Sustainability **2015**, *7*, 12258-12278; doi:10.3390/su70912258

OPEN ACCESS

sustainability

ISSN 2071-1050

www.mdpi.com/journal/sustainability

Article

Certification of Markets, Markets of Certificates: Tracing Sustainability in Global Agro-Food Value Chains

Arthur P. J. Mol and Peter Oosterveer *

Environmental Policy Group, Wageningen University, P.O. Box 8130, Wageningen 6700 EW, The Netherlands; E-Mail: arthur.mol@wur.nl

* Author to whom correspondence should be addressed; E-Mail: peter.oosterveer@wur.nl; Tel.: +31-317-427494.

Academic Editor: Md Saidul Islam

Received: 30 July 2015 / Accepted: 2 September 2015 / Published: 8 September 2015

Abstract: There is a blossoming of voluntary certification initiatives for sustainable agro-food products and production processes. With these certification initiatives come traceability in supply chains, to guarantee the sustainability of the products consumed. No systematic analysis exists of traceability systems for sustainability in agro-food supply chains. Hence, the purpose of this article is to analyze the prevalence of four different traceability systems to guarantee sustainability; to identify the factors that determine the kind of traceability systems applied in particular supply chains; and to assess what the emergence of economic and market logics in traceability mean for sustainability. Two conclusions are drawn. Globalizing markets for sustainable agro-food products induces the emergence of book-and-claim traceability systems, but the other three systems (identity preservation, segregation and mass balance) will continue to exist as different factors drive traceability requirements in different supply chains. Secondly, traceability itself is becoming a market driven by economic and market logics, and this may have consequences for sustainability in agro-food supply chains in the future.

Keywords: voluntary certification initiatives; agro-food supply chains; traceability; sustainability; marketization

1. Introduction

Over the past decades, increasing globalization in agro-food trade has been paralleled with a growing importance attached to sustainability of products and of the circumstances under which product have been produced. This is especially mounting in global value chains and networks [1,2] that trade products to the wealthier markets in the North, where among others ethical, environmental, health, animal welfare, and (child) labor values of products and production processes play a growing role in driving consumer demand. However, also in newly emerging and transitional economies such as Brazil and China a growing (upper) middle class is starting to show an interest in ethical and sustainability aspects of products and production circumstances, although there is still a world to win here (see on aquaculture fish: [3]).

Since the mid-1990s and following this growing demand for sustainability in transnational value chains, a rapid increase in the design and implementation of all kinds of (mostly voluntary) public, private and hybrid standards and certification schemes can be witnessed, to ensure that sustainability of products and production circumstances are communicated towards customers and consumers downstream the global value chains. Hence, we see the blossoming of sustainability labels and certification systems in global value chains of food (fish, coffee, tea, cocoa, vegetables, *etc.*), (bio) fuel/energy (electricity, liquid biofuels) and agro-industrial commodities (timber, cotton, textiles). Most of these labelled and certified products started as niche markets and included only a limited number of producer and consumer countries (as was initially the case for fair trade coffee, and for organic products). However, over the years these certified products developed into quite substantial markets with truly global reach [4]. Key in these certification schemes is that sustainability claims put on final consumer products can be traced back through the global chain of custody to initial (primary) production circumstances. This requires transparency of the value chain, traceability of products [5] and verification of sustainability claims, especially when product attributes themselves do not allow distinguishing between sustainably and not-sustainably produced products (credence goods). Different tracking and tracing systems have been developed and applied in agro-food value chains to relate sustainability claims made on final products (for instance through a label or product information) back to the initial agricultural production circumstances.

This article has three goals. We (i) analyze the prevalence of the various systems to trace sustainable products through value chains; (ii) identify the factors that determine which kind of traceability system is applied for different agro-food commodities; and (iii) assess the consequences of emerging trade in sustainability certificates (rather than sustainable products) in value chains. For this we have reviewed global traceability systems currently applied for key traded agro-food commodities, analyzed relevant scientific literature and compared agro-food traceability systems with those in other markets. After introducing four systems for tracing sustainably produced products, the prevalence of the various systems in different commodity markets is analyzed. Subsequently, we analyze the factors behind applying different traceability systems and focus especially on the role of book and claim systems (as they create a market of certificates). The final section draws conclusions.

2. Tracking and Tracing Sustainability in Value Chains

2.1. Sustainability Governance through Information

Especially in the field of environmental governance, the notion of regulation or governance through information has emerged over the last two decades [6–8]. Informational regulation or governance refers to the idea that information (and informational processes, technologies, institutions and resources linked to it) is fundamentally restructuring processes, institutions and practices of governance, making these governance processes essentially different from conventional modes of governance. Where conventional governance highly relies on authoritative resources, belief in information control, and state power, in informational governance information is becoming a crucial (re)source with transformative powers in specified practices, although nobody is in control of information. Information processes (e.g., on collection, monitoring, disclosure, dissemination, framing, verification) now start to become acts of governance with transformative power, instead of just enabling processes for formulating and implementing authoritative state policies. This counts especially in contexts where environmental/ sustainability governance transcends the nation-state and becomes international/global. Hence, state agencies, international organizations, companies, utilities, NGOs, retailers, consumers and the like govern—and are being governed—through the production, use, release, framing, accessibility, demand, and verification of information.

In directing (transnational) agro-food chains towards sustainability the collection, processing, verification, disclosing and disseminating of information, by value chain actors and stakeholder related to value chains (NGOs, policy-makers, *etc.*), are crucial acts of governance that transform social practices of production and consumption. This becomes evident when one thinks of, for instance, guaranteeing sources of origin, tracking and tracing of animal diseases, eco-labelling and certification [9], corporate social responsibility reporting and auditing, separation of GMO and non-GMO products, media controversies on the sustainability of food products. Through these informational processes and practices actors profile and advance sustainability of agro-food products. With information moving center stage in the growing market for sustainable agro-food products, new practices, actors and power relations emerge in sustainable value chains. Sustainability information becomes of value in agro-food chains independent from products themselves and may even become a commodity in a separate market. Tracing sustainability of products is a new practice that is rapidly moving to the center of sustainability governance of global agro-food chains and this comes along with new actor roles and changing power relations.

