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Smallholder value chains as complex adaptive systems: a conceptual framework

Alastair Orr
International Crops Research Institute for the Semi-Arid Tropics, Nairobi, Kenya
Jason Donovan
International Centre for Research in AgroForestry, Lima, Peru, and
Dietmar Stoian
Bioversity International, Montpellier, France

Abstract

Purpose – Smallholder value chains are dynamic, changing over time in sudden, unpredictable ways as they adapt to shocks. Understanding these dynamics and adaptation is essential for these chains to remain competitive in turbulent markets. Many guides to value chain development, though they focus welcome attention on snapshots of current structure and performance, pay limited attention to the dynamic forces affecting these chains or to adaptation. The paper aims to discuss these issues.
Design/methodology/approach – This paper develops an expanded conceptual framework to understand value chain performance based on the theory of complex adaptive systems. The framework combines seven common properties of complex systems: time, uncertainty, sensitivity to initial conditions, endogenous shocks, sudden change, interacting agents and adaptation.
Findings – The authors outline how the framework can be used to ask new research questions and analyze case studies in order to improve our understanding of the development of smallholder value chains and their capacity for adaptation.
Research limitations/implications – The framework highlights the need for greater attention to value chain dynamics.
Originality/value – The framework offers a new perspective on the dynamics of smallholder value chains.

Keywords Development, Complex adaptive systems, Value chains
Paper type Research paper

1. Introduction

Value chain development (VCD), which facilitates the participation of smallholders and small and medium rural enterprises in higher value markets for agricultural and forest products, has become a key component in the strategies of many development agencies, donors and governments (Humphrey and Navas-Alemán, 2010; Staritz, 2012). VCD is widely seen as a way to combine economic growth and equity objectives by enhancing value chain performance while simultaneously reducing poverty among smallholders, including women and other marginalized groups (Stoian *et al.*, 2012).

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The rise of VCD in development programs has led to a flood of guides and diagnostic tools. These guides and tools provide practitioners and researchers with a framework to engage with market actors, to identify market opportunities, the conditions for market access, and the capacity of smallholders and other actors to engage in the chain. However, most assume that users will identify critical elements in the context, understand their relevance for VCD, and make the necessary adjustments for data collection and analysis (Donovan *et al.*, 2015)[1]. Consequently, they provide an incomplete picture of how policy, institutional and market trends, culture and local circumstances could shape the possible outcomes of interventions to strengthen specific value chains with smallholders and other resource constrained actors, or the actions needed to reduce uncertainty for different actors in this chain. Similarly, many value chain guides and tools see performance as driven primarily by financial incentives. They quantify how much of the product flows through different market channels, and they measure costs and revenues to estimate how much value is added at each stage in the chain. The result is a snapshot that captures "stylized facts" about the value chain frozen in time. They pay scant attention to value chain dynamics; what happened in the past and what could happen in the future go un-mentioned.

By contrast, analyses of specific value chains have revealed the importance of contextual factors for understanding the dynamics of VCD and the underlying reasons for successful performance. A study of the value chain for shea nuts, for example, shows how an oligarchy of middlemen has successfully adapted to changes in the context – the end of state regulation, market liberalization and political shocks – and defeated efforts by processors and NGOs to source shea directly from suppliers (Rousseau *et al.*, 2015). Poorer smallholders may be excluded from high value agricultural markets by their limited capacity to adapt to market risks (Poole and Donovan, 2014; Tobin *et al.*, 2016). Cooperatives, which are often expected to play a critical role in VCD, may be unable to adapt sufficiently to market conditions to become viable businesses that can serve their members effectively (Donovan *et al.*, 2017). On a larger scale, historical studies of global value chains show how these are created, by policy and by conflicts between different interest groups (Mintz, 1985) and how they have adapted to changing contexts over time (Beckert, 2015). This disconnect between value chain guides and the academic analysis of value chains highlights the need for tools to identify these contextual factors at the diagnostic stage of VCD. How robust is the value chain to unexpected shocks? What might happen if conflicts develop between different value chain actors? How might value chain stakeholders adapt to meet these challenges? How long might this adaptation take?

Questions like these are critical for VCD with smallholders in developing countries. There are examples of the successful integration of smallholders in value chains – successful for now, that is (Stoian and Donovan, 2008; Harper *et al.*, 2015). But there are also examples of mixed success (Donovan *et al.*, 2008; Ricketts *et al.*, 2014) and outright failures (Donovan and Poole, 2014). Indeed, the failures may well outnumber the successes. This should not surprise us. Experience in Africa and Latin America has revealed the struggles of smallholders to participate in relatively demanding and high-risk business environments across a range of agri-food sectors (Conroy *et al.*, 1996; Reinhardt, 1987; Dolan *et al.*, 1999; Gibbon and Ponte, 2005). Furthermore, in business as in evolution, "it is failure rather than success which is the distinguishing feature of corporate life" (Ormerod, 2005, p. 12). Fewer than half of today's Fortune 500 companies were listed as such 20 years ago (Fortune, 1996, 2015). From a business perspective, therefore, failure is not an aberration but the norm. The risk of failure is particularly high in value chains in developing countries where smallholders are active participants. Smallholders are more likely to have limited access to information, productive assets, and fewer degrees of freedom to adjust to shocks. Such chains tend to have multiple layers that increase the odds of failure, and supply is subject to shocks from changes in the political and legal contexts and in agro-ecological conditions such as droughts or the incidence of pests and diseases.

We argue that understanding the performance of value chains involving smallholders needs to move beyond the conventional focus on "upgrading" and "governance" to focus more strongly on the complexity inherent in value chains and the capacity of value chain actors to respond to changes in the context. This suggests the need for an expanded conceptual framework to help us understand the factors that create complex systems, and the ways that value chain actors can adapt to changes in the context. This paper presents a conceptual framework based on an analogy between value chains involving smallholders and complex adaptive systems. Complex systems thinking has been applied to a wide range of social sciences (Kiel and Elliot, 1997; Fuller and Moran, 2001; Lansing, 2003) and to foreign aid (Ramalingam, 2013) but has been largely absent from discussions on value chains in a rural development context[2].

