

Article

How Blockchain Can Shape Sustainable Global Value Chains: An Evidence, Verifiability, and Enforceability (EVE) Framework

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Abstract: Law, regulation, and private standards have evolved to enhance sustainability in value chains. However, the volume of hard and soft laws has created complexity and fragmentation for consumers and firms. In addition, global value chains are increasingly disaggregated, making it difficult for consumers to enforce breaches of sustainability representations. Blockchain, as an immutable and digital record keeping system, is a tool that can deal with this growing complexity in global value chains. Documents verifying sustainability that were once in the private domain and stored in paper copy can now be made accessible in a secure and transparent blockchain platform. Despite a growing interest in the potential of blockchain to transform businesses, there are few concrete examples or scholarly literature showing how blockchain is operationalized in practice. Using a “conceptual framework analysis” approach, we develop an Evidence, Verifiability, and Enforceability (EVE) framework to illustrate how blockchain can enhance sustainability by providing information to consumers on the origin of products, assurances as to the veracity of the information, and a mechanism to enforce representations through the blockchain smart contract function. However, there need to be safeguards put in place for blockchain technology to meet its promise and we discuss some of these challenges.

Keywords: blockchain; value chain; governance; sustainability; smart contracts

1. Introduction

Gibson Guitar Corporation is most famous for their Les Paul electric guitar—the wooden craftsmanship is highly valued by guitar enthusiasts. But in 2011, Gibson was famous for the wrong reasons, when armed US Federal Marshals raided the Tennessee-based corporation’s headquarters, under the belief the company had been trafficking in illegally obtained wood. If the company was in possession of illegally obtained wood to build their guitars, they would be in breach of the Lacey Act, a century-old statute restricting the trade of endangered species, which was amended in 2008 to cover plants (trees) as well as animals.

The Lacey Act, 1900, a federal United States statute, requires companies to certify the legality of their value chain. Companies cannot (whether knowingly or unknowingly) import into or export from the United States any fish, plant, or wildlife protected under this statute. An Environmental Investigation Agency investigation concluded that Gibson had knowingly imported illegally sourced rosewood and ebony from Madagascar. Gibson argued the wood was sourced legally from India. Under the Lacey Act, companies must store documentation on the provenance of their wood, and regulators must be able to access this paper-based information, or chain of custody documentation.

Gibson later settled with federal prosecutors and paid substantial penalties over the impugned wood sourced from Madagascar. While some commentators called this a win for anti-deforestation efforts, others argued that the onerous value chain reporting was bad for business.

There are increased consumer demands for sustainability which can be defined as production that meets the needs of the present, allows firms to generate profits, and does not compromise the welfare of future generations [1]. A broad definition of sustainability encompasses both the ecological and social impact of products across the value chain (think pollution, child labour, and fair trade). Along with this trend for sustainability, supply chains are becoming more disaggregated, meaning firms have greater responsibility for sustainability beyond their direct ownership and control, which requires greater coordination or more networked forms of governance across their value chains [2]. While laws and regulations like the Lacey Act are advancing sustainability in value chains, consumers are also demanding sustainable products. While law and regulation have facilitated improved environmental and social practices among firms, there is perception that government interventions have not gone far enough in delivering sustainability. Private actors have stepped in to fill this gap by creating voluntary standards for firms to enhance their sustainability. For example, in the forest sector, the Forest Stewardship Council (FSC) and Programme for the Endorsement of Forest Certification (PEFC) are two standards that have emerged to enhance sustainability and to give consumers assurances that their products are sustainable.

These developments have created a complex maze of law, regulation, and private standards in global value chains that span national borders. For firms determining the provenance of their products and ensuring they meet these multitude of laws and standards is costly. For regulators and auditors, verification is challenging given the paper-based documentation in global value chains, and the diverse sources of information that are often social and qualitative in nature. And for consumers and retailers, verifying whether products are in fact sustainable and enforcing their rights for misrepresentations about sustainability is problematic. Who do you sue and where do you sue those who have made misrepresentations?

We argue in this paper that blockchain is a digital record keeping mechanism that can deal with this complexity, and can provide accessible information on the sustainability of products. There is a nascent and growing literature on blockchain and its potential to transform how we do business [3] and to advance sustainability by creating traceability, transparency, and better coordination in global value chains. Yet, there are few concrete examples or scholarly literature showing how blockchain is operationalized in practice or what areas are critical for businesses to focus on in developing blockchain—this is likely because blockchain is an emerging technology and very much in the development phase.

This paper aims to fill this gap in literature and using a conceptual framework analysis methodology, develops a conceptual framework for thinking about how blockchain can advance sustainability in global value chains and reshape the influence of law (both hard and soft law).

We develop an Evidence, Verifiability, and Enforcement (EVE) framework, to illustrate how blockchain can provide open-access evidence for firms, regulators, and consumers on the provenance of products, and the sustainability of value chains; this evidence is verified by a network of stakeholders who provide assurances the firm has in fact met sustainability standards; and this information as well as the blockchain smart contract function can support consumers in efficiently enforcing their rights. Drawing on the EVE framework, blockchain provides the infrastructure to support better governance in global value chains and address important “pain points” in value chains, however, there are important safeguards that must be developed to maintain the integrity of the blockchain.

2. Conceptual Background

2.1. Value Chains and Sustainability

The management of global value chains and supply chains poses several challenges for firms. Supply chains involve a sequence of firms that are involved in various stages of the production of a product or service. Each firm makes decisions, from the choice of raw materials and other inputs, transportation modes, inventory levels, pricing, and so on. Although large multinational firms may exert significant influence over their suppliers, no firm can control all the decisions made within the supply chain.