2.2. Value Chain Traceability Typology

While there is now a growing literature on traceability in agro-food supply chains (see [10] for a useful review), most studies concentrate on food safety and food quality (where food product characteristics are essential). Very few studies address traceability systems for sustainability (where production process characteristics and cultivation of crops/raising of animals are key). In addition, in the rapidly growing literature on sustainable or certified agro-food chains [4,9,11–14], only very limited attention has been paid to the kinds of systems for tracking and tracing sustainability through such global value chains.

Following earlier work of transparency in agro-food value chains [15] traceability systems can serve different purposes. Four ideal-types of traceability can be distinguished (Table 1), where information on the quality of products and production processes is traced for different target groups. The first (also in time) type of traceability in value chains relates to logistics, total quality management of chains and products and verification of product specifications. As such it is a restricted form of traceability for a limited number of economic actors in value chains, primarily motivated by economic interests, and focused on tracing product quality. This so-called management-traceability has its origins in management sciences and logistics [16] and is not directed at, nor does it involve, citizen-consumers or public authorities. A second type of traceability in value chains relates to legal and policy requirements of public authorities on especially food safety and product qualities, such as in the EU tracking and tracing policies. Here public bodies and authorities demand tracking and documenting of information along the value chain, to be disclosed to regulators and inspectors when asked for. Mad cow disease, bird flu, swine fever and other highly contagious animal diseases have rapidly diffused state requirements for this kind of tracking and tracing around the globe [17]. A third and wider form of traceability in value chains relates to quality and sustainability of production processes and products as articulated in public or private labeling and certification. Here traceability is meant to track and verify information along the value chain for consumers and public and private certification bodies and is strongly associated with the consumerist turn and what some call an alternative food economy [18]. Organic, green, sustainable, fair trade and all kind of other sustainability product and production process claims are articulated in standards, disclosed in labels and information systems, guaranteed through certification, and aimed at price premiums and niche market competitiveness. These claims on the consumer product need to be verified and trusted through traceability systems. This can be labeled consumer traceability. Finally, global agro-food value chains are subject of and involved in public scrutiny of their sustainability performance. Information on the sustainability of production processes and product characteristics needs to be traceable to safeguard reputational capital of chain actors and to gain a competitive advantage in the public domain. The Carbon Disclosure Project, the activities of Transparency International, television programs on tracing production and product quality claims, but also claims of certification and labeling bodies and the subsequent certification of certification systems through ISEAL, are examples of public tracking and tracing.

Table 1. Four ideal types of traceability in value chains and networks.

Ideal type value chain traceability	Tracing information from	Tracing information for	Focus on product/process
Management traceability	Upstream * economic producers in chains	Downstream * economic customers in chains	Product quality
Regulatory traceability	Economic actors in chains	Regulatory and inspection bodies	Product quality
Consumer traceability	Economic actors in chains	Consumers and certification bodies	Product & processes quality and sustainability
Public traceability	Economic actors in chains, certification bodies	Public (citizen-consumers, NGOs, media)	Product & processes quality and sustainability

* Upstream refers to chain actors higher up in the value chain such as primary producers and raw material processors. Downstream refers to chain actors lower in the value chain such as final processors, customers and retailers.

Sustainability tracking and tracing, which involves both product and production process information, is more prevalent in consumer and public traceability types and less in management and regulatory ones. Hence, we will especially focus on the consumer and public traceability. The scarce literature points out that consumer and public traceability forms can differ, among others, in their organizational structure; the involvement of different public and/or private actors; the system of information collection, reporting and flow along the value chain; and the rules and procedures of conformity/verification assessment, and subsequent certification.

2.3. Power and Markets

With the emerging importance of certified sustainability as a preferential product quality, a potential for premium prices, an access requirement for some markets and a core element of reputational capital, traceability systems have become more consequential, more complex and more costly. Tracking, tracing, verifying and certifying information on the sustainability of agro-food production processes and products for consumers and the wider public involve new practices, power relations and power brokers. New practices of separating (sustainably and non-sustainably produced) product flows, of monitoring, registering and reporting, of verification, of handling out labels and certificates, and of trading in sustainability certificates have emerged in agro-food chains. With these new practices, new actors and power brokers have emerged along the traced value chain, such as verification and certification agencies, trading platforms, registries, and traders in certificates. In addition, new powers relations have been formed, with a power shift towards actors at the consumer end of value chains, but also towards actors outside the value chain such as tracing and certifying agencies.

One of the major changes in practices, actors and power relations in traced sustainability markets comes when sustainability certificates emerge. As we see, for instance, with electricity, carbon and fisheries [19–23], sustainability certification can lead to a market for certificates, relatively decoupled from the material sustainability of primary production and products. With sustainability certificates in agro-food, tracing sustainable products is no longer tracing the product through the value chain to its origin, but the establishment of a new market with new rules, new resources and new actors. As often with new markets, there are market winners, losers and advocates, and major debates on the direct and long-term sustainability performance of markets in sustainability certificates are taking place. One of these debates concerns the use of market-based tools as instruments for environmental policy which is criticized by some scholars as they fear the appropriation by dominant market actors [24] and that their structural limitations will prevent the radical transformations in current supply systems they consider necessary [25].

3. Models of Tracing Sustainability

A large variety of certification systems have been developed to guarantee downstream consumers that products are produced upstream in a sustainable manner. In the literature and in the practice of different global commodity chains these certification systems prove to make use of one or more of four models of sustainability tracing [26–29]. Figure 1 clarifies the differences.