Are smallholder value chains really complex systems? Some economists object that the argument from analogy is unscientific, because only if the economy really is a complex system can we ever discover universal laws like those in biological systems (Beinhocker, 2007). This raises questions about the nature of economic models. When economists develop a model they think of themselves as picturing the "real world." However, what they may really be doing is imagining a world which they then picture in the form of a model (Morgan, 2014). They create an imaginary world ("a complex system") which they use to explore the real world. In this view, economic models can also function as analogies or as metaphors (Gilboa *et al.*, 2014). In the same way, the conceptual framework presented here imagines smallholder value chains as complex systems. Instead of thinking about value chains as if they were a complex system, we ask what if they were a complex system. Like a metaphor, the conceptual framework presented here functions as a tool of interpretation, helping us to see a pattern and connections in smallholder value chains that we might otherwise miss.

We have applied the theory of complex adaptive systems to VCD involving smallholders to provide researchers with an expanded conceptual framework to understand value chain performance over time. The framework is then applied to selected case studies of value chains involving smallholders, thus providing insights into its usefulness and options for future refinements. The scope of this paper is limited. Our aim is not to review the current conceptual frameworks for VCD or to advise practitioners on how smallholder value chains might adapt to complexity. Rather, our aim is to suggest that complex adaptive systems offer a way of thinking about smallholder value chains that can help explain their performance. The focus, therefore, is on the common properties of complex adaptive systems and their relation to experience with smallholder value chains. We suggest that this perspective is relevant for smallholder value chains because of their greater exposure to uncertainty, shocks, and sudden changes, and also that this perspective is helpful by focusing attention on the contextual factors that help determine performance as well as the need for VCD to build capacity for adaptation.

We use the analogy of a complex adaptive system to answer the following three questions:

RQ1. Which common properties of complex adaptive systems are most relevant for understanding value chains and their development?

RQ2. Can we combine these common properties into a conceptual framework that can enhance our understanding of value chain performance?

RQ3. How can this framework be used to develop research questions, and applied to real-world case studies of smallholder value chains?

The paper is organized as follows. Section 2 summarizes relevant research on complex adaptive systems. Section 3 presents a conceptual framework, while Section 4 discusses applications to smallholder VCD. The final section concludes.

2. Complex adaptive systems

We begin by defining terms before summarizing the common properties of these systems and their relevance for smallholder value chains. Our aim is not to give a potted history of thinking about complex adaptive systems (see Mitchell, 2009, for the full story and; Rosser, 1999 for a shorter account) but to isolate the key features of such systems relevant for thinking about smallholder value chains.

Definitions

Writers distinguish between complex adaptive systems, where adaptation plays a large role and non-adaptive complex systems, such as a hurricane (Mitchell, 2009). This paper focuses on complex adaptive systems because it seeks better management as well as understanding of stakeholder reactions, interactions, and adaptations in response to systemic shocks. Because thinking about complex adaptive systems has emerged from a range of disciplines, with each discipline contributing key ideas, there is no universally agreed definition of a complex system or a "unified theory" of complex systems (Gleick, 1998). However, the essence is captured by Mitchell's definition:

> A system in which large networks of components with no central control and simple rules of operation give rise to complex collective behavior, sophisticated information processing, and adaptation via learning or evolution (Mitchell, 2009, p. 13).

Complex adaptive systems challenge two fundamental assumptions of neoclassical economics. First, a complex adaptive system is not in equilibrium, but in constant movement. Second, complex adaptive systems challenge the concept of "representative agents," or the assumption of "a single actor who rationally calculates the decision that will maximize his or her self-interest from now until the end of time" (Ormerod, 2005, p. 179). Challenging these neoclassical assumptions has generated new fields of research. Evolutionary economics and the new growth theory both assume dis-equilibrium (Nelson and Winter, 2002). Similarly, the theory of interacting agents has contributed to the growth of behavioral economics, helping to understand stock market fluctuations and the business cycle (Ormerod, 1998), why companies succeed or fail, why inferior technologies may dominate the market (Ormerod, 2005), and the operation of social networks (Durlauf, 2005; Mitchell, 2009). Just as viewing the economy as complex adaptive system has given new insights into economic behavior, so complex adaptive systems can enrich our understanding of the motivations, capacities, and behavior of value chains involving smallholders and offer insights into how to improve their performance.

Common properties of complex adaptive systems

Despite the lack of a single definition, complex systems share "common properties" (Mitchell, 2009, p. 293), which can provide the building blocks for a conceptual framework for VCD involving smallholders. In this section, we identify and describe seven common properties of complex adaptive systems that we believe to be most relevant for understanding value chains in which smallholders are important participants.

Time.

> Once we admit that an economy exists in time, that history goes one way, from the irrevocable past into the unknown future, the conception of equilibrium […] becomes untenable (Joan Robinson, 1974 quoted Arthur, 2015, p. 23).

In most value chain analyses in the rural development arena time is not considered because markets are regarded as stationary: they exist in equilibrium, or move imperceptibly from one equilibrium to another. At equilibrium an outcome simply persists and so time largely disappears, or in dynamic models it becomes a parameter that can be slid back and forth reversibly. Equilibrium also tells us nothing about the time required to move between

different equilibria (Ormerod, 2005). How long does it take for the price of a given crop to move to new equilibrium after a shock? Is the adjustment made rapidly, and the last few steps slowly, or is the path to a new equilibrium an entirely smooth process?

