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Testing the Effectiveness of Network Governance Mechanisms to Foster Ambidexterity of Agricultural Innovation Networks in East and Central Africa

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ABSTRACT

We tested three innovation network governance mechanisms for exploring and exploiting innovation opportunities. We analysed household-level panel data from agricultural innovation networks in Uganda, the Democratic Republic of the Congo and Rwanda. We found that first-order governed networks fostered capabilities for exploitation as well as exploration, while second-order governed networks fostered specialised capabilities for exploitation. Meta-governed innovation networks were most effective in combining multiple capabilities for exploration and exploitation. However, our results indicate that the relationship between network governance and ambidexterity of innovation networks is not robust, and we recommend further research on the context as a mediating factor between network governance and capabilities.

Keywords: ambidexterity; innovation; network governance; capabilities; innovation platforms; challenges; Africa

1 Introduction

Nine out of every ten farms in the world are family farms, and the majority of these are in developing countries. Despite their engagement in agriculture these farming families represent 70% of the world's food insecure people due to insufficient production or a lack of money to purchase food (FAO, 2014). This paradox of rural food insecurity stems from a lack of natural resource management knowledge, power imbalances, lack of voice in decision making and asymmetrical access to resources such as information, technology, and agricultural inputs. Tackling these production and entrepreneurial challenges requires collaborative efforts of innovation networks of family farmers and other actors in agricultural value chains. Innovation networks are defined as a "temporary organisational hybrid phenomenon", and "a new form of organisation within knowledge production for the exploration and exploitation of synergies and complementarities" (Pyka and Küppers, 2002). Ambidexterity is a concept that encompasses the routines and processes by which organizations organise their efforts and assets across different units (Jansen et al., 2009) for exploration and exploitation. Here we consider ambidexterity as a high order capability (Menguc and Auh, 2008) of innovation networks, which fosters other capabilities for supporting family farms to explore and exploit innovation opportunities.

Ambidexterity enables the agricultural innovation networks to mobilise, coordinate and integrate the capabilities of diverse stakeholders to innovate, and to allocate and combine agricultural technologies and knowledge across the family farms.

The debate on ambidexterity focuses on structural, temporal and contextual solutions (Stadler et al., 2014) —or challenges—for fostering simultaneous exploration and exploitation (Pérez Perdomo and Farrow, 2016, Pérez Perdomo et al., 2016). However, the structural challenges have received most attention of scholars of management and innovation theory given the effect of managing exploration and exploitation through different organisational structures (organisational ambidexterity) on the performance of organisations and firms (Cao et al., 2009, Chang and Hughes, 2012). The management of structural challenges is an emerging area of research in network settings (Pérez Perdomo and Farrow, 2016, Turner et al., 2013, Martini et al., 2013) and is strongly related to the structure, purpose and norms of the network, the acquirement and use of resources, the rules of engagement among partners and how the network partners are held accountable, i.e. the governance of the network (Alter and Hage, 1993, Provan and Kenis, 2008). Many studies have been unable to conclude which type of governance best enables family farms to foster capabilities to explore and exploit opportunities to innovate. Various authors suggest further research in order to arrive at general theories on how complex innovation networks build their ambidexterity (Turner et al., 2013, Martini et al., 2013, Mueller et al., 2013).

Hence in this paper we focus mainly on the structural challenges of managing exploration and exploitation in innovation networks (Pérez Perdomo and Farrow, 2016) with different forms of network governance. We empirically examine innovation trajectories among family farms in developing countries. We compare three types of network governance—first-order, second-order and meta-governance of multi-level networks—and the extent to which these prove successful in fostering family farms capabilities in their attempts to innovate. We analyse data on 2562 family farms in Uganda, Rwanda and the Democratic Republic of the Congo (DRC).

This paper is organised as follows. The next section discusses the notion of exploration and exploitation, and describes the concepts of first-order, second-order and meta-governance of multi-level innovation networks. Section 3 presents the data and methods. Section 4 examines the efficacy of first-order, second-order and multi-level networks. Section 5 concludes.

2 Exploration and exploitation

The governance of networks likely effects the management of exploration and exploitation of innovation opportunities. We relate three network governance mechanisms to exploration and exploitation management: i.e. first-order governance of small sized networks, second-order governance of large-sized networks, and multi-level networks with meta-governance.

