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A quantitative approach to innovation in agricultural value chains: evidence from Kenyan horticulture

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Abstract

In less developed countries such as Kenya trade is increasingly occurring through, and employment is found within, global and local value chains. Yet, although innovation is widely recognised as crucial for development, the endogenous relationship between small-scale innovations and participation in global value chains (GVCs) has yet to be explored sufficiently. This endogeneity is highlighted using the 3L's of labels, linkages and learnings as key overlapping factors that affect both the processes of innovation as well as GVC participation. Drawing on a survey of 320 fresh fruit farmers and 55 interviews in Kenya, we develop a novel method to quantify small-scale agricultural innovations, which are categorised into two overarching types. The first formal, emanate from meeting standard requirements; the second, informal, evolve from local contexts and are less codified. We find that GVC farmers perform more formal innovations, while local farmers perform similar levels of informal innovation to GVC farmers.

1. Introduction

Global value chains (GVCs), the inter-firm linkages involved in production from raw material supply through to final retail, are increasingly recognised as the architecture of the global economy (Gereffi et al., 2005). Such GVCs are coordinated by global lead firms, often from the global North, who govern such trade relationships. Standards are recognised as crucial in global value chains. Yet those suppliers who are unable to cope with these standards tend to get marginalized (Nadvi, 2008). A significant body of research has explored the development possibilities for Southern farms and firms from integrating into GVCs.

More recently, domestic and regional markets and value chains have expanded in the global South, often coordinated by Southern lead firms and new public and private standards. Thus, research has begun to explore the governance and development outcomes that arise from such chains (Horner and Nadvi, 2017). Although such outlets provide farmers with options to diversify, such end markets, also demand acquisition of new skills to comply with southern standards. Thus, an increased possibility of marginalization from supplying Southern lead firms also arises (Pickles et al., 2016).

Parallel to trends around integration into the global economy, the importance of innovation has been increasingly recognised. In largely separate discussions to that on value chains, research has explored the opportunities and challenges for innovation in the global South. A strict definition of innovation based on "new to the world innovations" is unsuited to developing countries (Lall, 1987; Viotti, 2002). Yet, with

lower cost technologies, techniques and the growing presence of ICT, there is potential for wider-understood innovation at all stages of production, across a diverse set of actors (Kaplinsky et al., 2009).

Yet until recently, although both are recognised as important, the relationship between participating in GVCs and innovation has rarely been explored (Lundvall et al. 2014). Recent research which has begun to explore this relationship (e.g. Lundvall et al., 2014, Parrilli et al., 2013, Pietrobelli and Rabellotti, 2011) has suggested that it is non-linear and endogenous. As we will explore, changing market dynamics are mandating innovation. While "national innovation systems", involving the key actors, institutions and linkages related to innovation within a national context are often focused on, it is important to consider global networks as a key source of knowledge and technology for innovation. From a value chain perspective, the consideration of innovation can help provide deeper insights into the variety of activities associated with participating in global trade.

This paper focuses on small-scale innovations, which are characterised by adaptation, novel incremental change or technology appropriation. Small-scale innovations are comparable in scale to frugal innovations (Prabhu and Jain, 2015). Although frugal innovations rely on aligning priorities of lead firms with grassroot actors to create win/win solutions (Knorringa et al., 2016), with asymmetric power relations within value chains, and diverging priorities of lead firms (Krauss and Krishnan 2016), collaborative relationships are often not possible. This is exacerbated by the fact that

some arguments in favour of frugal innovations have tended to position small-scale innovation as relatively spontaneous and self-guided by entrepreneurs. Thus, in this study we look at innovation as small-scale, which allows for fleshing out the underlying processes of absorption, and adaptation and diffusion (Berdegué et al., 2008). We have little knowledge of when and under what conditions small-scale innovation more readily occurs, potentially limiting our ability to transfer studies of innovation and development into coherent evidence-driven policy advice. In this paper, using a relational framework thereby helps nuance frugal innovation, making it more inclusive and broadening the remit of how we understand frugal innovation.

The aim is to *develop a quantitative framework to explore the links between value chains and small-scale innovation in an agricultural context*. Even with a revived emphasis on industrialisation, the agricultural sector is crucial in many countries, especially in the global South, and also acts as a key food supplier to the global North (Neilson and Pritchard 2009). Equally, given that agriculture tends to include a higher proportion of low-income and precarious workers, the sector is crucial for more inclusive development. This work uses a mixed-method approach by drawing on an empirical survey of 320 fresh fruit (avocado and mango) farmers and 55 interviews in Meru and Murang'a counties in Kenya to quantify aspects of small-scale agricultural innovation. We take farmers as an entry point into the global value chain, and unpack the key characteristics of the innovations that they perform and the varied factors that promote innovation. However, with the growing importance of domestic markets, we

econometrically analyse farmer innovations in local value chains, and how they compared with those in global value chains, demonstrating heterogeneity across different chains. To our knowledge, this is one of the first studies that attempts to measure small-scale innovation and explicate the endogenous relationship it has with global and local value chains.

The remainder of the paper is set out as follows. Firstly, we introduce the literature on changing perspectives on small-scale innovation, highlighting how participating in a particular value chain alters the processes of how small-scale innovation is achieved and identifying what we call the 3L's - learning, labels and linkages - that help drive small-scale innovation. In section 3, we outline the novel research approach we developed and used to quantify innovation. We outline details of the sampling and analysis in section 4. In section 5 we highlight core findings, and the econometric results in section 6, followed by linking the results to broader debates and policy implications in Section 7.

2. Small-scale innovations, value chains and the 3L framework

Value chains and small-scale innovations can be seen as co-evolving. Indeed, Pietrobelli and Rabelotti (2011 p.1261) argued that "the relationship between GVC and IS *[innovation systems]* is nonlinear and endogenous, and mutually affecting". While the seminal research of Morrison et al. (2008) and Pietrobelli and Rabellotti (2011) has focused on manufacturing industries, studying innovation of lead firms and large

suppliers in GVCs, our research attempts to unravel this co-evolutionary and endogenous process in the agricultural sector, focusing on farmers. This is one of the first studies to our knowledge that systematically unpacks this relationship across farmers in global and local value chains.

When studying the agricultural sector, some important contextual factors need to be noted. Studies of innovation, especially related to agriculture, have moved away from conceptualising innovation as one-time disruptive change to focusing more on indigenous knowledge and incremental changes. Indeed, a growing literature emphasises the importance of small-scale innovation in key practices and products in agriculture in developing countries (e.g. Spielman, 2005, Knickel et al., 2009). This means that small-scale innovation is centred on developing incremental innovations that enable meeting prescribed standards. Small-scale innovations have been explored within a number of sub-fields such as inclusive-, frugal-, jugaad-, grassroots- and responsible-innovation. For example, instead of investing in an expensive greenhouse, farmers build make-shift greenhouses with nets and sticks in rural Kenya.

Much literature on innovation has centred on technology absorption as a key aspect of development (Lall and Pietrobelli, 2002, Bell, 2006). As new technologies and techniques emerge, actors in the global South need to build know-how to allow for effective diffusion of that innovation into local practices. This active 'process of adaptation' and change is key to the successful circulation of innovations. That is to say, farmers inherently innovate when they are mandated to use new technologies, or

follow complex processes in order to continue their livelihoods. This is akin to the conclusions of Pietrobelli and Rabellotti (2011:1267) who found that LDC firms innovate based on their participation in GVCs as they have to prescribe to complex standards and requirements, and that developing efficient IS systems reduces the complexity of the requirement. This is the starting point which we use when developing the first genre of small-scale innovation linked to farmers in value chains- which we call 'formal innovations' which are linked to how value chains are governed i.e. be it through standards or labels, or codes of conduct, which involve a range of complex transactions, and which are codified to different degrees by lead firms and other actors within the value chain. Innovation here is more actively undertaken as farmers look to adhere to requirements and norms in order to access specific global markets (Korzun et al. 2014). For example, farmers may use and adapt rainwater harvesting techniques as part of achieving environmental standards. They may also incorporate new seed varieties into their farming cycles to ensure their produce can be sold into global markets.