The first model, *identity preserved* or *track and trace*, ensures that the certified product delivered to the end user (customer or consumer) is uniquely identifiable and can be related to the identity of producer

and resource base. Initially, it was especially developed and applied to distinguish GM from nonGM products [30], but this has widened more recently to tracing sustainably produced products. In order to be able to preserve the identity of the certified resource, half-product and final product they have to be kept physically isolated and separated from non-certified equivalents at each stage of the value chain, as well as from certified equivalents from another resource base. Only then full traceability can be organized from the origin of the product to the point of delivery to the end user; and the end user can be assured of the origin and identity of that specific product. In consumer-facing certification systems barcodes or other identification systems, often supported by recent developments in ICT, allow the consumer to trace the origin of the product to the producer [12]. The logistics, monitoring, reporting and verification required for identity preserved systems result in high costs along the value chain, to be compensated through price premiums, unique market access or larger market share. Due to the high costs, identity preserved systems are only applied when considered necessary, either because these are explicitly prescribed or when there is a clear market demand from consumers for such far-reaching certification systems. In most commodity value chains other traceability systems often prevail due to lower costs, reduced complexity, lower data availability requirements, and business preferences [30].

The second model, segregation, is more than incidentally lumped together with identity preserved systems [27], but they are different. In addition, in a segregated system of sustainability certification it is assured to the end-user that a certified product consists of natural resources and production processes (storage, transportation, processing, trading, packaging, selling) that fulfil all the requirements of the certification scheme. At every step certified produce is kept separate from non-certified produce. However, the final certified product cannot be uniquely identified and related to a single identifiable producer and resource base. Transporters, traders and processors mix produce from different certified producers and resource bases, which makes tracking and tracing the final product to a single initial producer/site no longer possible. However, costs are lower due to economies of scale and increased competition.

In the mass balance model the traded volume of certified sustainable produce is administratively monitored throughout the entire value chain to ensure that the volume of certified products downstream equals the volume of certified resource base upstream that very same value chain [31]. The mass balance system allows, however, for the mixing of certified and non-certified produce at any stage of the value chain after the certified produce has been registered and left the farm gate. For the end-user, there exists no longer a one-to-one physical or chemical tie or relation between the consumed certified end product and the certified resource base at the primary producer. Certified end products most likely also consist of non-certified resource base. However, at each stage there is a reconciliation between the quantity of certified material bought and the quantity of certified material sold, verified by a certification agency. As no separate storage, transport or production processes are needed for certified products and less verification, monitoring and control is required, costs are lower compared to the first two systems.

Finally, the book and claim model moves away from any physical/material link between the certified resource or primary produced crop and the final certified product. Operators under this model register the sustainable resource/produce upstream which is booked in a central registry at a trading platform, and for which the operator receives a tradable certificate. The producer then sells his certificates on the (global) market to interested companies through a credit trading platform. For each unit of certified sustainable product that is sold to customers/consumers, final manufacturers need to buy certificates

from this platform. The price of a certificate depends on supply and demand and may therefore vary widely over the years as the experience of GreenPalm has shown (the price dropped from 81.58 USD in December 2014 to 35 USD in September 2015 [32]. The major advantage of book and claim systems is that no segregation, monitoring and registering is needed of sustainable produce (after leaving the farm gate). Any final producer who wants to sell certified sustainable products, or any actor that wants to support the production of sustainable primary resource base/products, can do so via buying certificates on the credit trading platform. This reduces costs and complexities in organizing the chain and allows for easy trade of larger volumes of sustainable products. A well-functioning farm-gate and end-user monitoring and registration system, a market of certificates, and a central registry are crucial preconditions to let this system function. The system is more vulnerable for fraud, especially when geographies and numbers of buyers and sellers expand; for consumers contesting the sustainability of products; and for seizing price premiums by selling certificates.

