Socioeconomics
Discussion Paper Series

Series Paper Number 36

Smallholder Value Chains as Complex Adaptive Systems: A Conceptual Framework

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8/4/2015

International Crops Research Institute for the Semi-Arid Tropics

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This work has been undertaken as part of the CGIAR RESEARCH PROGRAM ON Policies, Institutions and Markets

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Abstract

Conventional analyses of value chains involving smallholders and the design of interventions that seek to strengthen their role in them often fail to account for important features of value chain performance. Markets, institutional frameworks and business relationships are dynamic, and value chain performance varies accordingly. Shocks and sudden changes occur frequently and require successful adaptation. 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. We outline how the framework can be used to ask new research questions, analyse case studies, and develop new tools to increase the ability for enhanced risk management and adaptation.

Keywords: complex adaptive systems, value chains, smallholders, agribusiness, risk management

JEL classification: Q13

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Acronyms

EC	European Community
NGO	Non-Governmental Organisation
ICRAF	World Agroforestry Centre
ICRISAT	International Centre for Research in the Semi-Arid Tropics
SME	Small and Medium Enterprises
VCD	Value Chain Development

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). Focusing VCD on opportunities for economic growth and social inclusion offers a way to combine efficiency and equity objectives by enhancing value chain performance while reducing poverty among smallholders, including women and other marginalized groups.

The rise of VCD in development programmes has led to a flood of case studies, guides and diagnostic tools. Many value chain guides and tools provide practitioners and researchers with a framework to engage with market actors and set the stage for collaboration in VCD. 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). Consequently, they provide limited insights into how policy, institutional and market trends, culture and local circumstances could shape the possible outcomes of interventions to strengthen value chains with smallholders and other resource constrained actors, or the actions needed to mitigate risk for different actors in the chain. Similarly, conventional value chain analyses 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 'stylised facts' about the value chain at a moment in time. They pay scant attention to value chain dynamics: what happened in the past and what could happen in the future remain unmentioned. How will changes in market conditions and the enabling environment affect value chain performance? How robust is the value chain to unexpected shocks? What happens when conflicts develop between different value chain actors? How can value chain stakeholders adapt to meet these challenges? How long will this take?

Questions like these are critical for VCD with smallholders in developing countries. There are examples of 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; Donovan and Poole, 2014) and outright failures, and the failures may well outnumber the successes. This should not surprise us. Experience in Africa and Latin America has brought to light the struggles of smallholders to participate in relatively demanding and high risk business environments across a range of agrifood sectors (Conroy et al., 1996; Reinhardt, 1987; Dolan et al,. 1999; Gibbon and Ponte, 2005). Furthermore, in business, as in evolution, failure is always more common than success. 'It is failure rather than success which is the distinguishing feature of corporate life' (Ormerod, 2005: 12). Fewer than half of today's Fortune 500 companies were listed as such 20 years ago (Fortune, 1996, 2015). Viewed in this light, failure is not an aberration but the norm. The risk of failure is particularly high in value chains originating from developing countries where smallholders are active participants. In this context smallholders are more likely to have limited access to information, productive assets, and limited 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-legal context and changes in agro-ecological conditions (drought or floods, pests and diseases).

These questions suggest the need for an expanded conceptual framework to understand the dynamics of value chains involving smallholders, and to develop tools that help anticipate changes and devise strategies that minimize risks. While this framework seeks to offer something new, it also draws on existing areas of inquiry, incorporating their strengths and recognizing their limitations. Political economy, for example, has enriched our understanding of power relations within value chains, but has focused on global value chains led by so-called lead firms – often global agri-food companies – rather than on local or regional value chains where smallholders play a more prominent role (Gibbon and Ponte, 2005). Moreover, political economy has emphasised the growth of buyer-driven chains rather than the producer-driven or intermediary-driven chains that are the concern of many VCD practitioners (Vorley et al., 2009). Finally, political economy sees value chain performance as driven by power relations rather than giving equal weight to other drivers. We have tried to take a broader view, where power relations within the value chain are part of a wider system over which no single actor has control.