Gereffi et al. [4] build a theoretical framework to explain governance structures in global value chains. They identify five types of global value chain governance structures ranging from purely market-based exchange on one end, to vertical integration at the other. These structures involve different levels of explicit coordination between firms in the value chain as well as different power dynamics. Irrespective of the specific governance mechanism, firms in the value chain have to deal with coordination challenges. In fact, value chains are replete with moral hazard and other information asymmetry problems. This can often lead to inefficient economic decisions, as upstream suppliers may choose to cut corners on quality, or may maintain lower levels of inventory than what is desired by firms downstream. The resolution of such incentive conflicts requires a careful design of contracts. Indeed, real world value chain agreements demonstrate the need for careful coordination of economic incentives and we observe a wide array of contractual agreements within the value chain [5].

More recently, the incentive conflicts within value chains are being felt in other ways. For example, customer preferences for sustainably sourced products are creating a challenge and opportunity for global value chains. On one hand, firms that can meet these requirements can expand their market share. But, given the complex and fragmented nature of global value chains, it is challenging for firms to ensure that any sustainability representations that they make to customers are indeed being enforced throughout the value chain. The hidden action (moral hazard) and hidden information that is prevalent in value chains are significant challenges that firms are struggling to overcome.

These challenges are particularly complex because most sustainability representations are hard to detect because they are essentially representations about “process quality” as opposed to “product quality”. To appreciate this distinction, consider a firm that claims that its product only contains a specific kind of material. While it may be difficult to ensure that the various suppliers adhere to this constraint, the end product can be tested to verify whether the firm’s representation is indeed valid. However, consider a different kind of claim that a firm may make; for example, that no child labour was used in its value chain. This is a claim about process quality because the end product cannot be tested to check the veracity of this claim. The firm, in this case, needs to have clear visibility into the actions of its suppliers, should be able to verify any claims that the suppliers make and, finally, should be able to hold suppliers accountable for their actions.

Chen and Lee [6] argue that supplier responsibility problems can be tackled by employing two types of controls. First, the use of screening instruments such as certification to identify risky suppliers, or conducting audits to detect potential violations; and, second, the use of different incentive instruments such as price premiums, recognition, relationship building, and/or investment in training to build awareness. While product quality can be easily tested, making it conducive to be controlled using a combination of a screening or monitoring mechanism, process quality is more obscure, making it difficult to determine what kinds of instruments and assurance responsibilities are to be assigned to this in a value chain. Furthermore, every product in the value chain has a combination of both product and process related quality attributes. Hence, the product quality and process quality must be viewed as a continuum, and the product quality attributes and process quality attributes in the end product may differ, depending upon the nature of the end product. Figure 1 presents the product–process quality continuum, which can be divided into four quadrants depending upon the number of attributes related to sustainable and responsible business practices.

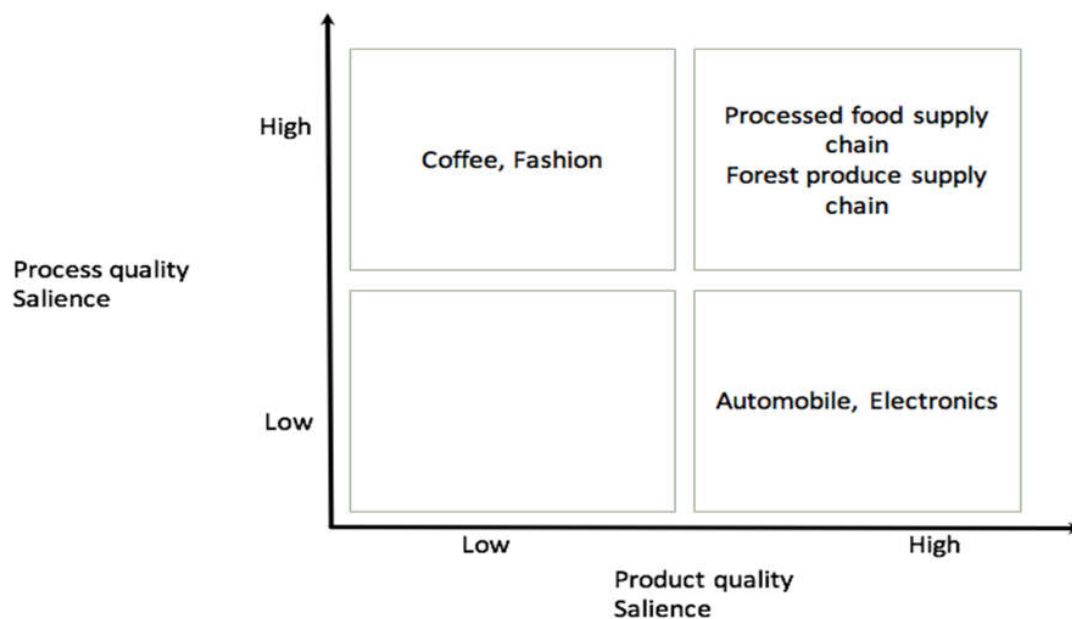


Figure 1. Product–process quality salience for sustainability representations.

There is a clear demand from consumers that firms adhere to sustainable and responsible business practices. There are, however, significant informational, technical, and operational challenges that need to be overcome by firms that manage global value chains. The growing responsibility of firms to manage for sustainability across disaggregated supply chains—with the attendant coordination and information problems—make sustainability challenging [2]. In this context, blockchain provides a potential mechanism to help solve these challenges, and we propose an Evidence, Verifiability, and Enforceability (EVE) framework to show how blockchain can be operationalized to advance sustainability in global value chains.