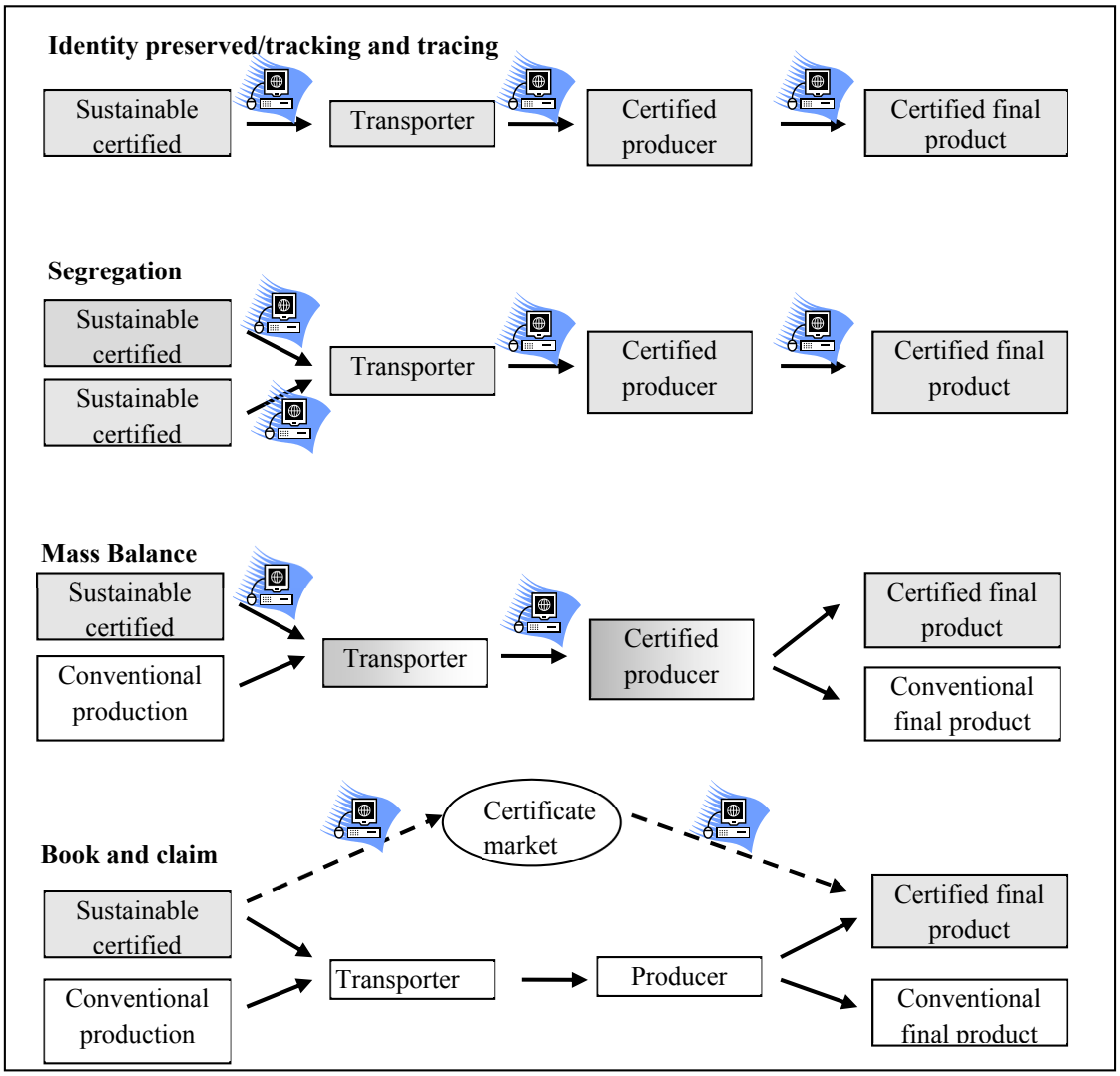

Figure 1. Four sustainability tracing models (adopted from [28,29]).

4. Explaining Prevalence of Traceability Models in Different Markets

The early voluntary certification initiatives usually cover various commodities (IFOAM, Fair Trade, UTZ), while the recent ones are more often focused on one specific commodity. While increasingly commodities are dominated by one certification initiative, such as the 4C Association in coffee, ProTerra in soy, BCI (Better Cotton Initiative) in cotton, Bonsucro (2013) in cane sugar and RSPO (Roundtable on Sustainable Palm Oil) in palm oil, there is not often a complete monopoly [4]. However, even if one certification initiative is developed for one product category, it often applies different traceability systems to fulfil traceability requirements/preferences of different market segments. Table 2 illustrates the diversity in certification schemes in agro-food provision, with the used/allowed traceability systems (see Appendix). With regard to traceability, they all allow for segregation, most for identity preserved, several for mass balance and only a few for book and claim systems. In addition, the spreading in terms of market share over the allowed traceability systems is not equal, with usually small shares of the marketed certified products having identity preserved traceability. What are the factors explaining preference for identity preserved and mass balance for most certification systems, in most markets for the major share, while only for some certification systems book and claim systems are an option and few marketed products have identity preserved traceability?

Table 2. Product categories, voluntary labels and traceability models (see Appendix).

Product	Label/certification organization/system	Traceability model allowed [1]				Year of introduction
		Identity preserved	Segregation	Mass balance	Book and claim	
Palm oil	RSPO [2]	**X**	x	x	**X**	2004
Soy	RTRS [3]		x	**X**	**X**	2006
	ProTerra	x	**X**			2012
Sugar	Fair Trade	x	**X**	x		1997
	Bonsucro		x	**X**	**X**	2006
Cotton	Fair Trade	x	**X**			1997
	Better Cotton Initiative [13]		**X**	**X**		2005
Marine fish	MSC [4]		**X**			1997
	This Fish	**X**				2010
Aquaculture fish	ASC [5]		**X**			2011
Timber	FSC [6]	x	**X**	x		1993
	PEFC [7]	x	x	**X**		1999
Biofuels EU market	15 different schemes	x	x	**X**		2009
(non)GMO crops	EU [8]		**X**			1997/2004
Biofuels	RSB [9]	x	x	**X**		2007
Agricultural products	IFOAM [10]	x	**X**			1972
	Rainforest Alliance	x	**X**	**X**		1987
	Organic label US and EU		**X**			1990/1991

Table 2. *Cont.*

Product	Label/certification organization/system	Traceability model allowed [1]				Year of introduction
		Identity preserved	Segregation	Mass balance	Book and claim	
Tea	Fair Trade	x	**X**	x		1997
	UTZ	**X**	**X**			2002
	Ethical Tea Partnership		**X**			2009
Cocoa	Fair Trade	x	**X**	x		1997
	UTZ	x	**X**	**X**		2002
Coffee	Fair Trade	x	**X**			1997(1988) [12]
	UTZ	x	**X**			2002
	4C association [11]	x	**X**	x		2006
Meat	GRSB	**X**	**X**			(2016) [14]

[1]. A capital and bold **X** means used for the major share of the market; small x means less often used; [2]. RSPO: Roundtable on Sustainable Palm Oil; [3]. RTRS: Round Table Responsible Soy; [4]. MSC: Marine Stewardship Council; [5]. ASC: Aquaculture Stewardship Council; [6]. FSC: Forest Stewardship Council; [7]. PEFC: Programme for the Endorsement of Forest Certification; [8]. EU: European Union; [9]. RSB: Roundtable on Sustainable Biomaterials; [10]. IFOAM: International Federation of Organic Agriculture Movements; [11]. 4C Association uses mass balance but the license/certificate must be passed on with the coffee up to the final buyer; [12]. Fair Trade originates from the Dutch Max Havelaar certification scheme for coffee, which started in 1988; [13]. BCI uses a combination of segregation (up until the ginner) mass balance (after the ginner). [14]. GRSB has developed a standards which McDonalds intends to implement in 2016 [33].

4.1. Historical Sequence?

The first traceability systems in sustainability certification of supply chains in the early 1990s resembled an identity preserved or a segregation system, where products could be traced back to sustainable production of the resource base. In general, one would expect that with the further globalization of value chains and networks, the mainstreaming of sustainability in larger markets, and the inclusion of more product categories in sustainability certification, sustainability traceability would increasingly develop from identity preserved models to book and claim systems. The latter type of system is especially apt for large volumes, lowers traceability costs, makes sustainably produced products more competitive with conventional products, and is more concerned with global sustainability and less with identity formation of smaller groups of (dark) green consumers. In that sense the more recent emergence of mass balance and book and claim systems in certification initiatives makes sense.