Furthermore, it is increasingly untenable to describe innovative activities as solely coming from prescriptive requirements within GVCs. Innovative activities are also likely to include not only explicit innovations passed through the GVC but also incremental, indigenous, inclusive, frugal and small-scale innovations based upon tacit learning, and adaptation to local conditions and needs, that are not necessarily linked into standards within value chains (STEPS Centre, 2010, Foster and Heeks

2013). Small-scale innovation has often been seen as a relatively spontaneous or informal 'second order innovation' as part of seeking "alternatives in the event of disruption" (Knickel et al. 2009: 134). For farmers, for example, small improvements in waste water storage to promote biodiversity on their farms or novel modes of crop management are arguably as important to their livelihoods as disruptive mechanisation technologies (Raina, 2009). Other examples have been documented where equipment is adapted or modified to fit with local needs such as in the case of adapting small-scale milling devices to fit with local crop varieties (Manyati, 2014, Abrol & Gupta, 2014). Thus, these types of innovations have higher degrees of local interpretation and tacit knowledge and are classified as 'informal innovations'.

This broader perspective of drivers and facilitators of small scale innovations also provides an important basis for extending frugal innovation literature. Frugal innovations are characterized as low cost, good enough innovations which better consider the needs of the poor (Knorringa et al. 2016, Radjou & Prabhu 2014, Zeschky et al. 2011). Typically large firms are seen as key enablers of innovation but a model of polycentric innovation also includes actors who develop locally appropriate innovations (Beers et al. 2014).

In this perspective, however, emphasis on grassroots innovations tends to focus on the 'informal innovation' activities of adapting innovations to particular contexts, yet without substantial consideration of more 'formal innovation' and contested activities related to the relations between polycentric innovators (Foster & Heeks 2014). Aligned

with this critique, definitions of frugal innovation often forefront product innovation (Knorringa et al. 2016, Pesa 2015) over process, organisational and business model innovation. This product focus may underplay some of the potentially more contested and power laden aspects of innovation that relate to the relationships between these innovators. If, as Knorringa (2016) argues, it is still unclear whether frugal innovations lead to capitalist exploitation or 'inclusive innovation', then this paper can begin to unpack the links between production relationships and inclusive innovation through this study of agriculture. This paper attempts to develop a novel process to measure small-scale, formal and informal innovation as explicated in detail in section 3 and empirically explored in section 5.

In order to explore the endogenous links between innovations and value chains, we build on recent work in this vein (Morrisson et al., 2008, Pietrobelli and Rabellotti, 2011) to isolate three critical aspects relating to small-scale innovations, which we refer to as 3 "L's"- labels, linkages and learning. Each of the 3L's are closely linked to both innovations as well as value chains and thus are key underlying factors that are instrumental in elucidating the processes through which farmers in GVCs and LVCs innovate and how these are co-evolutionary in nature.

The first are 'labels', which could be standards or certifications which are 'expert systems' that are employed by lead firms or governments to ensure a certain quality (product and/or process) has been reached (Nadvi 2008, Ponte and Ewert 2009, Evers et al., 2014). Various research has shown that standards act as entry barriers for

farmers in GVCs and can cause marginalization (e.g. Tallontire et al., 2011), especially because they comprise of a series of complex control points such as traceability, post and pre-harvest measures. For instance, a study by Okello et al. (2011) showed that six control points linked to shifting to safer pesticide, pesticide storage, traceability, pesticide disposal pits, charcoal coolers and grading sheds, were prime causes for Kenyan farmers' exclusion from high value vegetable chains exporting to Europe. Furthermore, the growing importance of standards within regional and local markets also suggests marginalisation processes may emerge similar to those that have emerged from selling into the global North (Pickles et al., 2016, Krishnan, 2017).

In terms of linkages, value chains and innovation system institutions are also quite different in agriculture (compared to manufacturing) as they move away from traditional state actors and institutions such as R&D and universities towards a wider set of local intermediaries, community groups and extension officers (Raina, 2009, STEPS Centre, 2010). Thus, when studying innovation from a farmer perspective in value chains, linkages are defined as the relationships (or ties) between dyads in a network of actors, be they individual (at varying scales) or organizational (Gereffi 1999, Henderson et al., 2002). In this paper, we move away from the governance typology of markets, captive, relational, modular and hierarchy as discussed by Gereffi et al. (2005) and focus on backward (input suppliers) and forward (with buyers) linkages, because we are unpacking mico-linkages across horticulture only. These relationships can be strong, i.e. high quality and dense, or weak and sparse

(Granovetter, 1973, Gulati, 1995). Furthermore, such relationships can also involve trust, which is related to the longevity and the strength of the tie (Uzzi, 1996). By using Ponte and Sturgeon's (2014) scale of micro-linkages i.e. dyadic relationships, we make the farmer the reference point of the analysis, and map all the dyadic relations accordingly.

Learning forms an integral part of innovation and its diffusion. Innovation system literature has looked at learning, in terms of both the introduction of physical technologies as well as the social technologies to produce, at the scale of the 'nation' (Nelson, 2004) as well as the region. From this interpretation, it is argued that all places have their own "national trajectories of innovativeness, technology orientation and learning" and thus "each nation, less or highly developed, has some kind of National Innovation System[1], no matter if working well or not" (Fromhold-Eisebeth 2007:219). Thus, when overlaying this with value chains and looking at it from the reference point of the farmer, we can nuance and extend learning- to the level of the farmer.

Within value chain literature a key source of learning comes through direct transfer or knowledge spillovers linked to the networks which firms and other relevant actors are linked into (Parrilli et al. 2013, Pietrobelli and Rabellotti 2011). This suggests that how GVCs operate in terms of knowledge, technology and learning is a key consideration in innovation. A particularly good example of this literature is the insightful framework developed by Pietrobelli and Rabellotti (ibid). Drawing on the

classic typology of GVC governance, they discuss and illustrate how different modes of learning in the value chain (via. standards, imitation, knowledge spillovers, face-to-face) vary across value chain governance (ibid).

We define '*learning*' as a process of acquisition, accumulation and appropriation of tacit and explicit knowledge (Ernst and Kim 2002, Gertler 2003). Tacit knowledge, drawing from the work of Michael Polanyi, relates to experiential knowledge and lies in 'imperfectly accessible conscious thought' (Nelson and Winter, 1982:79) namely intuition and perceptive abilities (Polanyi, 1966). It is distinct from *explicit knowledge* which can be coded, meaning knowledge can be structured into identifiable rules and relationships that can be communicated and articulated easily (Kogut and Zander, 1993) and this knowledge is alienable from the code writer. Popper (1972) indicated that codified knowledge can be abstracted and stored in the objective world, and shared and understood through faceless communication.

However, codification can never be complete as some knowledge remains sticky in a local context, thus limiting the efficiency of transferring knowledge (Gertler, 2003). This raises issues about the codification process, and therefore if codes do not leave room for interpretation (and in extension slight ambiguity), they create an inertia in knowledge production (Ancori et al., 2000; Kogut and Zander, 1992). To prevent inertia in knowledge creation, accumulating tacit and explicit knowledge is critical (ibid). Thus, for formal small-scale innovations to be performed efficiently, they have to be adapted or repurposed in line with the specific contexts of innovators (Cozzens

and Sutz, 2012, Kaplinsky et al., 2009). Thus, we look at learning as a continuum, wherein tacit are those forms of knowledge that are accumulated by the self, be it through personal experience or 'purely' cognitive abilities; while explicit forms of learning is accrued through direct transfer, learning by seeing, imitation and learning-by-doing which position themselves at various points in the continuum. Therefore, in this paper we consider explicit knowledge overlaps to varying degrees with tacit knowledge but still falls within the realm of 'explicit' as it has some level of codification, whilst only 'purely' personal experiences or conscious thought are classified as tacit.

In sum, small-scale innovation can be complex and multi-faceted. It relates to potentially both 'informal' or 'adaptive' processes and more 'formal' technologies diffused in the value chain. Furthermore, it may be driven by linkages and learnings which differ within value chains. The 3L framework of learning, labels (certifications) and linkages (backward and forward) aims to highlight key 'processes' that impact participation in GVCs as well as performing small-scale innovations. Thus, the 3L's are clearly driving factors that impact innovation and its implementation, along with value chains. However, before we delve into the different factors that bring out the co-constituted and endogenous relationship between value chains and innovation, we first need to outline a novel procedure to measure and aggregate innovation – the task of the next section.

3. Measuring small-scale innovation

To date, there have been few attempts at measuring small-scale innovations, with most studies relying on qualitative methods (George et al., 2012) while quantitative measurements have been adopted more for disruptive innovations (Cozzens and Sutz, 2012, Zanello et al., 2015). Some have indirectly attempted to measure innovation in developing countries, by using proxies such as capacity, technological capabilities, human capital or infrastructure (World Bank 2010). However, such studies have primarily explored innovation in Northern contexts, and there is a risk that the variables chosen may be less applicable in Southern countries.