Although our proposed framework is applicable in any value chain, we highlight the context of forest value chains which have been replete with information asymmetry and misrepresentations about sustainability. Forests provide a multitude of goods and services to people. Over-extraction of forests has led to ecological degradation and social conflict, resulting in enhanced law and regulation for better forest management and protection. These legal advancements have focused primarily on improving sustainability upstream in the value chain and have transnational and retroactive effect (like the Lacey Act and Gibson Guitar example). However, law and regulations (hard law) have not gone far enough to protect forests across the globe (think the Amazon or Indonesian Rainforests). In response, non-state regulation (soft law) filled this regulatory gap to promote more sustainable forest management across the globe.

The growth in the voluntary certification of forestry activity is touted as a global sustainability success story, with millions of hectares of forests across the globe covered by FSC, or the PEFC systems [7,8]. Forest certification establishes criterion and indicators on a range of issues for forest management and harvesting, with third parties auditing forest companies to ensure compliance in areas such as forest harvesting operations, to community consultation, biological outcomes, and labour standards. Companies that meet the standards for each certification can use the certification seal on their products, and have improved market access through procurement policies, and certified products may even attract a price premium in the market (though the evidence is inconclusive). Each company wanting certification has its activities audited by a third party, however, there are some important problems that create uncertainty around the provenance and sustainability of certified forest products. The first is that forest products are commodities and logs from uncertified forests (or illegally harvested timber) may be bundled in with certified wood in complex global value chains. Tracking the origin of timber is paper-based and opaque, and there are numerous cases of wood from unknown

origin being grouped in with certified wood, and ‘discovering’ this is complex. Second, evaluations and audits are also paper-based, and typically not available to the public. Existing paper-based systems are subject to tampering, create burdensome administrative and transaction costs (as in forest certification compliance) for those opting and those wanting to verify transactions, and enables rent seeking behavior by record keeping ‘gatekeepers’. Third, the social dimension for sustainability, which is qualitative in nature and includes perceptions of communities and stakeholders for operations, is difficult to capture in paper-based documents. There are few formal avenues for communities and stakeholders to verify audits and evaluations of a firm’s performance on social indicators, hence the social dimension of sustainability is obscured in sustainability reporting [9].

2.2. Responses to Demands for Sustainability in Global Value Chains

Law underpins social relations and commercial transactions: regulations influence how and where business is conducted, contracts establish the rules for different parties to business transactions at local to international scales (business to business and consumers), and the courts settle disputes between parties which creates precedent for others. It can be said that law binds global value chains—ensuring goods are traded along the value chain, and facilitating complex business transactions between people who often do not know each other (see, for example, [9,10] for a discussion on this).

It is not surprising that the law plays an important role in enhancing sustainability in global value chains. For example, in highly regulated sectors like forestry, law is acutely important to value chains. Upstream, statutes typically establish rights for companies to harvest timber, and create protections for the environment, workers, indigenous peoples and local communities. There has been a significant body of public interest litigation related to protecting forests, and ratcheting up the standards for logging and forcing companies to internalize costs they had externalized to the broader public. As forest products pass down the value chain, contract and trade law are important. Trade law includes free trade agreements or international trade law, as well, many countries have in place restrictions against the import of illegally harvested timber (see for example EU, Australian and US restrictions). As goods are distributed to customers in domestic or export markets, more consumer-oriented law applies, as well as those conditions of contracts between businesses and consumers that warrant the sustainability of the product. Representations around the sustainability of products are typically made in contract law, and breaches of these can result in damages paid to those suffering losses because of these misrepresentations.

While greater oversight by traditional institutions (e.g., legal and regulatory bodies) is necessary in this context, entities like non-governmental organizations (NGOs), etc. are also necessary to help address the issue and this paradigm has been termed non-state market driven governance (NSMD) [11]. Despite these developments, fundamental information and technical problems need to be overcome.

Gereffi et al. [4] argue that in market-based value chains, like global forest commodity markets, audits, and certification are important to address information asymmetry and to verify representations around sustainability. NSMD governance is voluntary and aims to promote those firms that are more sustainable in the marketplace. NSMD includes diverse actors, such as NGOs and civic actors, along with public and private actors, who can work in alliance to promote, define, and select preferred goods and practices through diverse mechanisms. These mechanisms can include certification of goods and processes, and market campaigns to either boycott or promote the activities of firms [12]. Locke [13] discusses the overlapping roles that private and public actors play in providing oversight to the activities of multinational firms and their global value chains.

Figure 2 shows the different forms of law that apply throughout the product life cycle of forest products—from statute and public law upstream, to trade law and contract law as the products move down the value chain (see Figure 2). Sustainability through law is mostly focused upstream—as the state, driven by public demands, has imposed more environmental standards on logging. This is however changing, as consumers are demanding more assurances on the sustainability of their products.

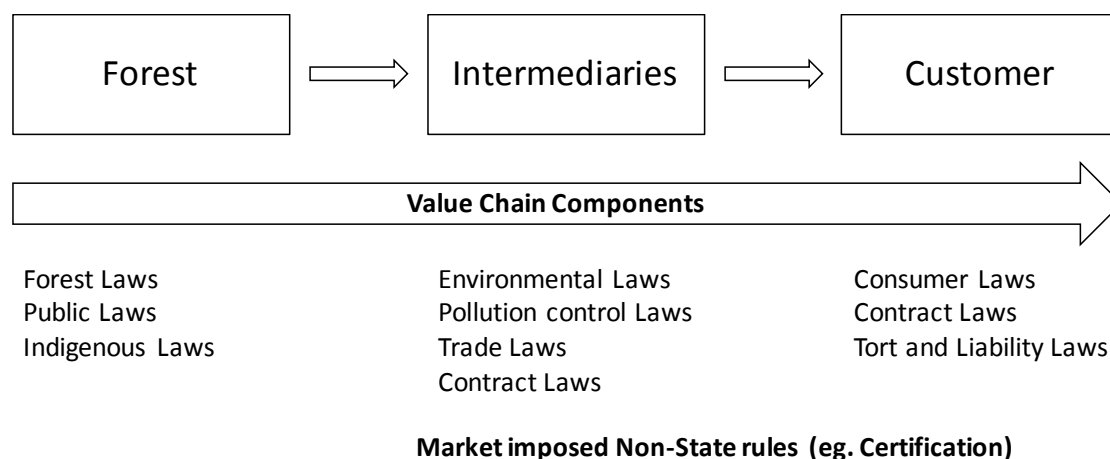


Figure 2. Law and global value chains.

