have since shown that the ASM did not affect average farmgate prices (Barrozo and Skidmore, 2025). Nonetheless, beyond the Amazon in the Cerrado, where producers' high capabilities enabled them to maintain market linkages with non-FSP buyers, they resisted the Moratorium's expansion: "*Producers in the Cerrado are stronger, different from the Amazon*" (BRS09-TRA).

Horizontal structures: As a sectoral standard, the ASM ensured absolute policy alignment among its signatories. With the participation of ABIOVE, it achieved high market share, covering 95% of Amazon soy exports by 2018 (Gollnow et al., 2022).

FSP outcomes: The short value chain, high producer capabilities, and high market share (95%) of the ASM were associated with high regional effectiveness, with the Moratorium reducing soy-driven deforestation in the Amazon by 57% between 2006–2015 (Gollnow et al., 2022) and preventing 18,000 km^2 of forest loss (Heilmayr et al., 2020). However, 43–50% of avoided deforestation was offset by clearance elsewhere in Brazil (Villoria et al., 2022). From the perspective of market access equity, the high collective market share of ASM signatories enabled producers' associations to argue that it limited their members' abilities to find non-FSP buyers in the Amazon. Although farmers' comparative wealth and capabilities mitigated major livelihood impacts, producers subsequently resisted the ASM's expansion to the Cerrado, where public and political support for conservation were weaker.

4.5 Comparative analysis

Across all four cases, midstream firms drove FSP implementation, although in cocoa, palm oil, and soy, downstream firms played important roles in policy design and adoption. FSPs almost invariably involved complex requirements to prove production was deforestation-free. Codification varied. While the ASM and TAC were highly codified, divergent downstream requirements by palm oil and cocoa limited FSPs' consistency between firms. Producers' capabilities varied by size. Larger and better-capitalized cattle, palm oil, and soy producers had higher capabilities, but smallholders generally lacked compliance capabilities independently of support by firms.

Where FSPs were highly codified and suppliers were highly capable – as in the case of large cocoa and palm oil traders – FSPs were implemented through modular linkages. More often, however, limited codification required firms to establish close relational linkages or, if suppliers' capabilities were low, captive or hierarchical linkages. In West African cocoa, traders acquired LBCs or established captive linkages with cooperatives. In Indonesian palm oil, firms coordinated deforestation-free production through relational linkages with highly capable suppliers, or through hierarchical linkages with their own

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plantations. Even in Brazilian cattle, where the TAC was highly codified, slaughterhouses emphasized the importance of relationships to encourage compliance by highly capable producers.

Yet in all three of these cases, limited market share and high demand for conventional commodities impeded firms from establishing the close linkages with suppliers needed to implement their FSPs. Smallholders with low capabilities were able to find buyers without deforestation-free requirements, and separate value chain streams emerged for FSP-compliant and conventional commodities. Previous research has interpreted this as FSPs producing value chain bifurcation (Cammelli et al., 2022). In all three cases, FSPs achieved at best moderate regional effectiveness, although inequity was mitigated by noncompliant producers' access to conventional markets.

Amazonian soy presented a contrasting case. High codification and high producer capabilities enabled traders to implement the ASM through modular linkages, and the policy's high market share was associated with large reductions in deforestation. Yet these modular linkages possessed characteristics usually associated with captive or relational linkages, as producers who did not comply with Moratorium requirements faced market exclusion or, reputedly, high switching costs to non-FSP buyers. The tighter requirements this entailed for Amazonian farmers vis-à-vis their peers in other regions were associated with resistance to the ASM's expansion.

Across all four cases, horizontal value chain structures – understood as the collective market share of firms with FSPs – thus played an important role in shaping the vertical linkages through which firms implemented deforestation-free production.

Table 4. Summary of findings across the four commodity value chains. The values taken by variables were assessed using pre-defined criteria (Table S2).