We measure innovation drawing on the innovation system literature, particularly the so-called 'wider' perspective on innovation and learning (Lundvall, 1992). In this perspective, small-scale innovation emerges as a cumulative outcome from multiple activities in a sector. Innovation is measured in four steps and depicted in Figure I:

- Level 1: The first level (the bottom most rung of the figure) identifies specific tasks we call *innovation activities.* These include the different small-scale innovations that are performed by farmers such as building makeshift greenhouses during rainy seasons or calibrating pesticide application tools to reduce wastage of pesticides and thus reduce overall costs. These activities are elicited through in-depth interviews with farmers and other relevant actors in the chain.
- Level 2: The next level up we aggregate inter-related innovation activities into specific *innovation components.* For instance, if farmers are performing

innovation activities related to water conservation for instance, be it making furrows, hand dug wells, roof top rain water harvesting, filling water tanks, which are incremental and related, they are all grouped under a specific innovation component. This helps unpack the key type of motivation or pressure related to each innovation activity. We use a version of principal component analysis to do this, which is explained in the subsequent paragraphs. These innovation components can be performed by both LVC and GVC farmers.

- Level 3: However, there can be multiple categories of innovation components as overall motivations for performing innovations can vary significantly. To explicate motivations that are linked to performing innovations linked to participation in value chains, we further aggregate the innovation components to form a the third level of innovation types. Thus, innovation components are categorized into formal and informal innovations. We achieve this by once again using a principal component analysis on innovation components to collapse the data into these two innovation types.

  The two main *innovation types* are: 1). Innovation from external pressures or those that are relatively exogenous to the farmer, which we refer to as *'formal';* 2). Local or more indigenous and adaptive forms of innovation that are *'informal'*. This division reflects our previous discussion on the structural differences of innovation in agriculture. It is important to note that these are by

no means representative of all the types of possible innovations, but are designed to explore different ends of the innovation spectrum.

- Level 4: Finally, it is possible to aggregate the innovation types up further to form an overarching measure of innovation, seen as a cumulative outcome from multiple *innovation types.* This can provide a measurement for innovation within a sector, for instance in our case fresh fruits. In a sense, this overarching measure can be used as a tool to compare across sectors to understand the complexity of innovations.

While determining sector wide innovativeness is useful, this paper stops at level three, the innovation types, as it endeavours to nuance the structural differences of innovation in agriculture for farmers in GVCs and LVCs. It should be noted that each *innovation activity* is not necessarily equal in terms of the level and difficulty of innovation. Small scale adaptations are likely easier to learn and use, whilst large scale disruptive activities require greater resources and learning. Nevertheless, overall innovation is seen as the cumulative effect of small scale innovations over time that can cause more disruptive effects (Gault, 2010). In this study, we unpack innovations in accordance with the innovation types. This measure of innovation is fluid and the levels can be increased or decreased depending on the granularity of analysis required and the quality of data available.

To measure formal and informal innovation as the cumulation of innovation components and activities, we use polychoric principal component analysis

(Kolenikov and Angeles 2004). Polychoric principal component analysis (PCA), is a common process of aggregation as it primarily reduces the number of dimensions (in our case innovation activities and components) and creates principal components that extract the most information from all the variables. Generally, the first principal component is used as a proxy for the common information contained in the variables corresponding to each innovation type. The results were then rescaled between the value 0 and 1, where 0 is the lowest level of formal/ informal innovation and 1 the highest.

In order to operationalise the innovation measures, we compare innovation activities amongst farmers participating in global value chains (GVC) versus those in local value chains (LVC). By doing this we are able to gauge the heterogeneous differences for farmers across these different chains. It also provides us with a basis for broad understanding of the three "L's" that were outlined in section 2.

4. Research strategy

It is important to note that there are clear systematic differences between farmers supplying into GVCs versus LVCs. Therefore, how GVC farmers innovate is also likely to differ from LVC farmers, especially if participation in GVCs is determined by very similar factors. We cannot assume uniform impacts across farmers, as it conceals interaction between value chain choice and other factors influencing innovations, leading to inaccurate conclusions. Since farmers self-select into value chains, it is likely that the coefficient that explains impact of GVC participation on formal/informal

innovations may be biased. More so when some GVC farmers may be more efficient and perform more formal innovations anyway, and thus the innovation effect may be overestimated. To correct for this, it is possible to use a Heckman selection model but this model which still assumes that the innovation function would differ only by a constant term between GVC farmers and non-GVC farmers. However, in reality the interaction may be more systematic, as some of the variables may affect both participation and innovation. Maertens and Swinnen (2009) have used propensity score matching, which helps unpack some systematic differences but only based on observables. In our model, we claim that unobservable factors simultaneously influence farmers' participation in GVCs and innovation, such as intrinsic ability, motivation to be stewards, care for their farmlands, individual skills. The switching regression (Maddala, 1983) helps account for this. Using an endogenous switching regression model treats each value chain as a regime and allows for structural differences between farmers innovating in global versus local value chains. Similar methods have been used by Rao and Qaim (2011) when studying structural differences in incomes and participation across farmers selling into regional supermarkets and traditional chains.

We fit a model where participation in a value chain is a binary choice decision made by farmers, who try to maximize profits (or utility). Utility is determined by a set of variables Z, which influence farmer capability, learning and costs (e.g. standards) linked to adjusting to new value chains i.e. the '3L' variables along with control variables. However, these variables, Z, may also impact the innovation processes of

farmers as well. Thus, decisions for farmers to participate in a GVC or LVC market occur through comparison of expected utility for GVC participation I_g^* against expected utility of LVC I_l^*. So only when $I_g^* > I_l^*$ will the benefits of participating in a GVC outweigh the constraints. I_g^* and I_l^* are latent variables, only actual participation in a GVC is observed 'I'; with $I = 1$ if $I_g^* > I_l^*$ and $I = 0$ if $I_g^* \leq I_l^*$. Thus, participating in a GVC is represented as:

$$I = Z\alpha - v \tag{1}$$

here, α is a vector of parameters, v is error term with 0 mean and variance σ^2. As farmers have heterogeneous characteristics, some farmers self-select into GVCs while others enter into LVCs.

Since it is possible that performing innovations are also possibly influenced by similar factors, it is possible to hypothesize that GVC participation leads to increased innovation performance and adoption. Thus, a simple model would entail:

$$y = X\beta + \gamma I + u \tag{2}$$

Where y is innovation type index, X is a vector of 3L variables of interest and controls, and I is the participation dummy. The coefficient y captures impact of GVC participation on formal and informal innovation types.

Since we posit that there are systematic differences across GVC farmers and LVC farmers, i.e. in terms of the 3L's and the performance of formal and informal

innovations, this econometric model discussed in Maddala (1986) treats each type of value chain as a regime shifter i.e. moving from participating in a GVC as regime 1 to an LVC as regime 2, which is represented as follows:

$$\begin{aligned} y_g &= X\beta_g + u_g, \\ y_l &= X\beta_l + u_l, \\ I^* &= Z\alpha - v, \end{aligned} \tag{3}$$

Where y_g and y_l represent innovation type index for GVC and LVC farmers. I^* is a latent variable determining which regime applies (forming the selection equation). β_g and β_l are parameters which will be estimated. Even though variables in vector *X* and *Z* overlap, proper identification requires that at least one variable in *Z* not appear in *X*. u_g, u_l and v are residuals that are contemporaneously correlated- i.e. jointly normally distributed with mean 0.

y_g is only observed for the subsample of GVC farmers and y_l for the LVC farmers, only y_i is totally observed which is defined as:

$$y_i = \begin{cases} y_g & if\ I^* > 0 \\ y_l & if\ I^* \le 0 \end{cases} \quad \text{and} \quad I = \begin{cases} I & if\ I^* > 0 \\ 0 & if\ I^* \le 0 \end{cases} \tag{4}$$

The covariance matrix of equation 3 is as follows:

$$\sum = \begin{pmatrix} \sigma_g^2 & \sigma_{gl} & \sigma_{gv} \\ \sigma_{gl} & \sigma_l^2 & \sigma_{lv} \\ \sigma_{gv} & \sigma_{lv} & \sigma^2 \end{pmatrix} \tag{5}$$

Where var(u_g)=σ_g^2 and var(u_l)=σ_l^2, var(v)=σ^2, cov(u_g, u_l)=σ_{gl}, cov(u_g, v)=σ_{gv} and cov(u_l, v)=σ_{lv}. The variance of v is set to 1, since α is estimable up to a scale factor (Rao and Qaim 2010). Also, σ_{gl}=0, since y_g and y_l cannot be observed together.