Figure 2 shows that non-state rules cover the full value chain, from forest stand to store-shelf, and these rules are superimposed on state law. These non-state rules are voluntary, but firms that commit to these standards are bound by the terms of their agreement with the certification body, as well, businesses and consumers purchase products on the basis of the promise these products are sustainable (reflected in the application of the certification seal, which is the trademark of the certification body). FSC and PEFC track the origin of timber through paper-based trails, and many of the written approvals by auditors are paper-based. There are dozens if not hundreds of transactions and approvals required across the value chain to give assurance on the sustainability of certified forest products and these include community or stakeholder-based assessments on the quality of consultation, or free prior and informed consent with impacted indigenous communities in FSC, for example. Each approval represents a promise that the standard has been met; if this promise is broken, then there is a breach of contract—those relying on these promises are in fact being misled. It is difficult, however, to prove this misrepresentation—paper is inefficient to store, and is not easily viewed by those living in far off places; and these records are at risk of being tampered with. Paper based records are subject to gatekeeper corruption as well. Digitizing these records and making them accessible on a secure and open source system is key to improving the reliability of certified forest products—this could, in theory, be accomplished through the blockchain, an open source and digitized platform described as the biggest revolution in record keeping since ‘double entry bookkeeping’ [14]. However, just because something is on the blockchain does not mean the record is accurate, and appropriate safeguards need to be in place to ensure the veracity of information in the blockchain.

2.3. What Is Blockchain?

Blockchain is a digital distributed ledger system where transactions and records are verified by community consensus [15]. The Bitcoin blockchain is the most established blockchain network, and records individual transactions in a block format. Each block contains transaction data that is validated and confirmed by individual nodes within the distributed ledger system. All changes to the blockchain are communicated and agreed across the entire network in a transparent way, and to ensure any changes recorded are undisputed. Each node receives a copy of the updated ledger, and an incentive or reward for participating in the update and validation. Once recorded on the blockchain, the record is immutable.

A blockchain could be used to record activity for certified forest products. Information can be recorded on the provenance of a tree (and confirmed through cell level data like proteomics), and whether all the standards have been met for certification, which is verified through a community consensus protocol that could include indigenous peoples and a range of stakeholders like unions, workers, suppliers, and NGOs. Each transaction would be confirmed across the network, and made

available to the public. This approach creates an open source, verified, and immutable chain of custody for those downstream on the value chain, who can view the records online with assurance these records are accurate, and that the provenance of products is authentic.

Blockchain also removes government and certification bodies as gatekeepers of sustainability in the value chain, which is important as their incentives may be more aligned with satisfying industry than sustainability standards. The community consensus approach can also empower stakeholders in the value chain to verify the sustainability of products. However, due to the large number of potential transactions in a forestry value chain, any blockchain solution must be highly scalable and this must be carefully balanced with security objectives (i.e., preventing hacking and tampering of records).

While blockchain offers considerable potential to create more transparent information, and can reduce information asymmetry to advance sustainability, an incorrect record of sustainability can be legitimated in the blockchain. Contract law can help solve this problem by creating positive obligations on those involved in the community consensus process to maintain the authenticity and accuracy of the records (and in verifying the accuracy of a record, an actor or node in the blockchain makes themselves accountable to that claim). Blockchain technology can also facilitate and enforce “smart contracts” between different parties to better support more sustainable activity and provide a mechanism for consumers to enforce their sustainability demands in opaque global value chains, where parties making representations are often hidden behind complex corporate structures.

A smart contract is a protocol or program within the blockchain that executes the terms of an undertaking between parties to a transaction, once all the conditions have been met (i.e., the transfer of property from a vendor to a buyer once funds have been transferred and conditions of sale met). It is important to note that smart contracts are not the same as contracts within common or civil law traditions, which are agreements between two or more parties who undertake to do or not do something. Legal contracts are typically complex and deal with a range of contingencies and obligations, while smart contracts are relatively simple and deal with simple transactions written in code. Legal contracts can be enforced in the courts, while as yet, smart contracts are not enforceable in the courts. However, smart contracts can be designed to deal with complex arrangements and enforcement mechanisms could be built into these systems.

3. Method

Blockchain is a mechanism capable of transforming social relations by creating new forms of agreements across boundaries, and new ways for transactions to be documented, stored and accessed [16–18]. Emergent social phenomena, like blockchain, are composed of multiple bodies of knowledge across diverse disciplines (think computer science, mathematics, law, economics, and social sciences among others). There is not yet a comprehensive theoretical framework for understanding blockchain and how it could positively influence sustainability in value chains, and interact with law, regulation, and non-state market driven governance. To do this, we follow the approach set out by Jabareen [19] called “conceptual framework analysis”, a grounded theory technique that establishes a process for building a conceptual framework.

A conceptual framework sets out “interlinked concepts that together provide a comprehensive understanding of a phenomenon or phenomena” ([19], p. 51). In building this framework, the goal is to identify a phenomenon’s key concepts, which, when organized and connected, constitute a theoretical framework that is illustrative rather than predictive. Each of these concepts has its own attributes, characteristics, assumptions, and roles that have specific functions within the framework. There are three forms of assumptions within conceptual frameworks: ontological (or the “way things are”), epistemological (or “how things really work”) [20], and methodological (the process of building the conceptual framework and understanding the real world).