This paper proposes a conceptual framework based on 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) but has been absent in discussions on value chains in a rural development context. This paper draws an analogy between value chains involving smallholders and complex adaptive 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). However, many economic models are in fact analogies that use inductive reasoning to compare the case of a theoretical model with real-world cases and judge the value of the model (Gilboa et al., 2014). Similarly, this paper compares the theoretical case of a complex adaptive system with cases of value chains involving smallholders to judge their similarities and the relevance of this model for explaining the performance of these chains.

We have applied the theory of complex adaptive systems to VCD involving smallholders with three specific objectives in mind. One is to provide researchers with an expanded **conceptual framework** to understand value chain performance over time. The second is to apply this framework to selected **case studies** of value chains involving smallholders. The third is to provide practitioners with **diagnostic tools** to help these chains adapt to complexity.

With the aim to provide a broader view on value chains involving smallholders and the design of interventions to support these chains, we use the analogy of a complex adaptive system to answer the following questions:

1. Which common properties of complex adaptive systems are most relevant for understanding value chains and their development?
2. Can we combine these common properties into a conceptual framework that can enhance our understanding of value chain performance?
3. How can this framework be applied to develop research questions, case studies, and diagnostic tools for smallholder VCD?

The paper is organized as follows. Section 2 summarises 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 do not propose to give a potted history of thinking about complex adaptive systems (see Mitchell, 2003 for the full story and Rosser, 1999 for a shorter account). We begin by defining terms and summarise the common properties of these systems and their relevance for smallholder value chains.

2.1 Definitions

Writers distinguish between complex *adaptive* systems, where adaptation plays a large role and non-adaptive complex systems, such as a hurricane (Mitchell, 2009). In this paper, we focus on complex *adaptive* systems because we seek not just better understanding but better management of complexity in VCD. Thinking about complex adaptive systems has emerged from a range of disciplines, with each discipline contributing key ideas. This helps explain why there is no universally agreed definition of a complex system or a 'unified theory' of complex systems (Gleick, 1987). 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: 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: 179). Instead of representative agents, complex adaptive systems have heterogeneous, interacting agents whose tastes and preferences are not fixed but are influenced by those of other agents (Kirman, 1992). 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).

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 behavioural 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). Viewing the economy as a complex adaptive system has thus had wide-reaching effects on economics at both the macro- and the micro-levels. In the same fashion, viewing value chains as complex adaptive systems can enrich our understanding of success and failure in value chains involving smallholders.

2.2 Common properties

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

2.2.1 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 (1973) quoted Arthur (2015: 23).

In most value chain analyses in the rural development arena, as in neo-classical economics, time is not considered because the markets exist in equilibrium, or move imperceptibly from one equilibrium to another, and are therefore stationary. 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 equilibria (Ormerod, 2005). How long does it take for the economy 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 dis-equilibrium or change. Because change is measured over time, time becomes a factor in 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.[1] In economics, this may result in 'technological lock-in' where one technology becomes the industry standard despite the existence of superior alternatives (for example, the QWERTY keyboard) (Durlauf, 2005). This implies that we need to take a historical perspective on value chain performance, analyzing the sequence of events that created shocks and led to adaptation by one or more chain actors (eg. Rousseau et al., 2015).

2.2.2 Uncertainty

Uncertainty refers to situations where the probability of a given outcome is itself unknown (Ormerod, 2005).[2] For an individual firm uncertainty is recognized to have a strong impact on business performance (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: 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 risk, for example,

[1] 'Environments in which a shock or a set of shocks has permanent effects on a system' Durlauf (2005): F225.