However, there is a need to account for unobserved factors along with observable systemic differences. If unobserved factors are significant, then the error terms of the regime equation and the selection equation will be correlated, suggesting endogeneity exists. Thus if $\sigma_{gv}=\sigma_{lv}$=0 then there is exogenous switching, but it either σ_{gv} or σ_{lv} are non-zero then there is endogenous switching (Maddala, 1986). The significance of the correlation coefficients between u_g and v is ρ_{gv}, computed as $\sigma_{gv}/\sigma_g\sigma_v$; and between u_l and v is ρ_{lv}, computed as $\sigma_{lv}/\sigma_l\sigma_v$ (Lokshin and Sajaia, 2004), are tested. This will suggest that both GVC participation and innovation types are endogenous and could be affected by each other. By using the correlations, we can calculate the expected values of the truncated error terms as:

$$E(u_g \mid I=1) = E(u_g \mid v > Z\alpha) = -\sigma_{gv}\frac{\varphi(Z\alpha/\sigma)}{\phi(Z\alpha/\sigma)} = -\sigma_{gv}\lambda_g, \quad (6)$$

$$E(u_l \mid I=0) = E(u_l \mid v \le Z\alpha) = \sigma_{gv}\frac{\varphi(Z\alpha/\sigma)}{1-\phi(Z\alpha/\sigma)} = \sigma_{lv}\lambda_l \quad (7)$$

Where φ is probability density and ϕ is cumulative density function of standard normal distribution. These densities form λ_g and λ_l, which are the Inverse Mills Ratios (IMR) evaluated at $Z\alpha$.

If a correlation between equation (6) and (7) exists, a two-stage model can be calculated. The IMR can be calculated from the first stage probit and then included in equation (3).

An alternate to this is a more efficient method that uses a full information maximum likelihood (FIML) procedure, which jointly estimates the selection and regime equations following Lokshin and Sajaia (2004). The co-efficients β_g and β_l in equation (3) measure the marginal effects on covariates on innovations unconditional on farmers in GVCs or LVCs. However, since there are covariates similar in X and Z, the coefficients can be used to estimate conditional effects, so as to measure direct effect of mean on y_g and the other part is indirect effect from VC participation as a result of correlation between unobserved components of y_g and *I*. *We use this FIML procedure in this paper, while using the 2 steps as a check for robustness.*

We complement the results of this quantitative analysis with interviews, both as a form of triangulation and to enrich the results. The data used in this study emerges from survey research of 579 horticultural farmers growing peas, mango and avocado collected February 2015-April 2015, conducted as part of a wider project exploring the activities of small-scale farmers in Kenya. The survey instrument was constructed from knowledge built on interviews (during October 2014-Dec 2014), with farmers selling into global and local markets, county governments, brokers, Kenyan export companies, Horticultural Crops Directorate, Kenyan horticulture business associations and NGOs; and was piloted in Jan2015.

A multi- stage sampling procedure was conducted to compare across global and local farmers. To determine whether farmers participated in global or local chains, the survey recorded all the markets farmers participated in. If they sold more than half their crop produce to a specific buyer they were classified as being in that chain. At the outset, a sampling frame was developed by collating data across multiple sources in the global (e.g. HCD traceability lists, Kenyan Export company lists) and local value chain (e.g. county government officials, area officers, snowball sampling through community members) to create a sampling universe. From the universe the data was stratified by county to identify hotspots of farmer density i.e. the main county (Murang'a, Meru) where most Avocado and Mango farmers were located. From each county- lists, farmers were picked at random (without replacement), while ensuring that each farmer sampled sells into a specific end market. To correct for oversampling we followed Deaton (1997), where sampling weights were calculated as the inverse inclusion probabilities. These inverse inclusion probabilities were calculated at two stages. The first stage involved weighting the sampling areas (counties) by total number of farmers (to ensure that a proportional sample is selected) and the second calculating a conditional probability (given a specific county) that the farmer selected is either on the export or local list. From the 579 farmers surveyed, a subset of 320 farmers growing avocados and mangoes were selected.

5. Results: The Kenyan case

In Kenya, the high value fresh fruit and vegetable (FFV) sector has grown annually at a rate of 10-12% in the last decade to emerge as one of the foremost foreign exchange earners in the agricultural sector (Krishnan, 2017). Demand for FFV is continuously growing, both on the export and regional front, as evidenced by an increase of over 30% in area under horticultural crops between 2000-2013 (HCDA, 2016).

The most prominent export fruits are mangos and avocados, which make up over 80% of all fruit exports from the country, with almost 40% of mangoes and 60% of all avocados exported (authors' calculations based on HCDA, 2016). The production process of both these tree crops are similar and thus comparable. Farmers were sampled from Meru (47% of total sample) and Murang'a county (53% of sample). Murang'a was selected as it is the largest exporter of avocados in the country and the third largest for Mangoes (HCDA, 2016), while Meru is a major supplier of mangoes (ibid).

5.1 GVC and LVC farmer characteristics

Table I outlines the characteristics of GVC (n = 132) and LVC (n = 188) farmers. It shows that, on average, farmers sold over 80% of their produce into a single value chain suggesting that whilst diversification was present, it was possible to clearly differentiate between these two value chains. GVC farmers appeared to be selling to their current buyers for approximately 6 years, with local farmers selling to buyers on average 8 years. However, interview results suggested that the length of time of participating in a specific chain did not necessarily encourage trust as many GVC

farmers feared overdue payments and high rejection from buyers (Interview: #7k #8k). GVC farmers had almost double the rejections of LVC farmers, highlighting the stringency of standards in global chains.

Another way this paper measures trust is through the existence of written contracts. The data reveals that about 51% of GVC farmers had written contracts, while the remaining had oral (relied on word of mouth) or none; starkly different to the LVC case where less than 1% had written contracts. Many GVC farmers interviewed claimed that a contract gave their work more legitimacy and they would have a stable market to sell their produce to (Interview: Farmer 4k,9k). We used an asset index as a proxy for income[i]. The results were scaled between 0 and 1, with 0 suggesting no assets and 1 the most assets. As can be seen, GVC farmers held slightly higher assets than those in LVC, although the difference was perhaps not as pronounced as one might expect. Dannenberg and Lakes (2013), for example, postulated that farmers who use ICT have higher chances of participation in a GVC and innovate more.

GVC farmers also tended to be better organized into farmer groups compared to LVC farmers. The reason for the relatively high organization of GVC farmers was attributed to the need to sell specific volumes to global buyers that were mentioned within contracts. Moreover, such a formation was reported to reduce the overall costs of logistics for lead firms, as well as to facilitate the disbursement of knowledge within farmer groups.

5.2 Small-scale formal and informal innovations

Drawing on the approach to measure innovation outlined in section 3, we highlight the innovation activities which form the basis of the measurements. Table II and Table III outline the innovation activities and components used to construct the "formal" and "informal" *innovation types* respectively. In line with the literature review that positions innovation as an incremental process of change and learning, the lists of activities include both novel activities undertaken by farmers, as well as imitative and contextual adaptations. The tables also highlight the responses amongst farmers participating in GVC and LVC. The results indicate that GVC farmers tend to perform innovation activities that are more formal (technical) compared to LVC farmers, while both groups of farmers perform informal activities to relatively similar levels.

Formal innovation indicates the importance to GVC farmers of the requirements related to irrigation processes and waste management. These are selected because interviews with farmers indicated that buyers were most concerned about issues relating to irrigation and waste management, and thus farmers had to perform considerable innovations to meet buyer criteria. Furthermore, waste management and irrigation processes are encoded within international standards such as GlobalGAP, and need to be adhered to in order to receive certifications. In contrast, informal innovations are more bottom up and adaptive in nature; and the differences are less striking in magnitude. For instance, innovation activities 3.4 and 4.4, related to preparing for unseasonal rains and conserving water, are performed to very similar magnitudes by both LVC and GVC farmers. Interviews with GVC and LVC farmers

elucidated that they had to adapt to climate variability and extremes as it would impact the quality of the crop, cause higher rejection levels and reduce their income. Thus, farmers innovated to prevent loss of livelihoods (Interview: Farmers #2k, #4k).

We then aggregated innovation activity to innovation component level, using the principal component method discussed above. Table IV, shows the aggregated results of each innovation type by GVC and LVC farmer. The values are scaled between 0 and 1. The findings clearly re-iterate what has been discussed that GVC farmers perform more formal and informal innovations, which are indeed significantly different from LVC farmers. However, the magnitude of difference is quite stark for formal innovations, while much less in the case of informal. The results of the t-test further re-enforce that there are significant differences between GVC and LVC farmer formal innovations and informal innovations.