At the core of this methodology is an inductive process of deriving concepts from data (in this case literature), and a deductive process of generating relationships between concepts [21]. To build a conceptual framework, Jabareen [19] sets out an eight-phase qualitative analysis process,

which together compose a process of theorization. Using a grounded theory method, the theories in multiple disciplines and literatures, become the data for this conceptual framework analysis to better understand the phenomenon in question—this approach emphasizes a continuous interplay between data collection and analysis [22]. Here, we examine blockchain and its potential to advance sustainability in global value chains.

Conceptual Framework Analysis

The first phase we followed involves “mapping the selected data sources”. This involved a complete review of the nascent literature on blockchain from a variety of disciplines, but relevant to sustainability, value chains, and law. The second phase involved an “extensive reading and categorization” of data, organizing these by discipline and importance to the disciplines and to the research objective. The third phase was “identifying and naming the concepts”, where we read the selected data, and identified and labelled concepts [23]. This is related to answering the research objective. The fourth phase involved “deconstructing and categorizing the concepts” the results from which are presented in Section 4.2. In this phase, we deconstructed each concept, identified the main attributes, characteristics, assumptions and their role; and then we organized these concepts according to their features and ontological, epistemological, and methodological role. The fifth phase involved “integrating the concepts”, where the concepts were reconsidered and then combined, or dispensed with if these were superfluous to the study. The sixth phase of analysis involved “synthesizing” the concepts into a theoretical framework—this process was iterative and when the framework made sense, the seventh phase was conducted of “validating the framework”. Here the framework was presented and discussed with experts and practitioners in two sessions. From these discussions, the experts and practitioners were able to produce a proof-of-concept blockchain that could be used by firms to document sustainability in their value chains.

The eighth and final phase involved “rethinking the conceptual framework”, where the framework was also shared with academics from economics, law, and computer science, and their feedback incorporated where this made sense. This last phase helped broaden the theoretical perspective to better capture the multidisciplinary nature of blockchain. The framework was then finalized.

4. Blockchain, Sustainable Value Chains, and Law

4.1. Drivers for Blockchain in Value Chains

As we have discussed earlier, one of the ways blockchain technology is redefining value chains is by reducing the dependence on traditional paper-based record keeping. Paper-based records are inefficient and impose significant transactions costs not only on companies’ storing this information, but also on other stakeholders who need to verify records of a firm’s value chain activities. However, paper-based record keeping is still the dominant mode for recording transactions in the value chain whether it be for compliance with law or with certification requirements. This results in major pain points in the value chain for traceability (monitoring events and other information associated with the product), compliance (meeting all the statutory, regulatory and certification requirements in diverse jurisdictions), accountability (identifying and monitoring the roles and responsibilities of all phases of the value chain), and enforcement (institutionalizing compliance to commitments throughout the value chain). These challenges are felt across industries and need to be addressed to achieve the goal of sustainability.

4.2. Concept Findings

A deep review of multidisciplinary literature on blockchain, sustainable value chains, and law, reveals there is no comprehensive theoretical framework on this important topic. While there is a nascent yet growing literature on blockchain and sustainability (which Giungato [18] estimated to be around 7% of blockchain literature), these offers neither illustrative insight into operationalizing

blockchain nor how the different components work together in ways that reshape the law ([24,25]). The findings from this analysis illuminates the process for building a conceptual framework for the emerging phenomenon of blockchain, in the context of sustainable value chains and law. As well, the study illuminates the different components of blockchain in this context, their characteristics, attributes, assumptions, and roles.

The following three concepts were found to compose the theoretical world of blockchain in the context of sustainable value chains, and law.

Concept 1, Evidence: The concept of “Evidence” relates to the secure storage of immutable data that creates information on different activities occurring in the supply chain, such that products and the way these are produced, are traceable in ways that are tightly coupled with digital protocols for physical verification and authentication [26–30]. While blockchain can reduce information asymmetry, the potential for this is dependent on economies of scale, path dependency and “trigger urgency” (see [31]).

Concept 2, Verifiability: There is a growing need for companies and consumers to verify sustainability data and information in increasingly disaggregated supply chains. “Verifiability” relates to the ability for different parties to efficiently comply with different legal and non-state requirements; as well, blockchain can make transactions in value chains more transparent through the distributed ledger system—what this means is different actors within the distributed network verify transactions, which provides validation oversight and distributes power and trust more equitably throughout the network [32–34]. There is a strong interrelationship between “Evidence” and “Verifiability” in blockchain and sustainable value chains [24], for example, where data and information (evidence) that is false is verified and put on the blockchain, it then obtains a quality of legitimacy (and is difficult to alter)—this raises the need to have effective distributed governance processes in place to ensure the validity and accuracy of blockchain data.

Concept 3, Enforceability: This concept encompasses the potential for blockchain to enhance accountability, by creating transparency around the roles and responsibilities of different actors within the value chain, and providing better mechanisms for enforcement which do not rely on third parties to resolve disputes (the smart contract function) (see [35]). The use of blockchain as a closed loop system can reduce moral hazard and principal agent issues, particularly if supported by an effective investigation and auditing function [36]. The use of smart contracts, it has been argued, “can offer “bottom of the pyramid” economic actors increased speed, efficiency, and trust that the contract will be executed as agreed, thus enabling arm’s-length transactions and payments triggered on receipt of goods” ([37], p. 433). Hirbli [38] calls for the use of incentives to transition actors into blockchain, and to better align sustainability goals. While there is emphasis on the autonomous and automatic nature of enforcement in blockchain, both Giancaspro [39] and Sulkowski [40] argue that blockchain is only effective if supported by a robust governance and legal framework, suggesting the capacity of blockchain to self-regulate is over-emphasized. While Luu et al. [41] identify that smart contracts are not without their own problems, and must be redesigned in an adaptive way to prevent outside attacks, which can undermine the integrity of the system (and again calling for a robust legal and governance framework to resolve disputes that go beyond the blockchain).