In complex systems, by contrast, the system is in a constant state of change or dis-equilibrium. Because change is measured over time, time is a property of complex systems. Time also enters complex systems through path-dependence, where the system becomes "locked" into a particular trajectory by events or shocks that have occurred in the past[3]. In economics, this may result in "technological lock-in" where a technology becomes the industry standard despite the existence of superior alternatives (the QWERTY keyboard, for example) (Durlauf, 2005). This implies the need to see value chain performance in historical perspective, analyzing the sequence of events that created shocks and led to adaptation by one or more chain actors. An example of market dis-equilibrium is the world coffee price crisis resulting from the rapid growth of coffee production in Vietnam during the mid-1990s and changes in technologies used by coffee roasters, which devastated coffee production in many parts of the world for nearly half a decade (Osorio, 2005).

Sensitivity to initial conditions. Complex systems are sensitive to small changes in initial conditions. The classic example is meteorology, where tiny changes in the parameter values of weather models lead to wildly divergent weather forecasts (Gleick, 1998). This is known as the Butterfly Effect ("a butterfly causing a hurricane on the other side of the world by flapping its wings").

The Butterfly Effect is caused by non-linearity. A good example is the logistic curve used to model population growth. Changing the parameter value of the curve (R) increases the non-linearity of the equation and beyond a certain value (3.1) the curve starts to oscillate. When the value is further increased to between 3.5 and 3.6 the logistic curve becomes "chaotic" or apparently random (Gleick, 1998; Mitchell, 2009). Thus, even in a simple model in which all the parameters are exactly determined, long-term prediction is impossible. By contrast, in a linear system, large results must have large causes. In linear systems, therefore, change is predictable, just as each value on a straight line at Time A is directly proportional to the value at Time B.

A complex systems perspective suggests that the performance of a value chain is sensitive to initial conditions. For example, when Kenya imposed an excise duty of 50 percent on sorghum beer in 2013, this effectively killed the industry (Orr, 2018). Similarly, the decision by the European Community to impose a maximum level of aflatoxin contamination of two parts per billion made it more difficult for groundnut growers in Africa to penetrate European markets and threatened to reduce trade flows by 63 percent (Otsuki *et al.*, 2001). Thus, the impact of a small change, such as a tax rate or a quality standard, can vary greatly depending upon the exact circumstances in which that change is made. While some small changes may have small effects, others can have very big effects. According to Ormerod (1998, p. 96), "this is the whole logic of the complex systems approach."

Endogenous shocks. In complex adaptive systems, shocks are distinguished from sudden changes to emphasize that shocks are endogenous or generated from within the system. In neoclassical economics, where the economy is in equilibrium, shocks are by definition external to the system. Business cycles are incorporated by allowing that economic equilibrium must adjust from time to time to such outside changes (Ormerod, 2005). By contrast, in complex systems shocks can arise internally, created by the system itself. Innovation is a prime example. In neoclassical growth theory, innovation is exogenous to the economy, something measured simply as a residual once other factors of production have been accounted for. By contrast, new growth theory sees innovation as endogenous, because investment in innovation generates increasing returns which results in further

investment and so on, in an endless cycle (Beinhocker, 2007). Moreover, innovation does not produce a one-off disruption to equilibrium but an ongoing sequence of demand for further technologies in a self-reinforcing cycle (Arthur, 2015). Innovation, therefore, is not imposed from outside but intrinsic to the working of the economy.

A complex systems perspective implies that we should not see shocks as only external to the value chain, but also as generated from within, by uncertainty, by technological change, and also by "interacting agents," whose individual behavior can have unpredictable results for the system as a whole. For example, the hike in excise duty for sorghum beer in Kenya was provoked by the government's need for extra revenue and what was seen as excessive profit-taking by Kenya Breweries (Orr, 2018). Similarly, the international coffee agreement to regulate production and world prices collapsed because of competition from new entrants that made such regulation unworkable (Talbot, 2004). In both cases, shocks that affected performance were generated from inside the value chain as the result of conflicts between different value chain actors. Shocks differ from sudden.

Sudden change. Since neoclassical economics views the economy as being in equilibrium, it is wedded to the idea that change is gradual. This is based on the Darwinian theory of evolution where small variations operating through natural selection lead to gradual change over time. By contrast, complex systems are characterized by sudden changes where the system lurches suddenly to a new equilibrium. The idea of a "Tipping Point" – "the moment of critical mass, the threshold, the boiling point" – has been used to explain sudden changes in consumer behavior (Gladwell, 2000) or in crime rates, where sudden jumps in crime can result from quite small changes in rates of social deprivation (Ormerod, 1998). Sudden changes are caused by feedback loops. For example, the higher the crime rate, the more criminals in the population, the weaker the social sanctions against crime, and the less incentive to stop being a criminal, which in turn results in more crime. This is a positive feedback loop, where the system shows explosive behavior. If a system contains only negative feedback loops (or diminishing returns, in economics) it converges to equilibrium and the "stationary state" that haunted classical economists. A system that shows a mixture of both positive and negative feedback loops exhibits "complex behavior" (Arthur, 2015).

Value chains involving smallholders are vulnerable to sudden changes that disrupt performance. These include food safety standards that may lead to being locked out of particular markets, the loss of a major buyer, a sudden pest outbreak, or a policy U-turn that can destroy a value chain overnight. Following the imposition of international food safety standards, for example, more than half the smallholders growing green beans in Kenya were dropped from the value chain immediately (Narrod *et al.*, 2008).

Uncertainty. Uncertainty refers to situations where the probability of a given outcome is itself unknown (Ormerod, 2005)[4]. Uncertainty is recognized to have a strong impact on decision making by individual firms (Wilding, 1998):

> I may be choosing to put venture capital into a new technology, but my startup may not know how well the technology will work, how the public will receive it, how the government will choose to regulate it, or who will enter the space with a competing product. I must make a move but I have a genuine not-knowingness – fundamental uncertainty. There is no "optimal" move (Arthur, 2015, p. 5).