		Cattle, Brazilian Amazon	Cocoa, West Africa	Palm oil, Indonesia	Soy, Brazilian Amazon
FSP investigated		Terms of Adjustment of Conduct (TAC) agreements signed by slaughterhouses	Cocoa and Forests Initiative (CFI) and signatory firms' sustainability programmes	No Deforestation, no Peat, no Exploitation (NDPE) commitments adopted by firms	Amazon Soy Moratorium (ASM)
Supply chain characteristics		Comparatively shorter supply chain although multiple calving, raising, and finishing tiers	Long supply chain with numerous tiers	Long supply chain with numerous tiers; mix of large vertically integrated firms and independent actors	Comparatively shorter supply chain with fewer tiers
Value chain governance characteristics	**Lead firms**	Slaughterhouses, although brands and retailers played a role in FSP adoption	Chocolate manufacturers and cocoa traders and grinders	Consumer goods manufacturers, followed by LISCs and large traders	Retailers (McDonald's) and traders (Cargill, followed by ABIOVE)
	Polarity of governance	**Unipolar:** Midstream; slaughterhouses sign and implement TAC agreements	**Bipolar:** Downstream adoption and design, midstream design and implementation	**Bipolar:** Downstream adoption and design, midstream design and implementation	**Unipolar:** Implementation driven by midstream traders, though downstream firms involved in adoption and design
	Complexity of FSP	**High**: Implementation requires farmers to present numerous documents including a GTA, CAR, LAR, and tax invoice to slaughterhouses, which monitor deforestation using PRODES; slaughterhouses subject to public audits	**High**: Implementation involves registering and mapping farms; yield estimates; assessing deforestation risks; monitoring deforestation in protected areas; and conducting awareness-raising activities with farmers	**High**: Implementation requires satisfaction of numerous criteria including identification, management, and monitoring of HCS and HCV areas; palm oil traceability to mills; satellite monitoring of deforestation; and observation of FPIC	**Moderate**: ASM requires producers to register properties in CAR, but this is already a legal requirement, and monitoring is performed by ASM signatories and the GTS using INPE PRODES satellite monitoring system
	Codification of FSP	**High**: TAC is a sectoral standard enforced by the Federal Public Prosecutor (MPF)	**Moderate**: Some firms' policies are based on Fairtrade or Rainforest Alliance. Downstream firms adopt in-house policies to differentiate brands, but CFI ensures high degree of consistency between firms	**Moderate**: Upstream firms often implement NDPE using RSPO; midstream firms use RSPO and own policies; downstream firms adopt specific albeit similar policies to differentiate brands. RSPO and IRF provide some codification	**High**: ASM is a sectoral standard
	Capabilities in the supply base	**Mixed**: Capabilities are greater among larger than smaller producers, who often have low compliance capabilities	**Low**: Smallholder farmers depend on large-scale training and support by firms	**Mixed**: Industrial growers, large traders and LISCs are highly capable; smallholders have low capabilities for compliance	**High**: Amazonian soy producers have high capabilities to execute ASM-compliant transactions
Value chain structures	**Vertical: value chain linkages**	Relational (FSP streams), although some hierarchical linkages emerging as finishers adopt full-cycle management; market (conventional streams)	Hierarchical (traders with vertically integrated LBCs); modular/relational (manufacturers with traders); relational (traders with farmers); market (conventional streams)	Hierarchical (vertically integrated LISCs); modular (RSPO-certified streams); relational (NDPE streams); market (conventional streams)	Modular, although high market share of ASM meant soy producers complained of high switching costs to non-FSP buyers, a characteristic associated with captive or relational linkages
	Horizontal: collective market share of FSP	**Moderate**: 26% of cattle purchases in Pará, Rondônia and Mato Grosso covered by TAC alone, but 75% covered by TAC and G4 (Levy et al., 2023)	**Low**: While CFI signatories account for 85% of global cocoa use, only 26% of global trade is covered by an FSP due to indirect sourcing (Parra-Paitan et al., 2023), and 55% of Ivoirian exports were untraceable in 2019 (Renier et al., 2023)	**Moderate**: On paper, 70% of firms and 89% of smallholders are covered by an FSP, but only 46% of smallholder plots are in supply bases of mills with FSPs (Chandra et al., 2024)	**High**: ASM covers 95% of Amazon soy exports (Gollnow et al., 2022)
FSP outcomes: regional effectiveness and market access equity		**Moderate effectiveness, moderate equity**: TAC reduced deforestation by 0.57% year^{-1} on compliant properties (Brandão et al., in review); non-compliant small producers risk exclusion and acquisition but retain access to conventional markets	**Low effectiveness, moderate equity**: Deforestation reduced in Ghanaian reserves (Addoah et al., in review) but cocoa continues to be grown in protected areas; noncompliant farmers excluded from sustainability programmes but retain access to conventional markets	**Moderate effectiveness, moderate equity**: NDPE policies produced no additionality (Stigler et al., 2026) but oil-palm deforestation has fallen nationally (Angelsen et al., 2025); noncompliant industrial, mid-sized, and smallholder producers all retain access to conventional markets	**High effectiveness, moderate equity**: ASM reduced soy deforestation by 57% (Gollnow et al., 2022); non-compliant producers were excluded, although their high capabilities likely mitigated livelihood impacts; producers resisted policy expansion to Cerrado