[2] By contrast, 'risk' is a situation where the probabilities of an outcome can be measured (Knight, 1921). In economics, this is sometimes called 'Knightian' risk to distinguish it from ordinary usage.

actions to reduce production losses from known diseases and actions 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, and changes in the comparative advantage of one country versus another. The future is not just unforeseen but unforeseeable. As Keynes expressed it: 'the prospect of a European war… the price of copper… the rate of interest twenty years hence… About these matters there is no scientific basis on which to form any calculable probability. We simply do not know' (J. M. Keynes, quoted in Arthur, 2015: 5).

2.2.3 Sensitivity to initial conditions

Complex systems are very sensitive to small changes in initial conditions. The classic example is meteorology, where the climatologist Edward Lorenz discovered that tiny changes in the parameter values of weather models led to wildly divergent weather forecasts (Gleick, 1987). As a result, weather forecasts beyond six-seven days ahead are worthless. Lorenz described this 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 3.54 and 3.55 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. This has been dubbed 'The Dogma of Large-Large' (McCloskey, 1991). 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.

The Butterfly Effect implies that the performance of a value chain is sensitive to initial conditions. For example, when in 2013 Kenya imposed an excise duty of 50 % on sorghum beer, this effectively killed the industry (Orr et al., 2013). Similarly, the decision by the EC to impose a maximum level of aflatoxin contamination of 2 parts per billion made it more difficult for groundnut growers in Africa to penetrate European markets and threatened to reduce trade flows by 63% (Otsuki et al., 2001). The Brazil nut trade from the Amazon worth more than $100 m per year was also threatened. Thus, the impact of a given change (eg. in policy, or a tax rate) can vary substantially depending upon the exact circumstances in which the change is made. While some small changes may have small effects, others may have very big effects. According to Ormerod (1998: 96) 'this is the whole logic of the complex systems approach'.

2.2.4 Endogenous Shocks

In neoclassical economics, where the economy is in equilibrium, shocks are by definition external to the system. Shocks like the business cycle are incorporated by allowing that from time to time its equilibria must adjust to such outside changes (Ormerod, 2005). By contrast, in complex systems shocks are not just external. They can arise internally, created by the system itself. Two sources of internal shocks are 'uncertainty' about the future, discussed above, and innovation. In neoclassical growth theory, innovation is exogenous to the economy, and 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, resulting in further investment and so on in an endless cycle (Beinhocker, 2007). Moreover, innovation does not produce a one-time disruption to equilibrium but an ongoing sequence of demand for further technologies in a self-reinforcing cycle (Arthur, 2015). Innovation is therefore intrinsic to the internal working of the economy rather than something imposed from outside.

A complex systems perspective implies that we should not see shocks as something external to the value chain, but also as generated from within the value chain, by uncertainty, by technological change, and also by 'interacting agents' whose individual behaviour can have unpredictable results for the system as a whole. For example, the government of Kenya's decision to hike the excise duty for sorghum beer by 50 % was provoked by the need for extra revenue to pay for its programme of decentralization and what was seen as excessive profit-taking by Kenya Breweries (Orr et al., 2013). Similarly, the international coffee agreement to regulate production and world prices broke down 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.

2.2.5 Sudden change

Neoclassical economics is wedded to the idea that change is gradual, since the system can be regarded as being in equilibrium. This is based on the Darwinian theory of evolution where small variations operating through natural selection lead to gradual change over time.[3] 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 behaviour (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 and the weaker the social sanctions against crime. This reduces the incentive to stop being a criminal, which in turn leads to more crime. This is a positive feedback loop, where the system shows explosive behaviour. If a system contains only negative feedback loops (in economics, diminishing returns) 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 behaviour' (Arthur, 2015: 17).

Value chains involving smallholders are easy prey for sudden, large 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 rip the foundations from a value chain literally overnight. For example, more than half the smallholders growing green beans in Kenya were dropped *immediately* following the imposition of international food safety standards (Narrod et al. 2008).

[3] Alfred Marshall's *Principles of Economics* (1890), the fount of neoclassical economics, quoted Charles Darwin's phrase '*Natura non facit saltum*' ('Nature does not make leaps') on its title page.