The same holds true of value chains where smallholders play an important role. Some threats to its performance are known and steps can be taken to mitigate them (e.g. actions to reduce production losses from known diseases, access to credit for purchase of inputs, and to support the management of a newly organized cooperative). But some threats are unknown, because we do not know what the system will do next. These include changes in the political and legal framework, changes in consumer preferences, outbreaks of pests and diseases, and changes in comparative advantage between countries. The future is not just unforeseen but unforeseeable. This implies long-term support to build the adaptive

capacity of actors in smallholder value chain, which may ultimately include the capacity to switch from one value chain to another.

Interacting agents. The property of complex systems with the biggest impact on economics is that of "interacting agents," defined as the "interdependence in behavior across individuals" (Durlauf, 2005, p. F238). Neoclassical economics uses the convenient fiction of representative agents in whom individual tastes and preferences are fixed. In contrast, complex adaptive systems have heterogeneous, interacting agents whose tastes and preferences are influenced by those of other agents (Kirman, 1992). The classic example is the ant model, in which the foraging behavior of individual ants is determined by the behavior of other ants (Ormerod, 1998). Similarly, for some consumer goods (movies or smart-phones), individual consumers have to discover their preferences, which is why the opinions of others influence their behavior so strongly. The theory of interacting agents also helps explain how inferior products can drive out superior technology and why stock markets boom and bust (Ormerod, 1998).

The concept of "interacting agents" has important implications for system performance. First, small observed differences between agents can have a large effect on the overall system. For example, a mild racial preference by individuals – avoiding being a minority group – can result in complete racial segregation in a neighborhood or even an entire city (Ormerod, 2005). Second, interacting agents produce unpredictable results. Even if we know exactly how individuals will behave, we still cannot predict the behavior of the system because the whole is more than the sum of the parts (Ormerod, 1998). Once tastes and preferences are allowed to change, the economy is no longer in equilibrium. As economic agents interact they produce novel and unexpected outcomes, which in turn lead to adaptation and change (Arthur, 2015). Thus, the property of interacting agents is a source of uncertainty generated from within the system.

Interacting agents can also help explain aspects of value chain performance. Value chains have several stages where actors have different functions and different, sometimes conflicting, goals and preferences. Interactions between these functional actors play an important role in the performance of the value chain. This is vertical interaction between agents. In addition, each separate function in the value chain may have several actors. This is horizontal interaction between agents – a critical feature of smallholder businesses, such as cooperatives and farmers' associations. In both cases, interactions can have positive or negative outcomes. Actors are not homogeneous and their goals and behaviors may conflict, but actors can also share goals and cooperate to achieve a common objective.

Table I shows how interacting agents might affect the performance of value chains involving smallholders. We distinguish between interactions between internal value chain actors, and between these internal value chain actors and support service providers. Below we highlight some examples of vertical and horizontal interaction between agents.

Some interactions occur horizontally between internal value chain actors:

- Smallholders join cooperatives or associations to benefit from cheaper farming inputs, collective marketing, credit, and other services, but cooperation may breakdown if there is elite capture, free riding or other forms of unequal benefit-sharing that create distrust between agents.
- Even if collective smallholder businesses are based on relationships of internal trust, they face a dilemma when deciding if a given surplus is distributed among members (e.g. as dividends) or reinvested in the business.
- Competition between buyers and processors can lead to price-wars between rival firms (a "race to the bottom") or to cooperation and price-fixing by cartels.

Agents	Participation in value chain	Funding sources	Objectives in value chain participation	Conflicting interactions between agents
Value chain actors				
Smallholders	On farm production, with surplus for chain; artisanal or collective processing	Sales of raw materials or semi-finished products Non-farm income	Sufficient income to meet basic needs	Production gluts, price collapse
Cooperatives and other forms of collective smallholder businesses	Aggregation of production; provision of farming inputs; technical, business and financial services provided to members (including marketing and credit)	Membership fees, donor projects, selling services to members	Support to smallholders by sharing costs, building social and other capital, and negotiating higher prices	Elite capture, free-riders, gender bias
Buyers and processors	Transformation and marketing for downstream buyers	Value added to raw materials or semi-finished products	Market share, growth in share price	Price-wars, price-fixing, lobbying government, taxation
Consumers	Demand for products	Subsidies, tax reductions	Utility, value for money	Changing tastes and preferences
Support service providers				
Non-governmental organizations	Provision of technical, business and financial services	Access to funding from bilateral donors, government agencies; revenues from sales of products and services	Institutional growth, mission advancement	Competition with the private sector, crowding out
Policies				
Governments	Regulatory body	Tax revenue, electoral support from smallholders and farmer organizations	Re-election, political legitimacy	Conflicts between government ministries (e.g. Finance, Agriculture)

Table I. Interacting agents in value chains involving smallholders

- Consumers influence other consumers to buy products that meet specific ethical or quality standards (e.g. fair trade).
- Consumers increase demand for new and exotic products (e.g. Quinoa or avocados) that result in new and more lucrative markets for smallholders.

Other interactions occur vertically between internal value chain actors:

- Collective smallholder businesses may develop as multi-tier enterprises, with base cooperatives as first tier, marketing cooperatives as second tier, and advocacy organizations as third tier (e.g. the international co-operative alliance).
- Business partnerships between cooperatives and large-scale buyers for the production of high value chains, such as horticulture for supermarkets and certification cocoa.

Finally, some vertical interactions occur between internal value chain actors and governments:

- Buyers use trade associations to lobby governments to introduce legislation or nontariff barriers to give them a cost advantage over foreign competitors or for tax-breaks if they buy from local producers.
- Governments impose international food safety standards that increase costs for smallholders who must either meet these standards or seek alternative markets.