The 3L's of value chains and innovation

In this section, we explore the three "L's" – labels, linkage and learning related to value chains and innovation. In this research, the two main types of standards that we explore are GlobalGAP, which is an international food safety standard, used by over 90% of FFV exporters from Kenya (GlobalGAP, 2016); and the Kenyan Horticultural Crops Directorate Code of Conduct, which set up its first code of conduct as a memorandum of understanding between the buyer and the seller in 1995. The HCD and business associations together attempted to develop local standards that included indigenous practices, however this failed because these local standards were 'good

enough' or 'benchmarked' against international certification, which made Kenya less competitive within export markets (Tallontire et al., 2011). Thus, by 2010, this standard evolved into a stripped-down version of GlobalGAP. Thus local codes seem to evolve from international standards rather than from local indigenous interpretations. In terms of labels, Table V identifies that only 18.6% of LVC farmers adhere to standards while almost 65% of GVC farmers are currently GlobalGAP certified. Indeed, in interviews, many of the remaining 35% of GVC farmers follow requirements of GlobalGAP even though they are not certified by it.

Linkages are aggregated into backward and forward linkages of network relationships. In the survey farmers were asked to rank the quality of their relationships as strong, weak or intermediate (between strong and weak). The ties were proxied by the frequency and timeliness of help they received from input suppliers and buyers and if it engendered trust. Farmers were asked if they had access to all inputs and information relating to standards from other actors in the value chain and whether they trusted the individuals they received inputs from and sold to. Appendix 1 provides a breakdown of the linkages. The findings are represented as an index value scaled between 0 and 1, where values closer to 0 are closer to overarching weak relationships/linkages, while 1 are strong relationships, and the values closer to the mean would be considered intermediate[I]. The average index value of GVC farmers (0.625) is higher than LVC farmers (0.433) and, according to t-tests, these values are significantly different from each other, suggesting that GVC farmers have more

supportive and helpful relationships overall compared to LVC farmers. This implies that GVC farmers with stronger linkages could potentially perform more complex formal innovations than LVC farmers. Informal innovations, being adaptive processes, would not necessarily require as strong linkages.

The 3rd 'L' learning, shown in Table VI, clearly shows that GVC farmers have higher explicit learning and are thus able to perform formal innovations. The interviews indicated that this was because they had to comply with certification requirements and thus are more likely to actively seek or be provided support by virtue of participating in a GVC. This type of motivation and support is less readily available for LVC farmers and hence we see a higher percentage of them adopting more tacit modes of learning. However, in the case of informal innovations, tacit learning is far higher than explicit learning. We can attribute this to the fact that contextual uncertainties including climate and livelihood risks often require incremental innovations which are not prescribed within training or standards.

Our survey allowed us to dig deeper into the modes of learning in table VI. Imitation for formal innovations is significantly different between GVC and local farmers. This suggests that GVC farmers tend to imitate more because they perform more complex requirements than LVC farmers. In comparison, informal innovations are self-driven, and therefore imitation is helpful here. It appears that GVC farmers tend to imitate best practices more than LVC farmers. Learning through face-to-face interactions to perform formal innovations is much higher for GVC farmers as their linkages are

stronger and denser. Whilst direct transfer for local farmers is rare, local farmers reported that agricultural extension officers and NGOs did not provide them with any training or demonstrations. When considering informal innovations, direct face to face learning was found to be almost non-existent. This is consistent with our definition, suggesting that these innovations grow out of tacit knowledge, and that explicit knowledge does not necessarily promote informal innovations as much.

These findings on learning mechanisms highlight the key underlying characteristics of the different innovation types across distinct value chains. Formal innovations are closely linked to GVCs, and thus tend to be most likely to occur amongst more connected GVC farmers and through more direct and organised modes of learning. Informal innovations are less formally specified, and appear to be important across all farmers. An important note to mention is that we find that *learning and linkages* are intrinsically related and cannot be easily separated. Therefore, we will attempt to *interact the terms* in order to get a nuanced understanding of the effects of learning and linkages. The last 3 rows in table VI depict the interacted terms of linkages with tacit and explicit knowledge. The t-test results indicate that there are significant differences between GVC farmer linkages and tacit/explicit knowledge when performing formal and informal innovations. Thus, in the econometric models presented in the next section, we unpack in greater depth why the tacit learning and linkages, as well as explicit learning and linkages, terms vary across farmers.

This section has elucidated the systematic differences between GVC and LVC farmers, suggesting that GVC farmers tend to innovate more, have more explicit forms of learning, stronger linkages, adhere to labels and are endowed with more productive assets compared to LVC farmers. The next section will quantitatively examine how performing formal and informal innovations differs across farmers in GVCs and LVCs and to what extent the 3L's impact these innovation types.

6 The dynamic relationship between value chain participation and innovation: Estimation results

The descriptive analysis in the previous sections reveals that there are significant differences across farmers who are in GVCs and LVCs in terms of performing formal and informal innovations. To analyse the 'extent' of these differences, we deconstruct the relationship between innovation and value chain participation, using the endogenous switching regression model as discussed in section 3. Appendix 2 provides a summary of the key variable used in the regression. As shown in Table VII, two separate endogenous switching regression models were run which are discussed in the following sections.

6.1 Value chain participation and formal innovations

Determinants of participation in GVCs (selection equation Model 1)

The results of the section equation (determinants of participation in a GVC) are briefly explained in this section. The regression results are displayed in table VIII. Column (3) and (4) are the co-efficient and standard errors for model 1, while column (1) and

(2) is an independent probit which is a robustness test for the selection equation in model 1. Before interpreting the results, we check for endogeneity of the duration variable. We believe that the longer farmers participate in a chain, the higher the probability of continuing to participate as exporters would know them better. Thus, there might be potentially endogeneity, which would lead to a bias in the coefficient estimate. Following the two-stage approach developed by Rivers and Vuong (1988) and detailed in Wooldridge (2002) we find that duration is exogenous.

Farmers who have stronger linkages and use more tacit and explicit forms of learning are more likely to participate in a GVC. These findings were supported by interviews with farmers where export oriented farmers' actively nurture relationships with other network actors. Adhering to a certification appears to have a significant and positive effect on continuing to participate in a GVC. Thus, clearly the 3Ls are jointly significant in driving participation in a GVC.

The asset index, has a positive and significant effect on being able to continue to participate in a GVC. These results are in line with several studies which show that capitalized farmers are more likely to be able to participate in GVCs (e.g. Hernandez et al., 2007). Having a contract seems to have a positive and significant effect on farmers' ability to continue to participate in a GVC. Many GVC farmers reported that having a written contract gave them a 'sense of security' and was crucial to 'guarantee' that their produce would be purchased.

The data showed the results for being a member of a farmer group as insignificant in shaping participation in a GVC. While some farmer groups or communities elect public relations heads, who help maintain good relationships with export firms (Interview: Farmers #1k #3k), being part of one did not automatically lead to participation in a GVC. Interviews suggested that farmer groups did not provide equal assistance to all its members, leading to infighting. Group members frequently cited the lack of trustworthiness engendered by leaders as a critical issue. This reduced cohesiveness leads to low collective efficiency, especially in terms of bargaining for better terms of contracts or prices.

Formal Innovations in GVCs and LVCs: Outcome equation Model 1

The results in

Table IX explain the formal innovation types for farmers participating in GVCs and LVCs. To properly identify the model (discussed in section 3), two variables in the probit (duration and having a written contract) are excluded from this regression, as these variables did not affect the innovation measure directly[ii]. To compare the results of this model, we also ran two-stage estimation (with IMR as explained in section 4, equation 6 and 7)[3]. The coefficient estimates were in a similar range, but the FIML provides more efficient estimates. The results indicate that there are structural differences in how farmers perform formal innovations across value chains and further shows that the 3L's are the most significant factors that determine innovation types and value chain participation.

Certifications have a positive and significant effect on the levels of innovation amongst GVC farmers. Achieving standards is likely one that requires both significant incremental small-scale innovations, as well as possibly more disruptive ones. The importance of innovating was explained by one GVC farmer:

> *"These certifications are costly… I have to be creative in how to make them work for me with lower costs… no one tells you how you can achieve it being creative, they all expect big changes like suddenly using drip irrigation... but I don't have the money but need to achieve the same results as my friends who use drip… so I build furrows, and use sprinklers which are cheaper but almost as effective" (Farmer: #6k)*

It is interesting to note that the HCD Code of Conduct that is followed by some local farmers, has a significantly negative relationship with formal innovations. This means

that achieving a local standard does not promote innovation, thus questioning the extent to which local standards encourage local development.