2.2.6 Interacting agents

The property of complex systems with the biggest impact on economics is that of 'interacting agents', defined as the 'interdependence in behaviour across individuals' (Durlauf, 2005: F238). In neoclassical economics individual tastes and preferences are fixed. In complex adaptive systems, however, individual behavior depends on the behaviour of other agents. The famous example is the ants model, in which the foraging behaviour of individual ants is determined by the behaviour of other ants (Ormerod, 1998). Similarly, for some consumer goods (movies, smart-phones) individual consumers have to *find out* what their preferences are, which is why the opinions of others influence their behaviour 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 assumption 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 at the individual level – avoiding being a minority group – can result in complete racial segregation in a neighbourhood 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 behaviour of the system because the whole is more than the sum of the parts (Ormerod, 1998). Thus, the property of interacting agents is a source of uncertainty which is generated from *within* the system.

Similarly, interacting agents helps explain many aspects of value chain performance. Value chains have several stages where actors have different functions, but also different, and often conflicting, goals and preferences. The 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. Again, the interactions between actors with the same function affect value chain performance. 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 1 shows how interacting agents might affect the performance of value chains involving smallholders. Below we highlight some examples of vertical and horizontal interaction between agents:

Table 1: Interacting agents in value chains involving smallholders

Actors	**Participation in value chain**	**Funding sources**	**Objectives in value chain participation**	**Conflicting interactions between agents**
Smallholders	On farm production, with surplus for chain; artisanal or collective processing	Sales of raw materials or semi-finished products	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 (incl. 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
Processors and buyers	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
Governments	Regulatory body	Tax revenue, votes from smallholders	Re-election, political legitimacy	Conflicts between different Ministries (eg. Finance, Agriculture)
Non-Governmental Organisations	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
Consumers	Demand for products	n.a.	Utility, value for money	Changing tastes and preferences

<u>Horizontal interactions</u>

- Smallholders join cooperatives or associations to benefit from cheaper farming inputs, collective marketing, credit, and other services, but cooperation may break down 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 internal trust relationships, 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.
- Consumers influence other consumers to buy products that meet specific ethical or quality standards (eg. Fair Trade).

Vertical interactions

- Buyers use Trade Associations to lobby governments to introduce legislation or non-tariff 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.
- Consumers increase demand for new and exotic products (eg. quinoa) that result in new markets for smallholders.
- 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. ICA – International Co-operative Alliance).

2.2.7 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: 13). Adaptation, therefore, is the survival mechanism to cope with the uncertainty of complex systems. Some economists take a biological view, and argue that firms can plan and strategise 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: 226). Although firms plan and strategise, the same pattern of 'extinctions' that holds true for biological species also holds true for SMEs and big companies, which suggests there are limits to how far firms can plan and adapt to changing market conditions (Ormerod, 2005). Successful adaptation can also 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: 441).

Adaptation, therefore, is the distinguishing feature of the wider economic system in which value chains involving smallholders are embedded. Their performance in a 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, regulatory frameworks may all differ across these chains. However, certain characteristics usually go together. Perishable, high-value commodities 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 un-enforced, where purchasing power is limited and quality incentives are scarce, and where consumers have little choice in the type of product they buy.

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

Value Chain Characteristics	**Adaptive capacity**			
	Low	→		**High**
Business Model	Smallholders selling in spot markets	Organised smallholders selling in spot markets	Contract Farming	Integrated agri-business
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

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. By contrast, value chains with large agribusiness companies as 'lead firms' 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 value chains involving smallholders, therefore, is through the business model. These models come in different shapes and sizes, ranging from individual smallholders selling on spot markets (the most common form), to organized smallholders selling in spot markets, to contract farming, to integrated agribusiness (Haggblade et al., 2012). However, the last three business models share a common rationale, which is to optimize performance in the value chain by reducing the chance of something going wrong. They provide value chain actors with a buffer that helps reduce Knightian risks (which are known), cope with uncertainty (which is unknown), and reduce the potential for endogenous, catastrophic shocks generated by conflicts within the system. In other words, they are institutional mechanisms for managing complexity.