Adaptation. Complex systems are "adaptive," meaning that they evolve and can learn. Adaptation is defined as "change in behavior to ensure survival or success" (Mitchell, 2009, p. 13). Adaptation, therefore, is the mechanism to cope with the uncertainty of complex systems. Some economists take a biological view and argue that firms can plan and strategize to avoid failure, or that failure itself can function as a means of adaptation through learning (Harford, 2011). Others are more skeptical, arguing that "the complex interactions between individuals give rise to inherent limits to knowledge about how systems behave at the aggregate level" (Ormerod, 2005, p. 226). Although private firms plan and strategize, they share the same pattern of "extinctions" as biological species, suggesting limits to their ability to cope with changing conditions (Ormerod, 2005). Successful adaptation may even be due to pure chance (Ormerod, 2005). In short, although complex systems are defined by their ability to learn, adapt, and evolve, adaptation has limits.

Adaptation is the key to understanding the evolution of global value chains, which are driven by the unceasing quest for competitive advantage. As the historian of the global value chain for cotton concludes:

> The constant reshuffling of the empire of cotton, ranging from its geography to its systems of labor, points towards an essential element of capitalism: its ability to constantly adapt. Again and again a seemingly insurmountable crisis in one part of the empire generated a response elsewhere: capitalism both demands and creates a state of permanent revolution (Beckert, 2015, p. 441).

Adaptation, therefore, is the distinguishing feature of the wider economic system in which value chains involving smallholders are embedded. Their performance in an economic system characterized by "permanent revolution" greatly depends on how well the different actors can adapt to constant and at times abrupt change in market conditions.

Figure 1 applies adaptation to value chains involving smallholders. Buyers, markets, commodities, coordination, and regulatory frameworks may all differ across these chains. However, certain characteristics usually go together. Perishable, high value commodities

Value Chain Characteristics	Adaptive capacity			
	Low	→		High
Business Model	Smallholders selling in spot markets	Organised smallholders selling in spot markets	Contract Farming	Integrated agribusiness
Buyers	Local firms	→		Transnationals
Market	Local	→		Global
Commodity	Staple food crops	→		Fresh produce, plantation crops
Value of commodity	Low	→		High
Product differentiation	Low	→		High
Coordination between actors	Low	→		High
Regulatory framework	None	→		International

Source: Business models based on Byerlee and Haggblade (2014)

Figure 1.
A typology of adaptive capacity in value chains involving smallholders

that are traded in global markets are associated with transnational firms and tight regulatory frameworks, and products are differentiated for different consumer segments. These are not characteristics of value chains involving smallholders for staple food crops, which are typically traded in local markets where regulatory frameworks may be missing or unenforced, where purchasing power is limited and quality incentives are scarce, and where consumers have little choice in the type of product they buy.

Value chains where smallholders sell on spot markets are simple in the sense that they have fewer functions and actors. However, they also share the properties of complex systems, because their lack of vertical integration and weak coordination makes them less stable and less able to adapt to endogenous shocks and sudden changes. An additional level of complexity is added by the fact that smallholders are not a homogeneous group but include both smallholders who are already successful commercial farmers as well as emergent or potential commercial farmers (Department for International Development, 2015). These groups usually differ in their access to resources and in their capacity for adaptation. By contrast, value chains where large agribusinesses play a key role are more complex in the sense that they have more functions and actors, but they have streamlined the coordination problem and their global reach gives greater control in sourcing material and finding buyers. This makes it easier for them to adapt to changing market conditions.

One common form of adaptation in smallholder value chains, therefore, is through the business model. These models come in different shapes and sizes (Haggblade *et al.*, 2012). The most common model is one of individual smallholders selling in spot markets. The three other models – organized smallholders selling in spot markets, contract farming, and integrated agribusiness – share a common rationale, which is to optimize the performance of the value chain by reducing the chance of something going wrong. They provide value chain actors with a buffer that helps reduce risk (which is known), cope with uncertainty (which is unknown), and reduce the potential for endogenous shocks generated by conflicts within the system. In other words, these three business models are institutional mechanisms for managing complexity.

Where value chains involving smallholders successfully adapt, it is often thanks to an appropriate business model. This is particularly true for high-quality consumer markets. Experience has shown that smallholders can produce food of the required quality, and that "policy makers have to be wary of the pessimism that is common with regard to smallholders" ability to meet stringent food safety standards' (Narrod *et al.*, 2008, p. 371). In Kenya, however, successful adaptation to meet these standards has required the right institutional support, with farmer organizations contracted by exporters, a certification agency funded by donors and NGOs, and government investment in cold storage facilities (Narrod *et al.*, 2008). Similarly, Colombia's value chain for specialty coffee is founded on the Colombian Coffee Growers' Federation, an integrated agribusiness owned by smallholders that tightly controls all stages of the chain to ensure compliance with stringent quality standards and protect the brand (Bentley and Baker, 2000). Where adaptation proves too difficult, the solution may lie in alternative markets. For example, when Malawi was unable to reduce aflatoxin contamination of groundnuts to the level required by the EU, the industry switched to producing groundnut oil, where a simple filtration process reduces aflatoxin to a safe level (Emmott, 2013).

Where smallholder value chains lack the appropriate business model adaptation may be less successful. For example, despite strong demand for finger millet in Kenya, efforts to develop an inclusive business model to increase imports from Uganda were not successful largely because of poor decision making which resulted in an intermediary-driven business model rather than a buyer-driven model as originally intended (Orr and Mwema, 2013).

Similarly, small-scale forest users providing palm heart to local processing plants in the Bolivian Amazon were unable to adapt to sudden changes in market conditions in Brazil, their main buyer, because they lacked a business model that could identify alternative market outlets (Stoian, 2004). Even where appropriate models exist, many smallholders may be unable to benefit from them because they lack the minimum level of assets and skills to participate in the value chain. Successful adaptation may require new functions in the chain. If a critical mass of actors to perform these functions is not available, the value chain may breakdown; or if smallholders fail to adapt to new conditions, the value chain may become reorganized around them.