The interaction of tacit learning and linkages has a positive and significant effect for GVC farmers and promotes performing formal innovations. For GVC farmers, the links between tacit learning and formal innovation relate to the ways that innovation often requires "tweaking" in local contexts in order to be appropriate. One example found in wider discussions related to farmers involves adopting new pesticides in the right quantities. In this case, tacit learning was essential for ensuring that the maximum residue limit on export quality mangoes and avocados was not contravened. Thus, in this case tacit learning impacted the extent to which the produce was safe for export to EU. While tacit knowledge was important, the use of it was quite contested in GVCs, especially when farmers were asked to rely on 'expert systems' and perform requirements a 'specific way' that would ensure meeting global buyer requirements. Thus, the magnitude of effect of tacit knowledge and related linkages is far less than explicit knowledge and the requisite linkages.

For local farmers, the linkages and tacit knowledge variable was not significant in engendering formal innovations for several reasons. Interviews with local farmers suggested that they did not have to prescribe to stringent standards and never felt the 'need' to perform such innovations, while some also claimed that even if they did try to innovate to add something 'extra' to the crop, it would not necessarily be remunerated.

Explicit learning and the related linkages are positive and significant and abet increase in performing formal innovations across both GVC and LVC farmers. Direct transfers of knowledge are facilitated through trainings and workshops. Interviews with local farmers suggested that they benefitted greatly from spillover knowledge they received via other GVC farmers, as well as attending demonstrations that GVC farmers would hold on their land. This meant that in many ways GVC farmers were able to spread their knowledge even if through weaker ties, and cause overall benefit in stimulating local formal innovations. This suggests a slow and gradual absorption of new incremental practices trickling down across value chains and building livelihood resilience for local farmers.

The asset index appears to be positive and significant for LVC farmers to perform formal innovations. This is because local farmers have weak linkages and far less explicit knowledge compared to GVC farmers. Therefore, they have to rely significantly on their own 'capital' that can substitute for the lack of support. Several LVC farmers also stated that asset indexes were used as a measure to make up for the relative lack of infrastructural facilities in Kenya.

Rejection levels appear to be positive and significant forces that push GVC farmers to perform more formal innovations. We show in Table I that almost 15% of the crop is rejected per farmer, which causes significant income losses, as one GVC farmer explained:

> *"Buyers reject my crop and do not tell me why… So this time I did changed [adapted] growing practice to what I used to follow before [indigenous methods] and now they reject less..." Farmer: #7k)*

This points towards the importance of local context in formal innovations, occurring through bottom up change.

Farmer groups appear to be positive and significant in relation to LVC farmers' formal innovations. This means that being a member of a farmer group abets innovation and suggest that local groups are more inclusive. These results are starkly opposite to the GVC-related farmer groups which seem to be ineffective and exclusionary in terms of innovation, because of the lack of sharing of knowledge within the group and the dis-trust in members.

The lower part of table IX reports estimates for the covariance terms. The likelihood ratio test for joint independence of the selection and innovation equations is significant (12.77), suggesting that there is dependence between the equations, and *highlighting that endogeneity exists*. This model was able to control for this through the specification. Furthermore, since $\varrho_{eg}<\varrho_{lv}$ and is significant (following Trost 1981), it implies that *GVC farmers perform more formal innovations than even if they participated in LVCs*. Thus, they are more efficient farmers because of their experience of participating in a GVC. This re-enforces the links between GVCs and innovation.

6.2 Value chain participation and informal innovations

Determinants of global value chain participation: Selection equation model 2

The results for the selection equation in model 2 are presented in table X below. These variables are similar to the selection equation in model 1. The only difference is in the variables of tacit and explicit learning which are assigned values according to knowledge learnt doing informal innovations, while in model 1, these values were linked to formal innovations.

The results indicate that the interaction variables of tacit learning and related linkages and explicit learning and linkages are significant and positive. Since the results are similar to model 1, we do not repeat them.

Informal innovations and value chains: outcome equation model 2

Results in Table XI (outcome regression) show that certifications have a positive and statistically significant effect on both GVC and LVC farmers performing informal innovations. It denotes that international certifications and local codes of conduct (standards) are able to promote farmers' ability to perform informal innovations that could impact their crops. This is interesting as it shows that even though international certifications and HCD codes of conduct concentrate on export related good practices, they can potentially still promote bottom-up innovations.

The interaction terms of tacit and explicit learning mechanisms and linkages appear to be positive and significant factors that affect informal innovations across GVC and LVC farmers. Many researchers have qualitatively discussed the importance of tacit learning (e.g. Gereffi et al., 2005, Peitrobelli and Rabelotti, 2011), while many quantitative studies have focused primarily on explicit (e.g. Okello et al., 2011). Our

research suggests both are critical, especially because the effects of tacit-linkages and explicit-linkages have similar magnitude of coefficients. The importance of tacit knowledge signifies that explicit knowledge alone is not comprehensive enough for farmers. This insinuates that knowledge is indeed sticky, and highlights the need for bottom-up knowledge to promote not only informal but formal innovations.

We are able to empirically show that farmers in GVCs and LVCs perform formal and informal innovations differently because the 3L's effect each of them in different ways. Overarchingly, the 3L's are important because they are crucial factors that show the endogenous relationship between value chains and innovations.

Farmer groups have a contradictory effect on informal innovation in GVCs and LVCs compared to formal innovation. It seems that being part of a farmer group has a significantly negative effect on informal innovations for both GVC and LVC farmers. For LVC farmers this means that learning tacitly seems to be driving performance of informal innovations and collective learning through groups is not very helpful. For GVC farmers it reveals that being part of a farmer group has a negative effect on performing any kind of innovation. Thus, farmer groups need to be revamped significantly in order to attain collective efficiency. There is indeed a need to re-think what it means for farmer organization and the role it plays in promoting innovations.

The asset index has a positive and significant effect on informal innovations performed by LVC farmers. With low levels of explicit support and poor forward

linkages, the importance of maintaining and accumulating assets for LVC farmers is crucial for them to be able to continue to sell into local markets.

7 Discussion and conclusion

This paper seeks to build on recent work which explores the endogenous link between participating in value chains and innovation. In that context, we distinctively measure small-scale innovations in the agricultural sector, thus integrating a range of different innovative activities into a single measure. We develop two small-scale innovation types: formal, those linked to standards; and informal which are harder to codify and embedded in local contexts.

In considering the relationship between innovation and value chain participation, we consider the 3Ls – labels, learning and linkages to be crucial. The results suggest that adhering to labels increases the possibility of formally innovating, and thus raises interesting questions related to using standards as mechanisms to promote different forms of innovation and development. We find that farmers involved in GVCs are more likely to be involved in formal type innovation compared with those involved in local value chains, although some farmers focused on local markets are involved in formal innovations. For farmers focused on local markets, the evidence of some involved in formal innovations suggest a potential presence of 'entrepreneurial' farmers who, even without GVC linkages, are able to tactically absorb new practices and skills. Further work could look into the processes by which these 'entrepreneurial' farmers grow and what measure can make such activity more widespread.

Learning and linkages are the other two key factors that suggest an endogenous relationship. The introduction of the notions of explicit learning and tacit learning have highlighted the varying nature of learning across farmers and value chains. In the GVC case, most innovation occurs due to direct transfers of explicit knowledge linked to value chain participation. However, in our research we found that community-related linkages also played a crucial role in supporting not only farmers in GVCs but also LVCs. Thus, the footprints of often narrow training schemes are not solely responsible in prompting innovations, as knowledge spillovers and leakages appear to be trickling down to local farmers, building their overall capacity. Results around indirect explicit and tacit transfer also pose questions around the 'quality of learning' and whether spreading knowledge in less formal ways enables quicker conversion from explicit to tacit.

Having found formal innovation to be more prominent for GVC farmers, it is noticeable that informal innovation was observed across both GVC and LVC farmers. These findings highlight the importance of a range of small-scale, adaptive practices that have evolved locally, and which indicate new potential directions for policy and civil society action to support resilience building amongst farmers. Such informal innovations should not be assumed to 'simply diffuse', especially because of the difficulty in codification and reliance on tacit knowledge. The inability to perform informal innovations can cause loss of crop yields and quality and thus reduce sales of crops to both global and local buyers, impinging on income. This can potentially

cause spillover effects onto how formal innovations are performed. Further research could explore how informal innovation might be better disseminated, improved and learned from so as to maximise its efficacy of local contexts and for pro-poor growth.