At the same time, others argue that a reversed trend would make more sense [34]. Initially, mass balance and book and claim systems allow for encouraging producers to produce more sustainably and reward them for it, without necessarily involving additional costs for consumers and other value chain actors. Only when a sustainably produced product is recognized and valued on the market, companies can obtain a somewhat higher price from selling a clearly identifiable product from a single certified resource base. This enables identity preserved traceability systems.

In looking at the distinct products and certification initiatives, it becomes clear that there exists no easy relation between the allowed and prevailing traceability system on the one hand and the time lapse since the start of the certification initiative on the other. Although book and claim systems are emerging

more recently for some products and supply chains and then take a significant market share (Appendix), this is not an evolutionary development. We cannot conclude that once certification matures in a specified market, book and claim systems massively replace identity preserved, segregation and mass balance systems. Nor can we easily conclude that book and claim systems form a starting point for traceability, to be taken over by segregation and identity preserved systems once the market matures and price premiums are possible. Obviously there are (also) other factors involved in determining the prevalence of a traceability system for a sustainably produced agro-food products in a specific market.

4.2. Determining Factors

When comparing the different products, certification initiatives and traceability systems presented in Table 1, at least five factors play a major role in the allowed application and the prevalence (in market share of certified products) of the different traceability systems.

In those markets where products are consumed that are recognizable for individual consumers and where consumer identity through consuming labelled products plays a major role, identity preserved or segregation are more likely to prevail. Regarding final consumer products, such as coffee, vegetables, fish, wood and sugar, identity preserved or segregation is preferred above book and claim and even mass balance. When consumers cannot easily identify sustainability properties of products and cannot distinguish themselves through buying and consuming certified products, mass balance and book and claim systems are more likely to emerge, such as in the case of sustainable palm oil and biofuels.

Second, in markets/products where clear inherent product quality differences between sustainably produced and non-sustainably produced products exist (or are perceived to exist), identity preserved or segregation are likely to prevail. This is often the case with respect to organic vegetables, fruits and meat, and non-GM food products. Product markets where (perceived) product quality differences are absent, and sustainability claims are only related to production processes, are more likely to apply mass balance and book and claim systems, as in the case of liquid biofuels. This differentiation enhances when transport routes of product flows cannot be easily separated, for instance when sustainable and non-sustainable products have to use the same transport infrastructure. Electricity transported through the grid is a typical example [21], as would be any future traceability system for sustainable biogas transported through piped gas systems [35]. Segregation or identity preserved is then only possible for decentralized local systems, with direct connections between producers and consumers of products.

Third, when the lead firm in a global value chain is (perceived to be) quite vulnerable for sustainability questions and accusations from the public, consumers and consumer/environmental non-governmental organizations, one can expect identity preserved and segregation systems to prevail over mass balance and book and claim systems. A clear example is certified capture fish (MSC or This Fish) in value chains where major retailers are lead firms and demand fully segregated chains or even identity preserved [36]. Unilever announced in 2012 that it had set itself the target to buy all of its palm oil from traceable sources by 2015 to 2020, instead of buying it via the book and claim system of GreenPalm. The executive director of New Britain Palm Oil Limited NBPOL claimed with respect to GreenPalm book and claim certificates: “We feel that this is not widely understood and we do not think it is what consumers want in their products (...). Additionally, the entire system including all the associated claims is unaudited and therefore open to abuse. We feel the concept is flawed and potentially misleading” [37]. Identity

preserved and segregation systems are superior in guaranteeing individual global value chain companies sustainable resource bases within their chain of custody. Book-and-claim systems are not able to fully guarantee sustainable production of the actual products sold by the lead firm.

Fourth, if the main players around a global value chain are institutional actors (processing companies, traders, major environmental and consumer NGOs, states), which are only to a limited extent directly dependent on consumer legitimacy or citizen membership, one can expect book and claim systems to prevail. Institutional actors focus more strongly on higher level aggregated sustainability effects and less on the sustainability of individual, identifiable products. The systems' perspective of mass balance and book-and-claim systems, with their focus on "aggregated" sustainability, higher levels of efficiency, lower complexities, lower transaction costs (and thus better competitiveness vis-à-vis conventional products), are then often prevailing.

Finally, more extended supply chains, in terms of geographical reach, size of markets, number of actors in global production networks, and 'social distance' between initial producer and final consumer, 'prefer' book and claim and mass balance systems. While in shorter supply chains, with closer social proximity between producer and consumer and smaller markets, identity preserved and segregation systems of traceability are more likely to prevail.

Figure 2 puts together these five different dimensions that jointly influence what type of traceability system is allowed in certification and prevailing in the certified market of distinct commodities, giving examples for RSPO certified palm oil for food products, aquaculture fish labelled through ASC, and USDA organic food products. The larger the surface of the 5-edged figure, the more likely it is that book and claim systems emerge; the smaller the surface the more likely segregation and identity preserved systems dominate.