Definitions (Portuguese initialisms defined in English): ABIOVE, Brazilian Association of Vegetable Oil Industries; ASM, Amazon Soy Moratorium; CAR, Rural Environmental Registry; CFI, Cocoa and Forests Initiative; FPIC, Free, Prior, and Informed Consent; FSP, Forest-focused Supply chain Policy; G4, Public Livestock Commitment; GTA, Animal Transport Permit; GTS, Soy Moratorium Working Group; HCS, High Carbon Stock; HCV, High Conservation Value; INPE, Brazilian National Institute for Space Research; IRF, Implementation Reporting Framework; LAR, Environmental Production License; LBC, Licensed Buying Company; LISC, Large Integrated Supply chain Company; MA, Market Access; MPF, Brazilian Federal Public Prosecutor's Office; NDPE, No deforestation, no Peat, no Exploitation; RSPO, Roundtable on Sustainable Palm Oil.

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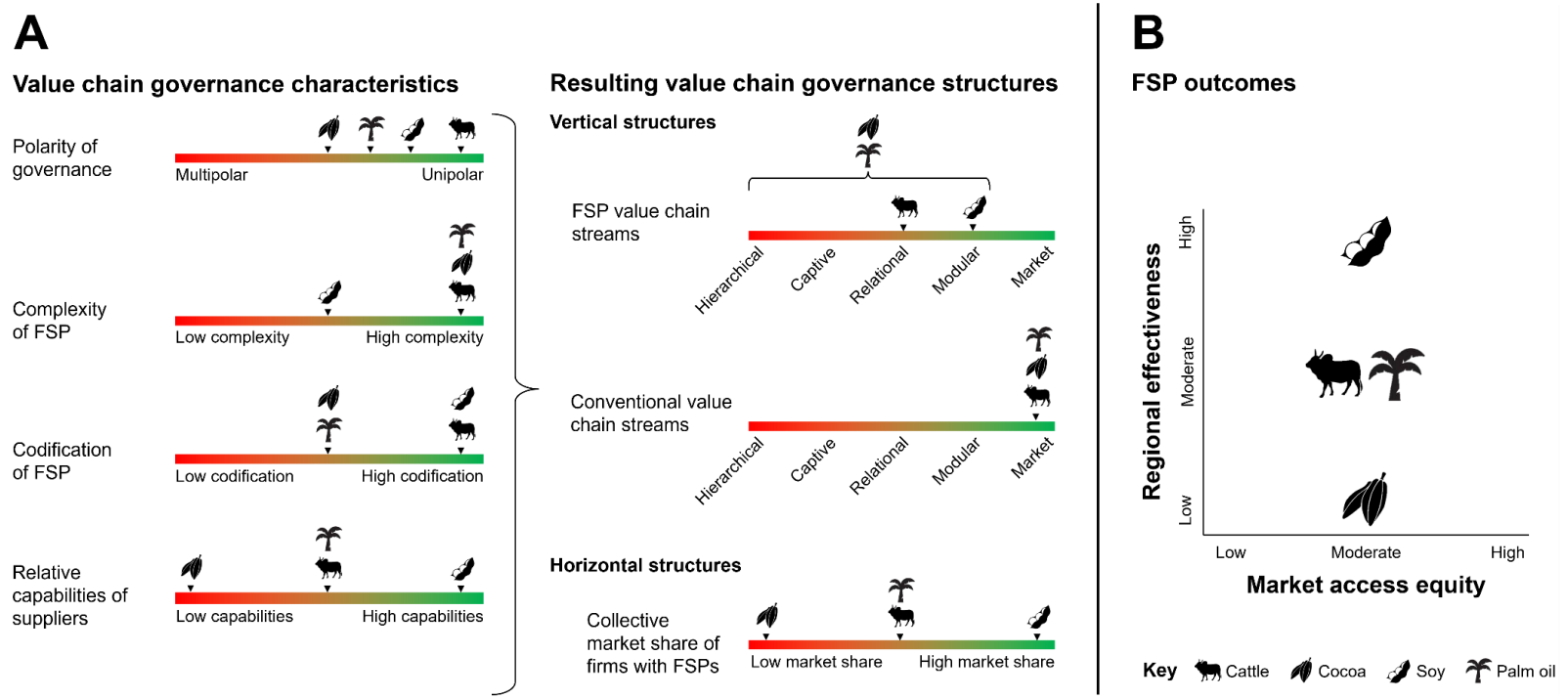