Adaptation can prove too difficult even for agribusiness companies. One striking example is the introduction of refrigerated containers for bananas. Formerly, bananas were transported in refrigerated ships owned by a few transnationals that controlled global trade. Refrigerated containers broke this monopoly. Today, most bananas sold in the European Union are bought and transported by small and medium exporters while transnationals own the ships (Anania, 2015). In this case, innovation created an endogenous shock within the value chain to which transnationals could not adapt. As Ormerod (2005) argued above, there are limits to adaptation.

All these business models depend to a greater or lesser degree on support service providers (research, input suppliers, finance), as well as government policy (trade and fiscal policy, grades and safety standards, labor laws). Government policy can make or break a smallholder value chain, as shown by the case study of sorghum beer in Kenya (Orr, 2018). Government policy can also determine risks for private investors. In Africa, privatization and market liberalization policies in the 1990s mean that systemic investment risks (price risks, economic coordination risks, opportunism risks) are no longer borne by governments but by private agents (Dorward *et al.*, 2004). These risks may make it unprofitable for buyers or service providers to support smallholder value chains. Without these support service providers, smallholder may be unable to function effectively. In this case, others may have to step in to create the conditions required for the value chain to succeed. A case in point is the smallholder value chain for pigeonpea in Eastern Africa, which required coordination between research, seed suppliers, and exporters to correct the market failures preventing the development of the chain (Jones *et al.*, 2002).

3. Conceptual framework

In this section, we integrate the common properties of complex adaptive systems into a simple conceptual framework. We provide a visual representation that can help us see a value chain as a complex adaptive system.

This framework was developed with two objectives in mind. The first was to focus on value chain dynamics. Most – though not all – VCD guides pay limited attention to these dynamics, which are consigned to a black box called "the enabling environment." An exception is the guide developed by the International Institute for Environment and Development (Vermeulen *et al.*, 2008) which develops a conceptual framework that identifies three sources of dynamism:

(1) drivers of change, or "the main external factors that cause change in the value chain";

(2) trends, or "the directions of change in the chain, caused by the drivers"; and

(3) institutions, or "the rules of the game," that "enable change to take place."

This guide uses these categories to "explore future scenarios in relation to uncertainties about drivers and trends and understanding the future implications for the value chain, its

actors and the inclusion of small-scale producers." However, it views these dynamics as external to the value chain. We expand this framework to include not only the dynamics in the wider system (the "enabling environment") in which the value chain is embedded, but also the dynamics that are internal to the value chain, such as the interactions between value chain actors and their capacity for adaptation.

Our second objective in developing this framework was to provide a tool for value chain analysis. We distinguish between heuristic devices and analytical tools. As Kaplinsky and Morris (2001) point out, most VCD guides use heuristic devices, such as value chain maps, that generate and describe data. These serve a useful function. However, VCD also requires analytical tools that can help explain the behavior of value chain actors and why performance varies over time. Our framework seeks to go beyond heuristic devices and to provide an analytical tool in the form of a set of concepts – linked together in a systematic way – that can be used to deepen our understanding of value chain performance. These concepts – "pressure points" in the value chain – serve as entry points for researchers to drill down into the internal dynamics of the value chain, revealing its inner workings and helping to explain the behavior of the value chain actors.

Figure 2 shows the conceptual framework. The components of this framework include:

(1) Seven common properties of complex systems that we consider relevant for value chains involving smallholders.

(2) Five common properties – sensitivity to initial conditions, endogenous shocks, sudden change, adaptation, and interacting agents – that directly affect the dynamics of the value chain.

(3) Two common properties – uncertainty and time – are shown as outer rings to show that they affect the five common properties in the inner ring.

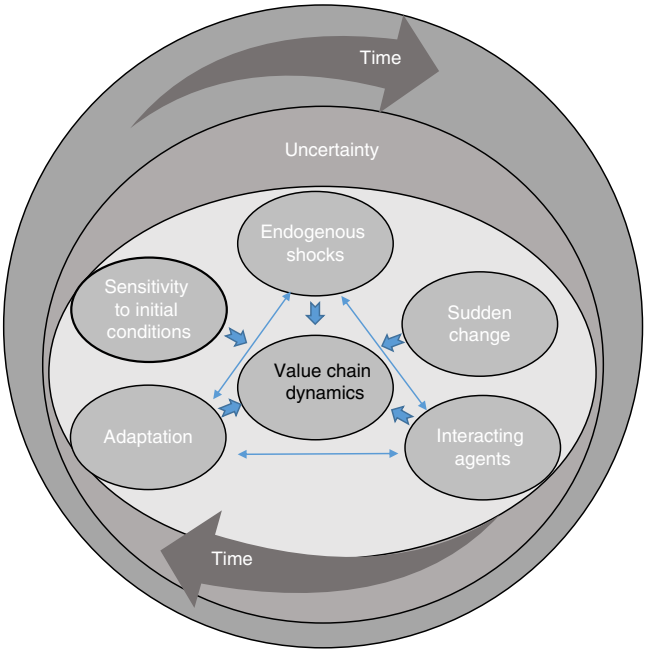

Figure 2.
Smallholder value chains as complex adaptive systems: a conceptual framework

(4) Five common properties – sensitivity to initial conditions, endogenous shocks, sudden change, adaptation, and interacting agents – are placed in a temporal sequence. Initial conditions, shocks, and sudden change are met by responses from agents, which in turn result in adaptations to the system.

(5) Feedback loops operate between the five common properties in the inner ring. To avoid cluttering the diagram, only some of these loops are shown here. Adaptation and interacting agents, for example, can lead to endogenous shocks and sudden changes.