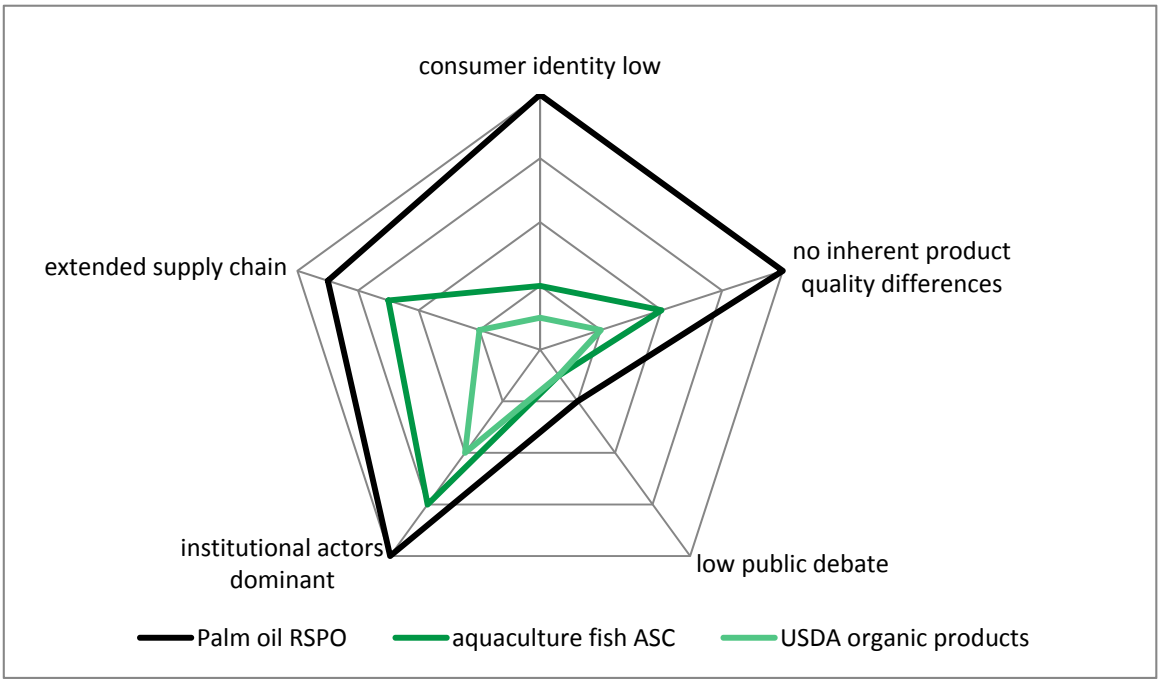

Figure 2. Determinants of traceability systems.

5. New Markets of Traceability

Mass balance or book-and-claim systems seem most promising if one wants to make cost-efficient contributions at sizeable scale to sustainability of agro-food products. When widely introduced, these systems (i) lower the costs of traceability because they require no separate systems of storage, transportation and processing; (ii) are less complex (and thus less costly) in implementation, monitoring, auditing and certification for all intermediate value chain actors, and (iii) make sustainably produced products really competitive with conventional ones. Only in this way sustainably produced products can seize significant market shares beyond niche markets, as also a large share of the middle class consumers, emerging economies, and major institutional actors such as mainstream retailers and lead firms are seduced to articulate demand for sustainably produced (semi-)products. It can be noted that in those global supply chains where multiple certification systems co-exist at the same time (e.g., palm oil, soy, sugar cane), book and claim systems handle the largest market share of certified products, compared to the other systems.

Book and claim systems differ from the other models because here certificates are developed as a new symbolic token that codifies sustainability, provides it with a monetary value and allows it to be traded over long geographical stretches independently from material (product) flows. In that sense book and claim systems reflect global ecological modernization, where "ecology" becomes articulated, forms a separate global "ecological" flow, and becomes "economized" [22,38]. From a global system perspective book and claim is an ecologically and economically rational design for greening global supply networks, as it incentivizes certified production of fresh produce, reduces transaction costs for value chain actors in tracing, and thus makes certified products competitive with non-certified alternatives. In its operationalization, however, these book and claim systems run against a number of challenges.

First, book and claim systems bring in a different set of actors in sustainable global value chains/networks, each with their own role and with their own interests and rationalities. Private brokers of green certificates such as GreenPalm in the sustainable palm oil value chain, private consultancies that set up trading platforms and systems such as Book & Claim [40], and various financial institutions that also function in carbon markets all have an interest in maximizing trade in these certificates. Trading certificates is business. Financial institutions trading certificates have a clear interest in price settings and manipulation, introducing all kinds of new financial products related to these certificates [39]. This makes the sustainability of the certificates more and more competing with their market value, introducing stronger economic logics and rationalities in these sustainability markets. As a consequence traceability becomes a market in itself; traceability is traded, new companies emerge that make a profit out of trading traceability, or from setting up systems and companies that become traceability brokers. An illustration for this trend is the advertisement by the consultancy firm Book & Claim offering assistance in setting up book and claim systems and trading platforms in any industry [40]. The relation with on the ground sustainability of primary production then becomes increasingly indirect or "footloose". Consequently, a stronger element of futures trading and speculation is brought into the sustainability commodity market, which allows middlemen and traders to take a larger proportion of the price and increases the risks of price volatility. Both consequences are considered to be problematic for the poor, producers as well as consumers [41,42].

Second, it is widely conceived that book-and-claim systems are more vulnerable to fraud than identity preserved and segregation systems, with mass balance systems in-between [29]. As the administration of sustainable primary production and the final certified products that are sold are decoupled, more vulnerabilities emerge in terms of illegal introduction of non-sustainable products, creation of certificates, fraud in monitoring and registration, *etc.* Experiences with the carbon credit systems show that this is not just a potential drawback, but that multiple forms of fraud do occur in trading systems of certificates [43,44]. Identity preserved and segregation systems are not immune to such fraud either (as several cases of organic product fraud have shown [45,46]), but such vulnerabilities are considered a lower risk as verification/certification takes place at different stages of the supply chain.

A third challenge is related to the division of responsibilities in some book and claim systems. Especially where buying and selling of sustainability certificates is detached from the organization that sets, monitors and verifies the production standards, responsibilities become blurred [47]. This is especially relevant in cases of fraud or illegality. Is the RSPO responsible for the green certificates handed out and traded by GreenPalm, the private organization that performs the book and claim system? Most actors involved in this book and claim system would probably consider this is not to be the case; but the RSPO will be the first to bear the consequences when certificates are not backed by sustainable oil palm plantations.