Where value chains involving smallholders adapt successfully, 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: 371). However, successful adaptation to meet these standards in Kenya has required the right institutional support, with farmer organisations 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 successful 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).

By contrast, where value chains involving smallholders lack the appropriate business model adaptation is generally 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 by the project management, which resulted in an intermediary-driven business model rather than a buyer-driven model as originally intended (Orr et al., 2013). Similarly, small-scale forest users providing palm heart to local processing plants in the Bolivian Amazon were ill-adapted when conditions in Brazil, the principal market, changed abruptly because they lacked a business model allowing them to 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 break down; 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.

Smallholder VCD usually focuses on value chains with low adaptive capacity. How can we increase adaptive capacity in these chains? What are the possibilities and what are limits of management and control in adapting to complexity in value chains involving smallholders? What tools and mechanisms to facilitate adaptation already exist? What new tools or mechanisms need to be developed?

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 VCD guides pay limited attention to these dynamics, which are consigned to a black box called 'the enabling environment'. An exception is the IIED guide (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'.

The IIED 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, these dynamics are seen as external to the value chain. We expand this framework to include not just 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 simply describe and generate 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. For example, the concept of 'governance' has been the key analytical tool for the analysis of global value chains. This framework seeks to go beyond heuristic devices, and 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 – provide entry points to drill down into the internal dynamics of the value chain and reveal its inner workings and the behavior of the value chain actors that can explain its performance.

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 properties – uncertainty, sudden change, shocks, adaptation, and time – that directly affect the performance of the value chain;
3. Two properties – sensitivity to initial conditions and interacting agents – that affect the performance of the value chain indirectly, by helping to create uncertainty;
4. Feedback loops that operate between the five common properties and the performance of the value chain. Feedback loops operate in both directions for

adaptation, since adaptation is a continuous process, and for shocks, which may be either external or internal;

One omission 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 % will reduce demand for a given commodity by Y%, then we know the risk associated with this tax increase. But what is the risk of the tax being imposed? This might depend 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’. However, simply because outcomes are uncertain, this does not mean that they cannot be anticipated and steps taken to mitigate their impact. While uncertainty may be beyond the control of individual value chain actors, there are tools to help manage uncertainty and reduce its negative impacts on performance.

4. Applying the Framework

This section outlines three ways in which the conceptual framework can be applied to value chains involving smallholders. The framework can be used to:

1. Ask new research questions;
2. Analyse case studies; and
3. Develop tools to manage complexity.

4.1 Research questions

Table 2 provides a set of research questions to explore complexity in value chains and value chain interventions, with questions for each of the properties of complex systems. These questions are not exhaustive, but they suggest the type of information that is needed when we apply the conceptual framework to a specific value chain. The questions concern the value chain and the set of interventions carried out to develop the chain, including support to smallholders. 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.