5. The Evidence, Verifiability, and Enforceability (EVE) Framework

This section presents the Evidence-Verifiability-Enforceability (EVE) framework as shown in the Figure 3, and illustrates how these different concepts are interrelated at vertical and horizontal levels.

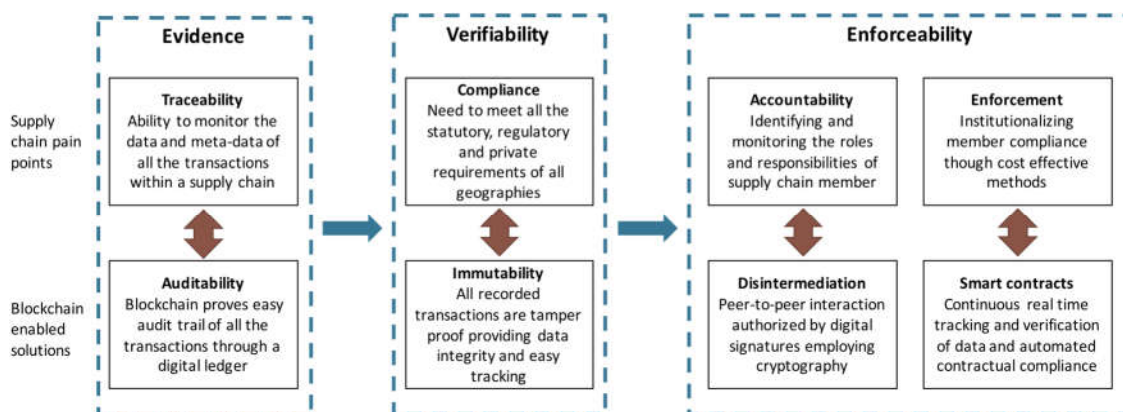


Figure 3. Blockchain capabilities for value chain pain points.

Drawing on the EVE framework, blockchain as a technology can be used by organizations to effectively address three pain points in the value chain. First, blockchain technology provides improved information transparency. Based on well-established principles of cryptography, blockchain operates as a repository for information (evidence) that can be recorded and shared through a peer-to-peer network across the value chain. Each firm in the value chain can maintain a record of its own copy of the ledger and each entry into the ledger is validated through a pre-defined consensus protocol. This allows for easy and quick access to the activities throughout the chain of custody. By providing an audit trail of activities through a digital ledger, blockchain technology enables efficient auditability not only by firms and regulators, but also by consumers. These records can be used as evidence in courts and protocols for dealing with this issue are being developed in some jurisdictions such as Brazil [42].

Not only is value chain information easily accessible but, once the information is on the blockchain, it is also highly tamper resistant. This is one of the key features of a blockchain and it based on the application of well-established cryptographic principles. The resulting immutability of the data on the blockchain allows for easily verifiability of the information. Not only is the data easily accessible, but those accessing it can be certain that it has not been tampered with. This allows the information to be used to satisfy compliance requirements.

Along with verifiability, the blockchain also allows stakeholders to assign accountability for various tasks and representations throughout the value chain (community consensus) to support verification. A firm that adds information to the blockchain—for example, about the source of particular forest product—would also have to identify itself through the use of cryptography-based digital signatures. This would allow firms to be held accountable if, subsequently, the veracity of the information on the blockchain was challenged.

Finally, the fact that information is easily accessible and verifiable, and firms can be held accountable, facilitates cost-effective enforcement of sanctions if a firm is found to be non-compliant in some way. Furthermore, the smart contract functionality of blockchain technology could, in theory, allow for automated enforcement of certain sanctions. For example, a non-compliant firm could face monetary (or other) penalties that are triggered automatically based on real-time information available on the blockchain.

In summary, the paper-based record keeping involving large number of value chain members makes the traceability of data (evidence) for both value chain members and non-state actors quite challenging. With an increase in the number of transactions and a large number of actors in the value chain, ensuring compliance (verifiability) to the complex set of laws across the geographies for each of the value chain members usually entails a huge financial burden on firms. Furthermore, the need for accountability among the value chain members and the need for enforcing the legal standings (enforceability) form the firm perspective and the regulatory perspective becomes mandatory in the presence of strong non-state actors. The proposed EVE framework presented above shows how

blockchain technology could address all of the above hurdles. In the next section, we explore how this framework can be implemented in the forest value chains (FVC).

6. Blockchain-Based Forest Value Chain Framework

The blockchain-based FVC framework tightly couples blockchain technology, smart contracts, and improved data collection methodologies for addressing the value chain pain points discussed in the previous section. The framework can be understood at five different levels with the importance of data visibility increasing as we move to higher levels and the complexity of compliance increasing as we move upstream in the value chain. The lowermost layer is the data collection level. The data is collected through various methods such as IoT sensors, proteomics, GPS location, radio frequency identification (RFID), barcodes, point-of-sales data, etc. Multiple types of data are collected and appended to the blockchain ledger. One of the major challenges associated with tracking the evidence in value chain is lack of uniformity in maintenance of records. Through the digitization of data, evidence collection and synthesis can be standardized and easily exchanged between various value chain members.