Figure 3. Panel A: Summary of findings for value chain governance characteristics (left) and vertical and horizontal value chain governance structures (right) across the four commodity value chains. In the vertical value chain governance structures, the predominating linkage types are shown for conventional and FSP streams in each value chain. **Panel B: FSP outcomes identified in each commodity value chain in terms of regional effectiveness and market access equity**. For both panels, the values taken by variables were assessed using pre-defined criteria (**Table S2**).

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5.0 A middle-range theory of deforestation-free value chain governance

Based on our findings, we now propose a middle-range theory to explain how value chain structures may influence deforestation-free governance by firms with FSPs (**Fig. 4**). Our theory builds on the key variables shaping FSP outcomes that we identified in our comparative analysis: the complexity and codifiability of FSPs; suppliers' compliance capabilities; horizontal value chain structures, conceptualized as the collective market share of FSPs; and the vertical structures – i.e., linkages – through which FSPs are ultimately implemented. In line with our aim to describe a well-bounded set of phenomena, the theory is focused on regional-scale outcomes; an expanded theory would be needed to incorporate spillovers between regions. Although our study's design precluded strong causal inference, the mechanisms proposed by the theory can be tested in future research to measure the impacts of different value chain governance structures on FSP outcomes.

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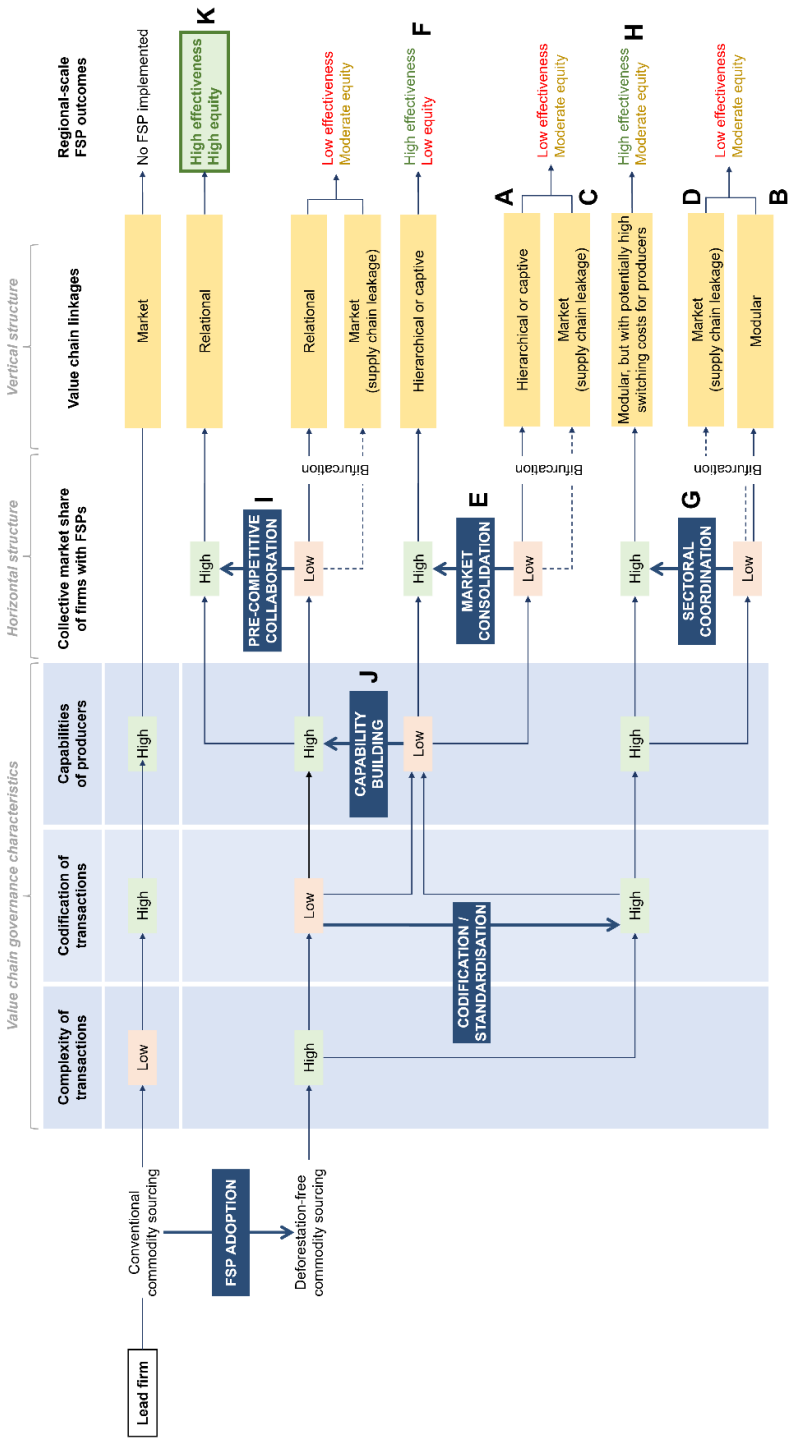