Conspicuously absent from this framework is risk. In economics, "risk" is defined as a situation where the probabilities of an outcome can be measured (Knight, 1921). Risk and uncertainty can be hard to distinguish in practice. For example, if there is a quantifiable probability that a tax increase of X percent will reduce demand for a given commodity by Y percent, then we know the risk to sales associated with this tax increase. But what is the risk of the tax being imposed? This might depend, *inter alia*, on which political party wins the next election, budget requirements, the influence of the Ministry of Finance, or on lobbying by the industry most affected by the change. Since these probabilities cannot be quantified, the decision to increase the tax must be uncertain. This suggests that many of the "risks" associated with VCD are better described as "uncertainties."

While this conceptual framework may help researchers better understand the complexity of smallholder value chains, from a managerial perspective what practitioners need are better ways to manage complexity, including diagnostic tools that improve foresight and allow faster adaptation. Based on experience with these case studies, we plan to develop such tools for smallholder value chains. This will form the subject of a separate paper.

4. Applying the framework

This section outlines two ways in which the conceptual framework can be applied to value chains involving smallholders. The framework can be used to: ask new research questions and analyze case studies.

Research questions

Table II provides a set of research questions to explore complexity in value chains and value chain interventions, with questions for each of the seven common properties of complex systems. Although these questions are not exhaustive, they suggest that the type of questions generated when we apply the conceptual framework to a specific value chain. A common set of research questions is needed to allow meaningful comparisons across different value chains, where smallholders play an important role and where interventions have been carried out to develop the chain.

Case studies

Many guides to VCD involving smallholders lack fully developed case studies showing how tools can be applied (Donovan *et al.*, 2015). We discuss how the conceptual framework in Figure 2 might be used to analyze such case studies.

A criticism of current analytical approaches to value chains involving smallholders is that "they remain qualitative and often case-specific" (Rich *et al.*, 2011, p. 221). In other words, they do not allow researchers to test hypotheses about the impact of alternative upgrading strategies or policy options. For example, the International Livestock Research Institute has used stochastic dynamic (SD) models, simulation, and game theory to understand livestock value chains in Africa (Hamza *et al.*, 2014; Naziri *et al.*, 2012; Rich *et al.*, 2011). One research problem was to develop the value chain for beef exports to the Middle East. An SD model was constructed to make an *ex ante* evaluation and compare the effectiveness of

Common properties of complex adaptive systems	Research questions for value chains involving smallholders
Time	How has the value chain developed and changed over time in terms of supply and demand, principal actors, and the institutional environment? What periodization is most appropriate to describe this development and what were the principal drivers of change? How have past events and trends in the evolution of the chain and output markets shaped the organization and performance of the chain? How have different actors in the chain benefited or been harmed due to changes over time in the context, or business relations?
Uncertainty	What were the major sources of uncertainty in the chain for value chain actors and relations between actors? What are the major sources of uncertainty in the market, and the political, legal and business environments?
Sensitivity to initial conditions	What assumptions do the value chain actors and their external supporters make about market conditions? What initial market conditions are likely to be sensitive to change and how could changes in these conditions affect the performance of the value chain? What initial conditions might affect the participation of specific value chain actors, such as smallholders or SME's? Why?
Shocks (endogenous, exogenous)	What are the most likely sources of shocks, based on past experience and deduction from similar cases? Are these shocks internal or external to the value chain? How predictable are these shocks? How will different actors in the chain be affected? What will be the immediate/long-term effects? How will these affect the performance/viability of the chain?
Sudden change	What sudden changes might affect the value chain? How quickly do market conditions change?
Interacting agents	Which actions by business actors might jeopardize/destroy the value chain? What mechanisms exist to coordinate actions among business actors in the value chain? What capacity do business actors have to influence policy-makers?
Adaptation	What mechanisms are in place to adapt to shocks? Do smallholders have the capacity for adaptation to these shocks? How quickly can actors respond to shocks and sudden changes? How do value chain actors adapt to shocks? How effective are these strategies? What new strategies can be implemented to prevent recurrence?

Table II.
Checklist of diagnostic questions based on seven common properties of complex adaptive systems

different interventions in reducing export prices and making exports more competitive (Rich *et al.*, 2011). SD models could also be used to identify the impact of shocks on the value chain and help identify adaptation strategies. However, modeling requires information on the cost, technical and behavioral parameters at each stage of the model. Consequently, the research costs of SD modeling are high, which may restrict its use to high value commodities with potentially large markets. One can also question the premise of reaching generalized conclusions about VCD based on quantitative models. How valid are these generalizations if the performance of smallholder value chains depends so heavily on the local context?

An alternative approach is through qualitative analysis, or analyzing each case study thematically according to the seven common properties of complex adaptive systems in the conceptual framework. Case studies can be used in three ways. First, if the objective is to test the relevance of the framework as a whole, the case studies must use all seven common properties. Second, if the objective is to use the framework to make comparisons between different smallholder value chains, the case studies must use the same set of common properties.

Finally, if the objective is to test the relevance of the framework for a specific value chain, the case studies may use the common properties judged most relevant for that particular chain. The four case studies in this special issue follow the third approach. While this rules out using the framework to make systematic comparisons between the case studies, it shows the flexibility of the framework as a device for framing narrative and analysis, and how the context influences which of the seven common properties are most important for value chain dynamics.

Box 1 gives a schematic example of the qualitative approach, applied to *khat* in Kenya. Here, the conceptual framework is used to frame the information about a specific case. This approach has obvious limitations. Unlike the SD modeling example, the case studies are not *ex ante* but *ex post*. They do not identify the shocks and uncertainties that might affect the performance of the value chain in the future. Moreover, qualitative case studies cannot formally test hypotheses about the relative importance of different properties in explaining the performance of the value chain. However, what the qualitative case study approach does offer is a way of understanding the past that can suggest ways to improve performance in the future and, by using the same framework of comparison, allowing us to show how specific properties of complex adaptive systems can affect the performance of smallholder value chains.