The second layer is the data management layer where blockchain technology is at the centre of operation. This layer acts as the solution to the multiple value chain pain points discussed in the previous section. The blockchain technology along with the append-only digital ledger helps the enterprise to store and validate the data collected in the previous stage. This layer includes a close association between the various value chain actors along with the auxiliary actors such as financial institutions, logistics providers, and third party certification agencies (among others).

The contractual layer forms the third layer. The FVC usually spans multiple jurisdictions, and includes a large number of actors, from harvesting to the retail of forest products in their final forms. The contractual obligations through the value chains are often complex in nature. The blockchain technology allows smart contracts to operate seamlessly across the channel involving multiple value chain members. Also, through smart contracts, blockchain technology allows rapid decision making in terms of transfer of goods and updating the ownership of the material, transfer of funds, etc.

At the contractual level, the first concern arising is along the lines of data sharing, since the members of the FVC would typically seek to keep data proprietary. This concern can be addressed through a digital identity function, which allows members to access and append only a certain part of the digital ledger to ensure the data transparency as well as data security across the value chain. Therefore, digital identity is used to control access to the data.

Levels II and III together help in the efficient verifiability of the data in the EVE framework. Through automated decision making and use of smart contracts, the cost of monitoring and reconciliation of the information (evidence) in the value chain can be tackled efficiently, making it attractive to the firm, and making it easily verifiable for investigators and for non-state actors evaluating the compliance with their requirements.

The fourth or the business layer of the framework connects all the members of the value chain. This includes all the business activities carried out by the members in the value chain for the effective flow of the material. Each enterprise in the value chain is able to control and manage the product qualities with the support of blockchain and smart contracts. They also make decisions on purchasing and value-added activities based on the suggestions provided by the decision support systems which uses the data collected throughout the value chain. This also allows the support institutions like banks, credit rating agencies to gather information across the value chain and to evaluate the efficiency of the overall operations and identify avenues for improvement and value enhancement.

The accountability of the various value chain members in the EVE framework is made easy through digitization of data, along with automation of the decision making based on smart contracts between the various members in the value chain. This helps in tracking the flow of material within the value chain and identifying the responsibilities at each of the levels in the value chain.

The regulatory layer of the framework integrates law and technology, thereby giving legitimacy to the framework. Law and technology interact through a complex system of dependencies and interdependencies, as both contribute (to a greater or lesser extent) to regulate the behaviour of multiple members, which are both directly and indirectly associated with the value chain. The regulatory system ensures the existence of a public, transparent, and explicit set of universal rules to sustain political legitimacy. The regulatory framework connecting various governance and oversight agencies for legal and regulatory compliance within the value chain, better supports the enforceability described by the EVE framework.

While the framework presented in Figure 4 shows the various levels for the operationalization of the smart contract in the FVC, it can be understood in terms of three distinct stages of technological evolution observed in the late twentieth and early twenty-first century, that represent the evolving relationship between law and technology [43]. The first phase involves the process of digitizing information—turning paper and ink into computer readable information. That phase is now well under way: copies of cases, statutes, and regulations have been available online for decades in large databases, and cases are increasingly managed in digital platforms. This is represented by the first and the second layers in our framework, where the primary focus is on converting the previously paper based data into the electronic data. With the advent of technology and cheaper mechanisms for data capturing, this stage of the framework is easily attainable. The second phase consists of bringing automation to decision-making processes. Most of the legal informatics research to date has focused on translating legal provisions into computer code. This phase is represented by the third and fourth layer in our framework. This phase is quite challenging, because of issues like the ambiguity of human language and the need for legal norms to be flexible and fact dependent. Furthermore, with an extensive spread of the operations in FVC, the type, nature, and jurisdiction of various laws becomes fragmented and complex. The third phase involves the integration of legal rules into code on the one hand, and the emergence of regulation by code on the other. With the widespread deployment of the global Internet network, new forms of regulation have emerged which increasingly rely on soft law (i.e., voluntary agreements and technical rules) to regulate behaviors. This phase is primarily represented by the fifth level of the framework. These stages denote the synergy between the multiple actors in FVC including regulators, consumer groups, auditors (among others).

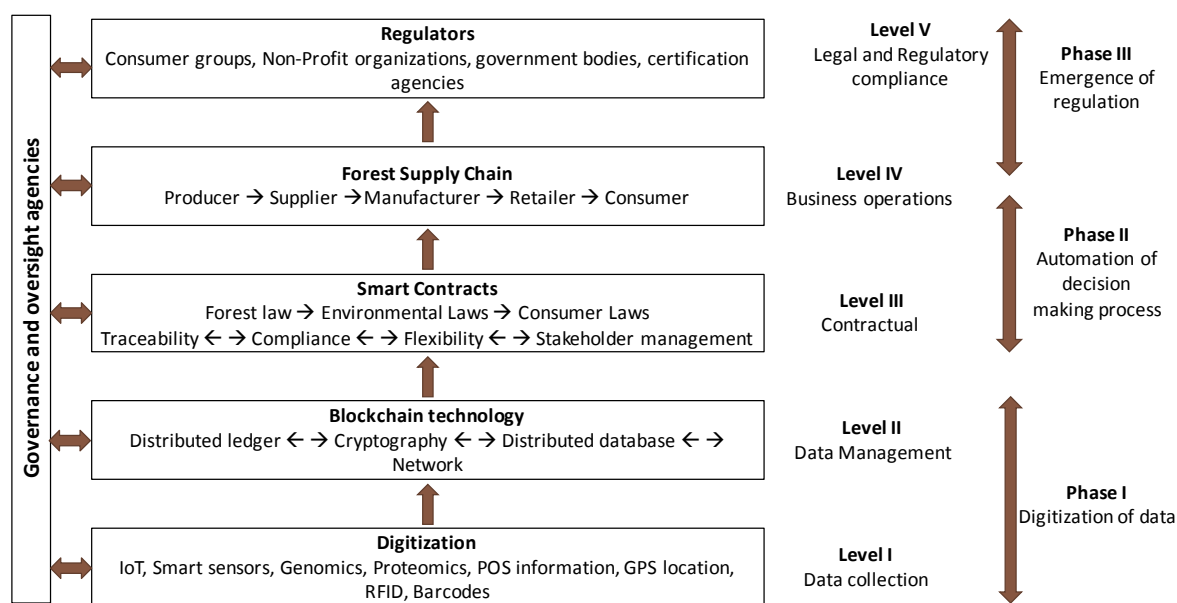


Figure 4. Framework for blockchain-enabled forest value chain.