Fourth, book and claim systems rarely operate in markets without alternative traceability systems; hence, they have to compete with them. In this competition, efficiency and costs are important but responsibility claims, assurance and trust as well. Some consumers are not impressed by the cost-efficiency of book and claim systems and prefer the greater transparency towards initial producers and resources offered by identity preserved and segregation systems. Such consumer preferences are increasingly articulated by large (and thus powerful) retailers, who sense consumer preferences and know what reputational damage can do.

Finally, book and claim systems have a lower level of environmental effectiveness through the equivalent of the "hot air" mechanism that prevailed in the flexible mechanisms in greenhouse gas emission reduction [19]. All production that fulfils sustainability criteria will be used in a book and claim traceability system, while in segregation systems and identity preserved systems volumes of sustainably produced primary commodities will exist that are not certified, due to the costs and the management complexities involved [2,18]. The latter situation results in higher volumes of sustainably produced primary commodities than certified in a market.

As book and claim systems are relatively new in agro-food markets we have paid special attention to the challenges these traceability systems face. However, articulating these challenges should not be interpreted as predicting a dark future for or discrediting book and claim systems. For one, the other traceability models each have their own strengths and weaknesses. Second, several of these challenges will not be decisive in decision-making processes on which traceability model to apply in certification of products for specific markets. What constitute challenges or even disadvantages for some actors in certified global production networks are sources of (economic) value, market share, low transaction costs or aggregated environmental gains for others.

6. Conclusions

The growing demand for sustainably produced agro-food products in an increasingly global market has resulted in developing distinct systems for certifying sustainability claims, which fit in a wider tendency of governance through information. Traceability forms a key element in these—mostly voluntary—sustainability certification initiatives. The four models of traceability (mass balance, segregation, identity preserved (or tracking and tracing) and book and claim) differ in how sustainability certification of a final product is related to the sustainability qualities of production circumstances and products at different stages of the value chain. In this paper, we focused on explaining the prevalence of different traceability models for different commodities and markets. There proves to be no simple historical or evolutionary development in the prevalence of traceability models in specific commodities and/or markets. In contrast to a straightforward evolutionary development in traceability models, five factors were identified that are co-determining the kind of traceability model applied and prevailing in a specific commodity-market combination. Analyzing these factors provides better predictive power of likely traceability systems than an evolutionary view.

Particularly interesting is the book and claim traceability model because it is rather new in agricultural and food markets and allows for decoupling the sustainably produced material flow from the flow of sustainability claims, making it particularly apt for global value chains. Products are traded separately from sustainability certificates. We identified competing claims among academic scholars, sustainability NGOs and value chain practitioners on the desirability and future outlook of book and claim systems, in "competition" with the three other traceability models. Some consider book and claim to be the most appropriate model in the context of globalizing markets and the proliferation of sustainability preferences among increasing segments of consumers due to its high efficiency, low costs, large aggregate sustainability gains and adequate fit with global value chains. Others believe and/or strongly prefer that the book and claim models will only play a temporary and transitional role in traceability system and will disappear over time. According to them, book and claim systems do not create a market for the sustainably produced products themselves but only for sustainability certificates, making their sustainability claims too vulnerable for fraud and consumer/public mistrust, endangering the entire landscape of sustainably certified products and markets. Our analysis showed that the prevalence of any traceability model remains strongly related to the architecture of the supply chain/network serving a specified commodity market: where is the power located in the chain/network, are lead firms to be found upstream or downstream, can the certified product play a role in consumer identity formation, are collective actors outside the value chain interfering strongly (regulatory bodies, NGOs), and how much premium is to be gained through different traceability modes?

Deciding on the most appropriate traceability system is not a straightforward process on the basis of (economic and environmental) costs and benefits, but relates as much to fundamental consumer identities, ideologies and power relations in chains. While technical-scientific claims can be decided on the basis of 'right' or 'wrong', debates involving fundamental ideologies and power inequalities are never resolved or closed easily. Hence, the debate on traceability system is likely to continue for some time. Despite the criticism we expect book and claim models to remain part and parcel of the options for sustainability certification, be it mainly for commodities that cannot easily (thus: at relatively low costs)

be kept physically separate throughout a globalized supply chain for a particular market (e.g., palm oil, soybeans, biofuels).

Acknowledgments

The authors kindly acknowledge the input from two anonymous reviewers that has contributed to this article.

Author Contributions

This paper has been the result of collaborative efforts from both authors. Each of them has participated equally in designing the paper, performing the research and writing the paper. Both authors have read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

Appendix: Traceability Systems of Different Commodities/Markets

Fair Trade certification, including more than 15 product categories such as coffee, tea, bananas, vegetables and cotton, follows mostly a segregation chain of custody traceability design, although for special markets identity preserved is offered, and for cocoa, sugar cane and tea mass balance systems operate to ensure that Fair Trade producers receive their premium. Tracing back to the origin of production is secondary to production procedures and product characteristics.

UTZ certified allows both mass balance and segregation certification systems in cocoa trade, but only segregation in coffee and tea. The organization gives clear reasons why it continues to have a mass balance system besides a segregation system on cocoa, because "while volumes of certified cocoa are still limited but growing and the processing is quite complex, keeping all certified cocoa separated would imply high investments in the supply chain" and UTZ rather invests in "training of farmers and actual purchase of UTZ certified cocoa" [48]. UTZ expects that with the maturation of the market certification will shift more towards segregation systems. The Sustainable Agriculture Network/Rainforest Alliance has developed a kind of "in-between" category in chain of custody certification, which they label "controlled blending" (only for cocoa until now). Controlled blending differs from mass balance in that it monitors sustainable products up till the gate of the manufacturer, whereas mass balance only monitors sustainable produce until it leaves the farm gate [49]. This enables the system to control the proportion of certified cocoa in each final product. Rainforest Alliance allows only for sugar cane and palm oil a mass balance chain of custody certification, after written permission from the Rainforest Alliance. Segregation and identity preservation are allowed on all product categories [50].