Having focused on small-scale innovation that is adaptive and incremental, this research also provides some insights for existing literature on frugal innovation. Epistemologically, much of the literature on frugal innovations focuses on top-down relationships that are driven by lead firms and which, in an endeavour to be more inclusive, attempt to forge interactive and polycentric relationships with local actors (Knorringa et al., 2016). Overall, the idea of collaborative growth is entrenched (Radjou and Prabhu, 2014). However, such collaborative processes are difficult to achieve in GVCs due to skewed power asymmetries, and the lack of involvement of farmers in setting standards. Thus, powerful actors 'govern' GVCs, while farmers only experience 'governance', which often leads to contested relationships (Nielson and Pritchard 2009). Another crucial point to highlight for frugal innovation is the link to product innovations. However, farmers in Kenya have to perform several process innovations which are informal and tacit in nature. These aspects are still to be included within the remit of frugal innovations and highlight a broad set of activities responding to changing local contexts (such as climatic shocks) as well as mitigating against demands of GVC relationships (such as standards and diffusion of problematic top-down innovation). Some of these aspects are less explored in frugal innovation, which positions small-scale innovation less within 'inclusive' processes

and more in terms of a new frontier of challenges and risk for farmers as diffusion of novel requirements and innovations make ever greater demands on them. Thus this paper, by giving agency to the farmer, contributes to the growing debate around "who innovation should be for" and "what does innovation mean for the poor".

Given the novelty of seeking to measure innovation within agro-value chains, there is scope for further research pursuing this agenda. The decisions on selecting what innovations to include in the farmer survey was a difficult task. The consideration of a wider range of innovation can improve the efficacy of the innovation measure. The endogenous link suggests that it is possible to consider both agricultural and innovation linked policy. These findings highlight the role of local innovation ecosystems in helping to support a move of farmers into international markets by focusing on the 3L's. Thus, policymakers have an opportunity to be able to help mutually address both value chain inclusiveness together with innovation through focusing on overlapping factors. At the same time, they need to be aware of the potential downsides of innovation which may, in some cases, incorporate farmers into unstable and subservient relationships with global markets and be less impactful in the long run.

NOTES

[1]Since the farmers were sampled from similar regions and have similar assets, they can be assumed to report relatively comparable strength and weakness of relationships.

[2] Broadly a national innovation system refers to the flow of technology and knowledge within a national state or embedded in a nation, by a network of institutions, which abet diffusion and uptake of innovations.

[3] Income data attained in the survey was not cross-validated. Asset indexes have been used in several studies (e.g. Carter and Barett 2006) as an alternative to income.

[4] Results are not shown due to space constraints

[5] GVC participation is correlated with duration 0.2688 (sig 0.000) and with contracts 0.2593 (sig 0.000), while formal innovation is correlated with duration 0.0588 (sig 0.3004) and contracts 0.0692 (sig=0.200. Falsification tests also suggest removing both variables.

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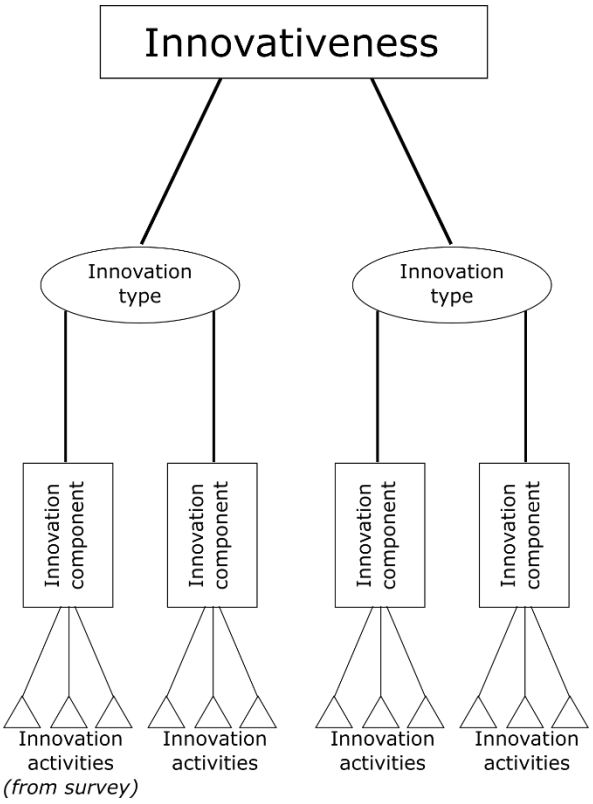
TABLES AND FIGURES

Figure I: Measuring innovativeness (a) Simple measure, (b) Measure using multiple innovation types



Source: Authors' construction

Table I: Descriptives and differences between farmers by chain participation

Variable Category	Variables	GVC (n=132)		LVC (n=188)	
		Mean	**SD**	**Mean**	**SD**
Value chain participation	% sold to current main buyer(s)	83.84*	1.30	86.83	1.02
	% sold to second buyer	12.46*	0.887	9.35	0.760
Controls	Sex (% male in each VC)	78.03**	3.619	68.08	3.463
	Farmer group (1= yes, % of each VC)	71.21***	4.034	31.91	3.43
	Alternate activity (% of each VC)	84.84**	1.87	90.95	1.669
	Asset Index[a] (value)	0.281	0.019	0.182	0.015
	Duration sold to most recent buyer(years)	5.80***	0.28	7.92	0.36
	Rejection levels (%)	19.46***	0.49	10.23	0.27
	Contracts: Written (% by VC)	51.51***	0.43	0.53	0.16

**Mean value is significantly different from local farmers at 10% level*

*** Mean value is significantly different from local farmers at 5% level*

**** Mean value are significantly different from local farmers at 1% level*

[a] Calculated using PCA, used as a proxy for income, as income data was not validated. The asset index includes, years of education, land size, owning mobile, internet, computer, electricity, various modes of transport, TV, radio, house type, access to paved roads

Table II: Innovation type- Formal

Innovation Activity (component 1 and 2)	**Formal Innovations**	**GVC n=132**	**LVC n=188**
Innovation component 1	***Waste management***		
Innovation activity 1.1	Do you dispose of chemical and inorganic wastes through modes of incineration?	4.62	21.43
Innovation activity 1.2	Do you dispose of chemical and inorganic wastes through pits away from land?	43.85	41.76
Innovation activity 1.3	Do you dispose of chemical and inorganic wastes through collection points by community initiated projects, municipality or exporters?	45.38	28.02
Innovation activity 1.4	Do you dispose of chemical and inorganic wastes through community initiated septic tanks?	3.08	0.00
Innovation component 2	***Irrigation mode***		
Innovation activity 2.1	Do you build natural furrows/ boreholes to irrigate crops?	4.62	22.53
Innovation activity 2.2	Do you install sprinklers to irrigate crops?	8.46	36.81
Innovation activity 2.3	Do you use boreholes/furrows and sprinklers to irrigate crops?	44.62	31.32
Innovation activity 2.4	Do you switch between drip and natural to irrigate crops?	42.31	7.69

Source: Authors' construction

Table III: Innovation type - Informal

Innovation Activity (component 3 and 4)	**Informal incremental innovations**	**GVC n=132**	**LVC n=188**
Innovation component 3	***Climate Variability***		
Innovation activity 3.1	During unseasonal rains/ floods do you diversify to other livelihoods?	46.15	60.33
Innovation activity 3.2	During unseasonal rains/ floods do you dig pads, ditches, terraces?	0.77	1.10
Innovation activity 3.3	During unseasonal rains/ floods do you create a makeshift greenhouse?	24.62	19.78
Innovation activity 3.4	During unseasonal rains/ floods are you able to do a combination of at least 2?	16.92	12.75
Innovation component 4	***Water Conservation***		
Innovation activity 4.1	Do you conserve water by making small or large water pads, ditches or trenches?	0.77	8.79
Innovation activity 4.2	Do you conserve water by buying water tanks and storing rainwater?	0.77	3.08
Innovation activity 4.3	Do you conserve water by setting up roof top catchments?	45.38	29.34
Innovation activity 4.4	Do you conserve water by performing at least 2 of these?	40.77	34.07

Source: Authors' construction

Table IV: General differences in Innovation type index of GVC and LVC farmers

Innovation Type	***GVC farmer N=132***	***LVC farmer N=188***	***Ttest***
Formal	0.529*** (0.017)	0.351 (0.008)	-10.34
Informal (Adaptive)	0.638** (0.019)	0.521 (0.016)	-4.32

T test results:

Mean value is significantly different from local farmers at 10% level ; ** Mean value is significantly different from local farmers at 5% level; * Mean value are significantly different from local farmers at 1% level*

Values in brackets are standard errors

Table V: General differences of labels and linkage between GVC and LVC farmers

Farmer chain	***GVC farmer N=132***	***LVC farmer N=188***
Labels or certifications (1=dummy) (%)	63.63***	18.61
Linkage Index[1] (value between 0 and 1)	0.625*** (0.012)	0.433 (0.011)