Figure 2: Value Chain Dynamics: An expanded Conceptual Framework

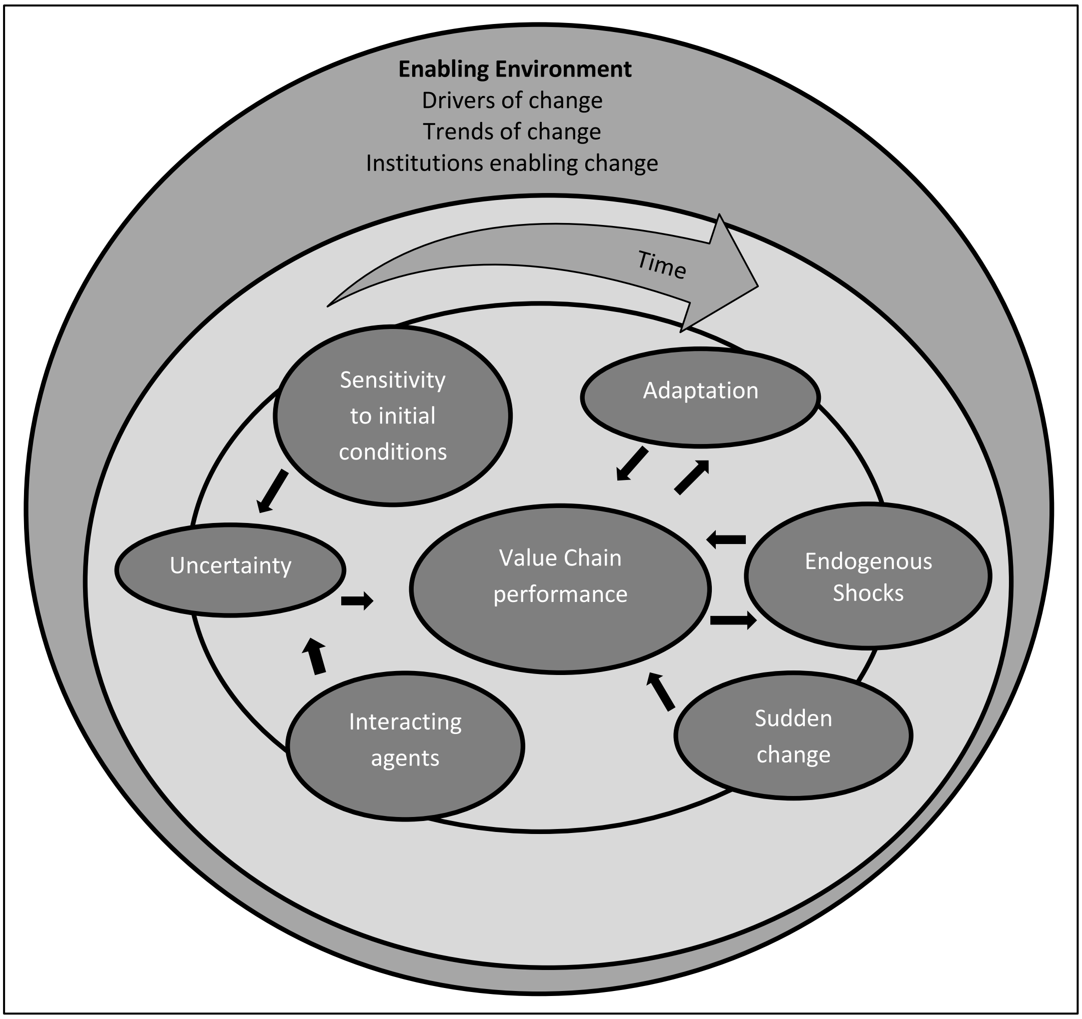

Table 2: Research questions based on common properties of complex adaptive systems

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 over time due to changes in the context, 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, political-legal and business environment?
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 eg. 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? Internal/external? Predictability, source? How will/were different actors in the chain be affected? What will be / were the immediate/long term effects? How will/did they affect the performance/viability of the chain?
Sudden change	How quickly do/did market conditions change? How quickly can/did actors respond to sudden changes?
Adaptation	What mechanisms are in place to adapt to shocks? How quickly can/did actors respond to shocks and sudden changes? How do/did value chain actors adapt to shocks? How effective are/were these strategies? What new strategies can be / were implemented to prevent recurrence?

4.2 Case studies

Many guides to VCD involving smallholders lack fully-developed case studies showing how tools can be applied (Donovan et al., 2015). We have selected four case studies for comparative analysis: sorghum beer in Kenya, camu-camu in Peru, palm heart in Bolivia, and high quality cassava flour in Nigeria. Below we discuss how the conceptual framework will be used to analyse these case studies.