The Stewardship Council systems (such as those of Marine Stewardship Council MSC, Forest Stewardship Council FSC, and Aquaculture Stewardship Council ASC) all work with a segregated system of chain of custody traceability (although FSC has also developed a mass balance system). In Stewardship Council systems certified natural resources are kept segregated throughout the supply chain from non-certified equivalents, up till the final consumer. Sometimes in these markets smaller

alternative certification initiatives opt for an identity preserved system of traceability, such as This Fish in capture fisheries.

Under the Round Table for Sustainable Palm Oil (RSPO; Kuala Lumpur, Malaysia, established in 2004) identity preserved, segregated, mass balance and book and claim traceability systems (or modules as the RSPO calls them) operate at the same time for different palm oil markets. Each of the four systems comes with different allowable claims regarding sustainability on the final products, and with different regimes of traceability at the various stages of the value chain [28]. To facilitate the traceability of identity preserved, physically segregated, or mass balanced RSPO certified sustainable palm oil, a new RSPO eTrace system has been launched. The system is designed to improve transparency and efficiency. For facilitating book and claim modules the private company GreenPalm (Hull, United Kingdom, established in 2008) has set up a credit trading platform for the RSPO. With over 750 members, sales of GreenPalm certificates over the first quarter of 2014 ranged to 850,00MT, up 54% compared to the same period in 2013 [51]. Certificate trading via book and claim makes up almost 63% of RSPO Crude Sustainable Palm Oil (CSPO) trading. Although these four different "modules" of traceability and certification are indicated on the Chain of Custody certificate delivered by the certifier, the system (or module) used is not always communicated clearly to the final consumer. Together, annual available certified sustainable palm oil in 2012 makes up 10% of the global market (around 5 million tonnes), but only about 70% of this volume has actually been traded as such.

The Round Table on Responsible Soy RTRS to some extent resembles developments in the RSPO, although it has been established much later. With the first producer was certified only early 2011, in 2014 it had 31 producer members (with a production area of over 450,000 hectares) and 96 members from industry, trade and finance. Besides the segregated and mass balance modules, the RTRS has established a book and claim system of trading responsible soy. Under the RTRS, soy companies, but also other interested companies and organizations not having access to soy value chains, can purchase "responsible soy production credits" directly from soybean growers on the Soy Credit Trading Platform (under the authority of RTRS), with one credit equalling the responsible production of one metric ton of soybeans. Credits can be bought, sold and re-sold, but once validated they can no longer be re-sold [52]. This resembles similar systems as the credit trading platforms of sustainable palm oil of GreenPalm and for carbon credits of ISCC (International Sustainability and Carbon Certification). The different models (segregated, mass balance and book and claim) come with different claims on the products, and even with different logo's to be used [53]. In 2014 over 1.3 million metric tons of responsible soy was sold (including segregated, mass balance and traded credits), in a global market for soy of nearly 240 million tons (FAO Statistics). The recently established ProTerra certification initiative for soy only operates identity preserved and segregated traceability systems.

Better Sugarcane Initiative or Bonsucro (London, United Kingdom, established in 2006) operationalizes several certification systems for sugarcane supply chains [54]. Next to "physically segregated shipment" and mass balance, Bonsucro has a credit trading system where companies wanting to make a claim of sustainable sugar can purchase credits of responsibly produced sugar from certified mills [55]. This facility is only accessible for Bonsucro members (34 mills and 181 other members in 27 countries) and comes together with registration and verification systems at the mills. There is also ample possibility of buying and reselling certificates, making the system into a real market. Prices are set between buyer and seller and Bonsucro charges a USD $1.3/ton fee. Bonsucro certifies only

sugarcane and by early 2014 the organization has certified 3.32% of global sugarcane production (55 million tonnes) and 3.66% (which equals 870,000 hectares) of the total land area under sugarcane. Of the end products, Bonsucro has certified around 3.8 million tons of sugar and some 2.6 million m^3 of ethanol.

Biofuels for the European market need to be sustainable under the EU RED directive (2009/28/EC) in order to allow these biofuels to count in the compulsory percentages of renewable fuel mixing in transport fuel [56]. To date, 19 different certification schemes have been allowed, using a mass balance traceability system (allowing also for segregation and identity preserved) [57]. The allowed systems include RSPO, RTRS, Roundtable for Sustainable Biofuels RSB and Bonsucro, which have developed special mass balance systems for RED-certification, (besides other segregation, identity preserved and/or book and claim traceability systems for other markets) [58]. Since 2008 the English RTFO (Renewable Transport Fuel Obligation) contained a book and claim traceability system for biofuels, but this was discontinued when RTFO had to be harmonized with the EU RED in 2011/12. Staaij and colleagues [29] note the complications of such a large and diversified mass balance system for biofuel traceability, as voluntary certification initiatives vary and EU countries differ in implementing and recording mass balance traceability. For instance, so-called second generation biofuels based on waste and residues are preferred in EU policy and can be counted double in the accounting sheets; but it differs per certification initiative what is seen as waste and residues and what not [59].

A recent initiative (started in 2011) is the Global Roundtable for Sustainable Beef (GRSB), aiming at achieving continuous improvement in the sustainability of beef production systems and value chains around the globe [60]. The GRSB is a multi-stakeholder initiative with representatives from producers and consumers around the world, such as Cargill, McDonalds, the Brazilian Roundtable on Sustainable Livestock, Solidaridad and WWF. The GRSB intends to formulate principles and criteria for global sustainable beef with the help of its members and other stakeholders while considering the indicators and the means of verification to be context-specific and not feasible as elements of a global standard. These important issues are left to local, national and regional groups. GRSB has not yet touched upon issues of traceability of sustainable beef, but it is unlikely that it will introduce mass balance or book and claim systems. One of GRSB's members, McDonalds, has announced that it will begin to purchase sustainable beef verified against these principles and criteria by 2016, after having developed specific targets, to ensure that sustainable beef is verifiable and transparent, making the need for a traceability system pressing [33].

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