Figure 4. A middle-range theory to propose how value chain structures shape deforestation-free governance options and outcomes. Letters **A–K** denote components that are described in the main text. **K** denotes one pathway to achieve both effective and equitable outcomes. This requires both pre-competitive collaboration and capability building by firms with FSPs if suppliers' capabilities are low, as is often the case with smallholder farmers. **H** may also achieve effective and equitable outcomes, although equity may be lower as noncompliant producers will have their market access restricted. Following Gereffi et al. (2005), low complexity is presented as only being associated with high codification and high producer capabilities, based on the assumption that transactions with low complexity will necessarily be easily codified and easily executed by all producers.

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Firms may seek to coordinate deforestation-free production by less-capable producers through captive or hierarchical linkages (**A**). Alternatively, when suppliers are highly capable and policies are codified, FSPs can be implemented through modular linkages (**B**). In both cases, high market share is important to avoid supply chain leakage undermining regional effectiveness (**C**, **D**).

Firms may attempt to increase their FSPs' market share and take greater control over production by seeking to consolidate the market (**E**), potentially by integrating their value chains. If successful, this could deliver higher regional effectiveness (**F**). However, we observed limited vertical integration in practice due to logistics and investment costs, while market consolidation was limited by competition. Market consolidation may also undermine equity. Although the concentration of agri-food value chains can provide contract stability and access to services (Maertens et al., 2011; Minten et al., 2009), it has raised concerns about the exclusion or dispossession of smallholders (Amanor, 2012; Clapp, 2021). Our participants were concerned that Brazilian cattle smallholders risked being assimilated into larger operations. In contrast, equity in cocoa and palm oil was preserved by FSPs' limited market share, which meant producers retained access to conventional markets.