5. Conclusions

Designing interventions to link smallholders with value chains will benefit from greater attention to the contextual factors that shape value chain performance over time. Smallholder value chains are volatile, with sudden changes of fortune and conflicts between

Box 1. Smallholder value chains as complex adaptive systems: *Khat* in Kenya

Time: for the past five years Kenya's exports of *khat* (*Catha edulis)* have grown by 10% per year, earning $232 million and making *khat* the country's most valuable regional export. In February 2015, however, this expanding and highly lucrative value chain suddenly collapsed.
Uncertainty: although legal in Africa, *khat* is banned as a harmful drug in the USA, Canada, China, and most European countries. An influential Somali lobby group campaigns against trade in *khat* on the grounds that addiction causes unemployment and family breakdown. The export market also depends on efficient air cargo services since *khat* has to be consumed within three days.
Sensitivity to initial conditions: about 40% of the Kenyan crop is exported, with two thirds of exports going to Somalia, and one-third to the Somali diaspora in Europe. A Europe-wide trade ban on *khat* would therefore have a significant impact on the performance of the *khat* value chain.
Shocks: following a ban on *khat* imports by the Netherlands in 2012, the UK became the hub for illegal trade in *khat* to Europe and the USA. In June 2014, supported by Somali lobbyists, the UK declared *khat* a Class C drug, effectively closing the European market to imports from Kenya.
Interacting agents: the Europe-wide trade ban led to oversupply in the regional market for *khat*, which resulted in falling prices in Somalia. Farmers in Kenya saw the price of *khat* (locally known as *miraa*) fall by one-third. At the same time, the Somali government increased taxes by 100% to $200 per bag. This reduced demand from *khat* traders in Somalia who believed that consumers were unwilling to pay higher prices. Middlemen in Kenya responded by suspending the 16 daily flights from Nairobi to Mogadishu needed to supply the Somali market.
Adaptation: the Kenya *Miraa* Farmers and Traders Association (KMFTA) has held discussions with the British opposition Labor party and hopes that the ban will be lifted in case of a change of government. The association will now move to the European Court of Justice to challenge the UK ban. Since the ban, government officials in Kenya have been meeting regularly with growers to discuss the latest developments and the possibility of growing alternative crops.
Conclusion: the experience of the *khat* value chain in Kenya makes sense when analyzed as a complex system where shocks produced sudden and unpredictable outcomes, where interacting agents created a "cascade" that closed down the value chain, and where asymmetric power between value chain actors and nation states prevented successful adaptation.

value chain actors that may lead to the breakdown of the chain, or the crowding out of smallholders. This suggests the need for an expanded conceptual framework to help understand the capacities of poor actors to engage in value chains and the major drivers of value chain performance over time. This paper re-conceptualizes value chains involving smallholders from the perspective of complex adaptive systems.

Conventional value chain guides that pay limited attention to contextual factors and focus on the price incentives for value chain actors fail to reflect the variable performance of value chains involving smallholders in developing countries. Many of these value chains are volatile, with sudden changes of fortune and conflict between value chain actors that may lead to the breakdown of the chain, or the crowding out of smallholders. This suggests the need for an expanded conceptual framework to help understand the major drivers of value chain performance over time and the role of smallholders and smallholder business development in these chains. This paper re-conceptualizes value chains involving smallholders from the perspective of complex adaptive systems.

Complex adaptive systems share several common properties that can help explain the variable performance of smallholder value chains. We identified seven common properties that we combined to build a conceptual framework. We emphasize that this is a framework, not a model. It is not a predictive tool – being nonlinear, complex systems are unpredictable. Instead, the framework provides a set of concepts that allow us to structure the analysis of a specific value chain, compare performance across different value chains, evaluate the effectiveness of adaptation, and identify more general lessons for the successful development of value chains involving smallholders.

In the final analysis, the usefulness of the framework has to be judged by its relevance for individual cases. We applied the framework to four case studies of value chains across different crops and continents. Because no two value chains are alike, the framework was used selectively, applying the common properties of complex adaptive systems that are most relevant for each individual case. In combination, the results will allow us to judge whether the framework has the potential to add to our knowledge of value chains involving smallholders.

Notes

1. An exception is the M4P guide (Department for International Development, 2008) which pays attention to the political, legal, and market context in which chain actors operate.
2. For exceptions, see Cooke *et al.* (2008), Curran and Cooke (2008), Curran (2008), and Ramalingam *et al.*
3. "Environments in which a shock or a set of shocks has permanent effects on a system" Durlauf (2005): F225.
4. By contrast, "risk" is a situation where the probabilities of an outcome can be measured (Knight, 1921). To distinguish this meaning from ordinary usage, in economics this is sometimes called "Knightian" risk.

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About the authors

Dr Alastair Orr is an Honorary Research Fellow, ICRISAT, based in UK. His research focuses on smallholder agriculture. His previous publications include work on Bangladesh, Malawi, and Kenya. The research for this paper was conducted when he was an Agricultural Economist with ICRISAT based in Nairobi, Kenya. Dr Alastair Orr is the corresponding author and can be contacted at: A.Orr@cgiar.org

Jason Donovan is a Senior Economist Markets and Value Chains at the International Maize and Wheat Improvement Center (CIMMYT) in Mexico. His main research interests are rural livelihoods, agricultural markets, business development, and seed systems. Prior to joining CIMMYT, he worked at ICRAF in Peru and CATIE in Costa Rica.

Dietmar Stoian holds a PhD in Forest Economics from the University of Freiburg, Germany. He currently works as a Senior Scientist, Value Chains and Private Sector Engagement at Bioversity International, Montpellier, France, with a focus on value chain development from a livelihoods perspective, forest governance, sustainability standards, impact investments, and sustainable food systems.

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