4.2.1 Qualitative methods

One approach is through qualitative analysis, or analyzing each case study thematically according to properties of complex systems that seem most relevant for each particular case. Box 1 gives a schematic example of the qualitative approach, applied to *khat* in Kenya. Here we simply frame the available information according to the conceptual framework. This might identify knowledge gaps that can be filled by additional research. We can also include quantitative data (eg. time series) to describe system performance, for example the impact of shocks, or the success of adaptation.

4.2.2 Quantitative methods

One criticism of current analytical approaches to value chains involving smallholders is that "they remain qualitative and often case-specific" (Rich et al., 2011: 221). A second approach is through quantitative analysis. For example, ILRI has used stochastic dynamic models, simulation, and game theory to understand livestock value chains in Africa (Hamza et al., 2014; Naziri et al., 2012; Rich et al., 2011; Rich and Hamza, 2013; Rich et al., nd). This approach is still relatively new. Consequently, the data needed for modeling may not be available and new data would have to be collected. The advantage of a quantitative approach is that it uses the tools as well as the concepts that are relevant for understanding complex systems. In particular, a quantitative approach allows the *ex ante* simulation of different outcomes, which is useful for managing complexity through adaptation.

4.3 Tools

Existing tools for developing value chains involving smallholders pay limited attention to the context in which these value chains operate, particularly to uncertainty and systemic risk. Our aim is to develop a practical tool that will help value chains involving smallholders manage complexity and increase successful adaptation.

This tool would include the following features:

1. A modular design, that can be applied across the entire range of value chains involving smallholders;
2. A typology of the most common and most disruptive risk scenarios linked to a portfolio of options for better anticipating and mitigating such risks
3. A diversity of instruments, ranging from check lists to 'what-if' scenarios, 'thought-experiments' and informal methods of risk-assessment.
4. A user-friendly approach that can be used by value-chain actors in stakeholder workshops without requiring additional resources.

This tool would build on relevant material from the existing literature as well as developing innovative ways of managing complexity. Based on evidence of real-life situations, the tool will provide guidance for identifying critical risk factors in a given chain, based on past performance and analogies with similar chains in other territories or different chains in the same territory. Similarly, risk mitigation strategies will be systematized and made available in form of a matrix including diverse adaptation options for different types of value chains and different stages of value chain development.

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 US, Canada, China, and most European countries. An influential Somali lobby group campaigns against trade in *khat.* 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 US. 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. Kenyan growers responded by doubling their prices from $300 to $600 per bag. 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 Labour 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 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 analysed 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.

5. Conclusions

Conventional value chain analyses focusing on the price incentives for value chain actors fail to capture the variable performance of value chains involving smallholders in developing countries. Many of these value chains are volatile, with sudden changes of fortune and conflicts 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 therein. This discussion 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 variable performance in these chains. We identified seven common properties that we combined to build a conceptual framework. We emphasise 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 (1) structure the analysis of a specific value chain (2) compare performance across different value chains (3) evaluate the effectiveness of adaptation, and (4) identify general lessons for successful adaptation in value chains involving smallholders.

For researchers, the framework provides an analytical tool for the analysis of value chain performance. The usefulness of the framework has to be judged by its relevance for individual cases. This requires a deeper, contextualized analysis of value chains involving smallholders. We will apply the framework to four case studies of value chains involving smallholders across different crops and continents. Because no two value chains are alike, the framework will be used selectively, highlighting the common properties of complex adaptive systems that are most relevant for each 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.

For practitioners, interest in complex adaptive systems is likely to focus on adaptation. In particular, how can value chains involving smallholders with low adaptive capacity be strengthened? Since existing value chain guides are silent on these questions, we will develop new diagnostic tools that will help practitioners to identify complexity and better anticipate risk in the value chain and potential solutions for risk mitigation. We have identified some promising possibilities. However, an inventory of existing tools and the identification of knowledge gaps require a more systematic approach that will form a separate activity and deliver a different type of product. These tools will complement existing guides for VCD and will be designed for use by development agencies, NGOs, and government programmes.

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