*T test results: *Mean value is significantly different from local farmers at 10% level ; ** Mean value is significantly different from local farmers at 5% level; *** Mean value are significantly different from local farmers at 1% level*
Values in brackets are standard errors
a=please see appendix 1 for backward and forward linkage breakdown

Table VI: Learning in value chains

Learning mechanisms (% share by farmer chain)	**Formal innovations**		**Informal innovations**	
Farmer chain	***GVC***	***LVC***	***GVC***	***LVC***
***Tacit* (average share by farmer category)**				
A) Through own cognition	30.60***	57.26	72.29*	80.11
	(1.08)	(0.90)	(1.32)	(0.89)
***Explicit* (average share by farmer category)**				
B) Imitation	9.35**	10.31	4.32**	2.63
	(0.27)	(0.34)	(0.45)	(0.36)
C) Knowledge leakage (through community, friends)	6.73*	16.26	16.77***	12.83
	(0.36)	(0.42)	(1.44)	(0.42)
D) Direct transfer, face to face interactions	52.87***	16.17	6.20	4.39
	(1.32)	(1.04)	(0.05)	(0.03)
Total Explicit (B+C+D) (% share by farmer category)	62.95***	42.74	27.29***	19.85
	(1.80)	(1.50)	(1.12)	(0.63)
Interaction terms				
Tacit* linkages	24.85*** (0.95) T=-5.48	17.90 (0.82)	32.21** (2.65) T=-2.73	18.04 (1.06)
Explicit*linkages	25.12*** (1.53) T=12.41	6.39 (0.71)	11.15*** (1.81) T=-4.31	2.88 (0.62)

*T test results: *Mean value is significantly different from local farmers at 10% level; ** Mean value is significantly different from local farmers at 5% level; *** Mean value are significantly different from local farmers at 1% level*
Values in brackets are standard errors

Table VII: Endogenous switching regression models

Dependent variable in models	**Selection equation (jointly estimated probit)**	**Outcome equation (FIML)**
Model 1	Participating in a GVC	Formal innovation type
Model 2	Participating in a GVC	Informal innovation type

Source: Authors' construction

Formal Innovations:

Table VIII: Selection equation- Probit model 1

Variables	Independent probit GVC farmer;		Jointly estimated probit GVC farmers	
	(1) Coefficient	(2) SE	(3) Coefficient	(4) SE
Labels	0.637***	0.261	0.640***	0.246
Tacit learning*linkages	0.024***	0.010	0.026***	0.010
Explicit learning*linkages	0.042***	0.009	0.040***	0.009
Asset Index	1.240***	0.253	1.338***	0.235
Alternate livelihoods	-0.817	0.565	-0.870**	0.506
Sex	-0.243	0.235	-0.352	0.246
Part of farmer group	-0.126	0.250	-0.160	0.231
Rejection Levels	0.288***	0.075	0.288***	0.077
Duration	-0.094***	0.027	-0.090***	0.023
Contract	1.475***	0.293	1.376***	0.264
_cons	-2.303***	0.367	-2.305***	0.378

significant at 10%, ** significant at 5%, * significant at 1%*

Table IX: Full information maximum likelihood parameters for formal innovations

Variables	Formal GVC		Formal: LVC	
	(1) Coefficient	(2) SE	(3) Coefficient	(4) SE
Labels	0.100***	0.021	-0.044***	0.022
Tacit learning*linkages	0.003***	0.001	-0.001	0.001
Explicit learning*linkages	0.007***	0.001	0.005***	0.001
Asset Index	-0.006	0.025	0.075***	0.026
Alternate livelihoods	-0.021	0.041	0.016	0.041
Sex	-0.005	0.022	0.009	0.016
Part of farmer group	0.017	0.021	-0.036**	0.017
Rejection Levels	-0.013**	0.007	0.005	0.006
_cons	0.273***	0.049	0.347***	0.021
ln σg	-2.263***	0.067		
Pgv	-0.463**	0.199		
ln σl			-2.251***	0.057
Plv			0.732**	0.115
Likelihood ratio test of independent equations χ2	12.77***			
Number of observations	320			
Log-likelihood	201.29			
Wald chi2(13)	260.95***			

***

Significance at 1% level
*** Significance at 5% level*
** Significance at 10% level*

Informal innovations:

Table X: Selection equation - probit model 2

Variables	Independent probit GVC farmer;		Jointly estimated probit GVC farmers	
	(1) Coefficient	(2) SE	(3) Coefficient	(4) SE
Labels	0.945***	0.232	0.629***	0.217
Tacit learning*linkages	0.028***	0.007	0.044***	0.007
Explicit learning*linkages	0.028***	0.008	0.031***	0.008
Asset Index	1.241***	0.256	1.033***	0.229
Alternate livelihoods	-0.510	0.547	-0.162	0.482
Sex	-0.123	0.228	-0.185	0.221
Part of farmer group	-0.098	0.251	0.013	0.207
Rejection Levels	0.349***	0.078	0.301***	0.070
Duration	-0.105***	0.027	-0.060**	0.028
Contract	1.385***	0.276	0.800***	0.284
_cons	-2.280***	0.346	-2.658***	0.355

significant at 10%, ** significant at 5%, * significant at 1%*

Table XI: Full information maximum likelihood parameters for informal innovations

Variables	Informal: GVC		Informal: LVC	
	(1) Coefficient	(2) SE	(3) Coefficient	(4) SE
Labels	0.057*	0.033	0.015	0.041
Tacit learning*linkages	0.003***	0.001	0.011***	0.001
Explicit learning*linkages	0.005***	0.001	0.012***	0.002
Asset Index	-0.066*	0.040	-0.026	0.057
Alternate livelihoods	-0.079	0.070	0.106*	0.064
Sex	-0.006	0.037	-0.040	0.025
Part of farmer group	-0.058**	0.034	-0.050*	0.026
Rejection Levels	-0.010	0.011	-0.005	0.012
_cons	0.663***	0.072	0.330***	0.038
ln σg	-1.668***	0.074		
Pgv	-0.934**	0.061		
ln σl			-1.865***	0.055
Plv			0.055	0.515
Likelihood ratio test of independent equations χ2	15.40***			
Number of observations	320			
Log-likelihood	49.57			
Wald chi2(13)	57.77***			

Significance at 1% level
*** Significance at 5% level*
** Significance at 10% level*

Appendix 1: Linkages - Breakdown of relationships

Actors	Relationship of farmer with actors	GVC	LVC
Seed suppliers	0= Weak (% of each farmer category)	2.68	0.41
	1=Intermediate (% of each farmer category)	63.6	50
	2=Strong (% of each farmer category)	33.72	49.59
Agro-vets	0= Weak (% of each farmer category)	4.6	7.41
	1=Intermediate (% of each farmer category)	51.72	62.3
	2=Strong (% of each farmer category)	43.68	29.59
Local Credit givers	0= Weak (% of each farmer category)	3.45	0.00
	1=Intermediate (% of each farmer category)	90.42	88.21
	2=Strong (% of each farmer category)	6.13	11.79
Extension officers	0= Weak (% of each farmer category)	12.2	44.83
	1=Intermediate (% of each farmer category)	47.56	36.78
	2=Strong (% of each farmer category)	40.24	18.39
Main buyers (exporters for GVC farmers and local buyers for LVC)	0= Weak (% of each farmer category)	19.51	54.39
	1=Intermediate (% of each farmer category)	44.31	24.72
	2=Strong (% of each farmer category)	33.74	20.88
Brokers	0= Weak (% of each farmer category)	31.42	19.51
	1=Intermediate (% of each farmer category)	50.57	36.99
	2=Strong (% of each farmer category)	14.56	8.54

Appendix 2: Summary of variables used in regression

Variables	*Variable explanation*	*Stage 1 regression*	*Stage 2 regression*
Labels	Having a local code of conduct or international certification dummy; values in %	Yes	Yes
Tacit learning*linkages	Interaction of total share of tacit learning with index of backward/forward linkages	Yes	Yes
Explicit learning*linkages	Interaction of total share of explicit learning with index of backward/forward linkages	Yes	Yes
Asset Index	Index of assets possessed before participation in current chain	Yes	Yes
Alternate livelihoods	Other livelihoods possessed dummy; values in %	Yes	Yes
Sex	male dummy; values in %	Yes	Yes
Part of farmer group	Membership if farmer group dummy; values in %	Yes	Yes
Rejection Levels	Dummy for if they have rejections; values in %	Yes	Yes
Duration	Number of years in specific chain	Yes	No
Contract	Dummy if they have a contract with main buyer	Yes	No
Dependent variables		*Binary variable GVC farmer or not*	*Index of formal innovations; Index of informal innovations*

i

ii