If suppliers are highly capable and policies are highly codified, firms may seek to increase their FSPs' market share through sectoral coordination, as we observed with the ASM (**G**). Increasing market share under these circumstances can enhance effectiveness, but may mean modular linkages take on captive or relational characteristics if producers incur high switching costs to find scarcer conventional buyers (**H**). In the case of the ASM, this pattern appeared to undermine the policy's legitimacy – its acceptance as being justified, desirable, or appropriate by producers (Bernstein, 2004; Suchman, 1995) – and likely contributed to resistance to its expansion.

In sectors dominated by smaller or poorer farmers with lower capabilities, pre-competitive collaboration (**I**) to build producers' capabilities (**J**) could enable firms to implement FSPs through relational linkages across a higher share of the market. This may present a more plausible pathway for firms to govern deforestation-free production both effectively and equitably (**K**). Capability building would reduce the transaction costs of FSPs without trapping small producers into captive or hierarchical linkages. Relational linkages may also enable firms to better accommodate producers' perspectives, needs, and participation in policy design and implementation.

The importance of capability building explains the training programmes we observed in cocoa. Yet it is limited in palm and practically non-existent in cattle, except for JBS' Green Offices initiative, which supports farmers to comply with environmental regulations (JBS, 2026). Even in cocoa, training programmes failed to build producers' capabilities at scale. This may be because there are few apparent incentives to invest in training farmers that do not become suppliers (Swinnen and Vandeplas, 2010), or cannot be counted in supply chain-level impact attribution systems (Cammelli et al., 2025). Consequently, we found that firms work in silos, focusing vertically within their own value chains with little horizontal collaboration and excluding indirect suppliers. Meanwhile, pre-competitive collaboration has been stifled by competition and antitrust regulations (Dermawan and Hospes, 2018).

Yet, firms do sometimes build suppliers' capabilities outside their direct value chains, occasionally through horizontal collaborations with competitors. In Indonesia, Musim Mas has trained >10,000 palm oil farmers through its Smallholders Hub program and hosted NDPE training workshops with Sinar Mas (Musim Mas, 2026). These cases suggest that pre-competitive

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collaboration on mass training may offer a cost-effective way to implement FSPs in a supply base with high turnover and many intermediaries (Cammelli et al., 2025; Nakao, 2026).

6.0 Conclusions and policy recommendations

This study examined how value chain structures shape the governance and outcomes of deforestation-free production by firms with FSPs. Although our comparative design precluded strong causal inference, we found that different value chain structures were associated with variations in governance approaches and outcomes. As expected, FSPs involved complex transactions and could not be implemented through market linkages. In the cattle, cocoa, and palm oil cases, where many producers were smallholders with low compliance capabilities, firms often implemented FSPs through closer relational, captive, or hierarchical linkages. However, as FSPs' collective market share was low or moderate, it was difficult for firms to establish such close linkages across the supply base. Value chains bifurcated between compliant and conventional streams and regional effectiveness was limited. This supported our hypothesis that effectiveness would be lower in cases with lower market share, although inequity was mitigated by noncompliant producers' access to conventional markets. In the case of soy, suppliers were highly capable, enabling the ASM to be implemented through modular linkages. Yet the high market share of ASM signatories meant noncompliant producers risked being excluded. Consequently, although the ASM achieved high regional effectiveness, and producers' high capabilities mitigated major livelihood impacts, the policy's legitimacy was undermined, preventing its expansion to other biomes.

Our middle range theory presents a range of governance options for firms with FSPs depending on the capabilities of their suppliers, their requirements for more or less differentiated policies, and the structures of their value chains. In general, sectoral coordination in value chains with highly capable suppliers, or pre-competitive collaboration to implement mass capability building in value chains with less capable suppliers – for example, through landscape or supply-shed approaches (Cammelli et al., 2025; Nakao, 2026) – are most likely to deliver effective and equitable conservation outcomes. Alternatively, firms could vertically integrate their value chains or build the capabilities of their direct suppliers only. These steps are likely to produce trade-offs between effectiveness and equity, but may be preferred by firms facing other pressures such as limited budgets or staff capacity.