7. Implications for Law and Sustainable Value Chains

We have developed an EVE framework that conceptualizes how blockchain can promote sustainability in value chains with consideration of hard and soft law, using the forest sector as a case analysis. “Evidence” collected and digitally stored in blockchain, is an efficient way to manage information and can resolve information asymmetry issues in global value chains. Information stored in blocks can be accessed in an open source and transparent system; and information can be validated through community consensus processes (“Verifiability”), and different nodes (or stakeholders in the system) can provide assurances on sustainability that are verifiable in the system. With verified and more accessible information, regulators and auditors can conduct efficient investigations of diverse information sources; and consumers are also better placed to enforce their rights (“Enforceability”). Blockchain records can be admitted as evidence in the courts and jurisdictions have developed processes for the use of these records in resolving disputes [44]. Enforcement of rights may also be made more efficient through the use of smart contracts, which are enforceable instruments within the blockchain that can specify terms and conditions negotiated by the different parties to the transaction, and the terms can be enforced automatically in the blockchain system. New forms of dispute resolution could also be established in blockchain, with liability determined in the blockchain and damages paid through the blockchain system. Blockchain systems can be developed that bridge the opaque divide between upstream and downstream in the FVC, and help pierce the corporate veil that shrouds FVCs in secrecy.

While blockchain offers promise, important safeguards must be developed to ensure records put on the blockchain are in fact accurate. Effective governance of the blockchain (i.e., who decides what is put on, when and how) is essential to maintaining the integrity of the records, and the rules for how the blockchain is governed should be based on the principles of transparency, equity, and accountability. While developing a blockchain system will be voluntary in the short term, with first movers adopting the system to maintain their records and demonstrate transparency in their value chain, over time we anticipate blockchain to gradually become the foundational standard adopted by all firms (this has been thoughtfully articulated by organizational theorists like Iansiti and Lakhani [3]). As more firms adopt blockchain, the potential for the system to become a victim of its own popularity increases—the blockchain could have too much information, and be subject to tampering as the volume of records increases to unmanageable levels. To mitigate this risk, having decentralized and diverse governance to verify blockchain records becomes even more crucial. It is critical to understand that the blockchain is a means to an end, rather than an end in itself, and without supportive governance safeguards, the blockchain could be misused, or become meaningless.

8. Conclusions

Global value chains for commodity products are subject to information asymmetry, and misrepresentations on sustainability are difficult for consumers to expose—this information problem has undermined sustainability in our globalized economy. This information asymmetry problem is especially true for sustainability in global forest value chains, where the emphasis is on process quality, or how the forest product was produced, like the Gibson Guitars example, raises questions like was the timber sourced legally? Or did indigenous peoples provide free prior and informed consent to the timber harvested? These questions are highly localized and qualitative, subject to power dynamics and corruption, and answered in paper-based format stored in places remote from where end users purchase products. While certification bodies as non-state-market-driven forms of governance are meant to certify products to give assurances as to sustainability, there have been concerns about the governance of paper-based information. It is difficult for consumers to access and verify information on the sustainability of products (particularly paper-based information), and then to enforce their rights in fragmented legal frameworks.

Our research objective was to examine how blockchain could advance sustainable value chains, and we used a conceptual framework analysis approach to illustrate how this interacts with hard

and soft law. Using this approach, we identified and synthesized three concepts from blockchain and sustainable value chain literature: Evidence, Verifiability, and Enforceability, as key concepts for how blockchain can advance sustainable value chains. The EVE framework helps illuminate how blockchain resolves information and governance problems in global value chains, and can support better compliance and enforcement of sustainability representations, using the forest sector as a motivating example.

The blockchain is a tool that can deal with every growing complexity in global value chains and the volumes of data and information for documenting sustainability. However, there are important safeguards that must be in place to advance sustainability in a meaningful way. The first safeguard is to ensure all stakeholders are supported to independently verify information on the blockchain; second, altering records must be an option if there are inaccuracies uncovered in audits or investigations and this information must be relayed to all stakeholders in an efficient and equitable way (for those affected upstream and downstream); third, blockchain records must also be available to all stakeholders to view, even if this is through a cell phone; and finally, enforcement through the blockchain through a smart contract function should be supported, to ensure breaches in representations are compensated, fostering a discipline to drive sustainability in global value chains, something which legal institutions have struggled to do given the complex and fragmented nature of global value chains.

Future research could examine what kinds of information should be presented in the blockchain and how, given the global nature of value chains; what kinds of multi-stakeholder governance frameworks could be designed to support the verification of blockchain records in an efficient and equitable way; and examining the workability of smart contracts as a tool to enforce breaches in representations for sustainability should be examined in more detail—should these contracts be subject to judicial review, if so, where? These kinds of questions have both theoretical and practical outcomes, both advancing our understanding of how technology, law, and governance can be interwoven in dynamic ways to advance sustainability in global value chains, as well as creating the tools to establish workable blockchains in practice that meet efficiency and equity criteria.

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