Our findings have important implications for public regulations in importing jurisdictions like the EUDR. The limitations on firms' abilities to govern deforestation-free production imposed by varying value chain structures are similarly likely to apply to EUDR compliance. Indeed, early projections have estimated that the EUDR's impact will be modest and undermined by leakage (Gilbert, 2024), and it has also been criticized for potentially leading to the exclusion of smallholders (McDermott et al., 2025; Zhunusova et al., 2022).

The EUDR has also undermined FSPs with more stringent criteria such as the ASM, which has an earlier cut-off date (2008 vs 2020 for the EUDR). While ASM signatories' control over producers was associated with high effectiveness, it also fomented opposition. Since we conducted our fieldwork, the less-stringent EUDR created an opportunity for the ASM to be challenged. Following a case brought to Brazil's national competition regulator by Aprosoja and restrictions on tax benefits for signatories in Mato Grosso, ABIOVE left the Moratorium in early 2026 (Rausch et al., 2026). This weakened the Moratorium and reduced its market share. The case of the ASM suggests that implementing FSPs through linkages that do or are perceived to involve more coercive control – such as market exclusion or the imposition of high switching costs – may impair their durability by undermining legitimacy. By comparison, our findings that noncompliant cattle, cocoa, and palm oil

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producers retained greater access to conventional markets may explain the comparatively limited opposition to FSPs in those sectors. If so, supporting equity by building producers' capabilities and avoiding value chain linkages with coercive features could help build more durable support for conservation.

Opposition to the ASM reveals a paradoxical challenge for FSPs: while incomplete market share is likely to undermine effectiveness by enabling leakage, increasing market share and tightening control over producers can undermine market access equity and legitimacy. Similar paradoxes have been reported between the goals of reducing deforestation and including smallholders in palm oil value chains (Grabs and Garrett, 2023). These paradoxes raise questions about whether FSPs can deliver deforestation-free production both effectively and equitably. Our findings suggest they can, but potentially only with transformative changes to value chain governance to de-commodify production and develop more supportive relationships with producers. This echoes calls for firms to support different types of smallholders, include them in FSP design, and engage with their norms and values (Addoah et al., 2025; Chandra et al., 2024).

Exporting and importing states could encourage firms to collaborate pre-competitively on building producers' capabilities by reviewing impediments in antitrust regulations and establishing pooled funds for training, with tax or due-diligence concessions for firms that invest. Importing states should also coordinate collaborative capability-building projects, such as the EU-funded Team Europe Initiative on Deforestation-free Value Chains. Yet, even with enhanced relationality and capability building, FSPs cannot tackle the underlying drivers of deforestation such as growing demand for commodities (Renier et al., 2025). Producing and importing states must also deliver on their commitments to end deforestation. Stronger public interventions to enforce forest protections and curb demand for forest-risk commodities will be vital as private governance nears the limits of its potential.

Code and data availability

Although interview manuscripts are confidential, aggregated data are available in the main text or the supplementary materials on OSF at: https://osf.io/6kwz8/overview?view_only=856bfdeca703431583cae324902db9c5.

Author Contributions

Conceptualization: JLW, FC, JG, TA, JB, KMPK, AC, SAL, RDG; Methodology: JLW, FC, JG, TA, JB, KMPK, AC, SAL, RDG; Investigation: JLW, FC, JG, TA, JB, KMPK, AC, WT, CR, SAL, SBK, CYAY, RDG; Visualization: JLW; Supervision: RDG; Writing—original draft: JLW, RDG; Writing—review and editing: JLW, FC, JG, TA, JB, KMPK, AC, WT, CR, SAL, SBK, VMR, CYAY, RDG.

Competing interests

JLW, RDG, FC, JB, TA, and PK have undertaken paid consultancy work for the UK Department for Environment, Food & Rural Affairs (Defra). JLW has received a meal from Musim Mas, an Indonesian palm oil company. RDG and JB have received funding from Suzano (Brazil). RDG serves as a paid science advisor for Rainforest Builder and Sumthing. All other authors declare they have no competing interests.

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