2.1 First-order governance: exploration

First-order governance is characteristic of small sized networks with fewer than six to eight organizations (see participant governance in Provan and Kenis, 2008), and is particularly characteristic of exploration (Gilsing and Nooteboom, 2006). Members of the network work together without hierarchy or higher levels of authority, have informal relationships and flexible ties that allow the entrance of new members

to these locally embedded networks. Networks with first-order governance exhibit high levels of trust and a high density of connections (Gilsing and Nooteboom, 2006), and have a limited use of contracts. These networks are sometimes coordinated without a formal management design.

This governance represents the case of family farms that work as part of teams; collaborating in a local social network, community of practice, small producer organisations or even networks of practice aided by the use of information and communication technologies (e.g. mobile phones). We hypothesise that first-order governed networks effectively enable family farms to foster organisational capabilities to explore innovation opportunities. For instance, a family farm might join a small local innovation network to tackle common issues related to production, marketing, saving and credits.

2.2 Second-order governance: exploitation

Second-order governance is a characteristic of larger networks, where face to face communication is not easy, and a lead organisation is required for coordination, (Pérez Perdomo et al., 2016, Pérez Perdomo and Farrow, 2016). Networks tend to be more exclusive, with participants sustaining formal relationships, and with institution-based trust (Gilsing and Nooteboom, 2006). This governance structure is not embedded in a context, and is based on a formal contractual relationship. Second-order governance favours the exploitation of capabilities because of the formal organisational relationships—whether by contracts or verbal agreements—to assure the stability of the network, and access to the specialised knowledge base of a lead organisation (Pérez Perdomo and Farrow, 2016).

Second-order governance represents the case of family farms that work in a large network with a lead organisation coordinating the network to foster specialised capabilities (e.g. knowledge-extension, technological, entrepreneurial and investment capabilities) necessary for exploitation of innovation opportunities. An example is the conventional linear intervention programmes focussed on the diffusion of technological packages. Some of these National Agricultural Research and Extension Systems (NARES) programmes focus on the exploitation of particular technologies to improve competitiveness (Spielman, 2005). Other NARES intervention programmes help farmers build linkages and contacts to exploit innovation opportunities (e.g. Gildermacher et al., 2009, Kaaria et al., 2008, Sanginga et al., 2004). Knowledge management strategies include the use of information (didactic manuals, leaflets, etc. for codified knowledge) for facilitating the diffusion of the technology, and specific activities (e.g. training, demonstrations, and field visits) to consolidate specialised capabilities related to the diffusion of agricultural technologies.

We hypothesise that second-order networks effectively improve family farms' knowledge-extension, technological, entrepreneurial and investment capabilities necessary for exploiting innovation opportunities.

2.3 Multi-level innovation networks with meta-governance: exploration and exploitation

Meta-governance is less straightforward than first and second-order forms and concerns how exploration and exploitation are managed in multi-level innovation networks. Meta governance permits the simultaneous management of structural challenges of multi-level and sometimes geographically dispersed innovation networks, like international organisations (Schemeil, 2013), ambidextrous clusters (Ferrary, 2011), and global networks of practice (Agterberg et al., 2010). Meta-governance allows the emergence of sub-networks that are coordinated by mobile hubs of innovation network members (Pérez Perdomo and Farrow, 2016). The governance, composition and organisation of the mobile hubs change according to particular challenges faced by the innovation networks at different times (Pérez Perdomo and Farrow, 2016). In contrast to a hub firm (Dhanaraj and Parkhe, 2006) or a *Network Administrative Organisation* (Provan and Kenis, 2008) that manages large and diverse participants and monitor its activities from a neutral and central position, meta-governance is not led by a single organisation or network broker that coordinates the whole network, in a centralised manner.

Meta-governance represents the case of family farms working as part of a multi-level network approach, like the Integrated Agricultural Research for Development (IAR4D) of the Sub-Saharan Africa Challenge Program (SSACP). Innovation networks that span multiple levels combine the input of various stakeholders in order to address multidimensional challenges (e.g. Buruchara et al., 2013, Hawkins et al., 2009, Cadilhon et al., 2016) and facilitate activities for helping family farms to build multiple capabilities to both explore and exploit opportunities to innovate. Important components of IAR4D for meta governance are the principle of participation by actors from multiple levels, a broad range of development objectives, and the innovation platforms where development challenges are identified, prioritised and action plans developed (Buruchara et al., 2013). Previous studies on impact pathways of SSACP innovation platforms (Nkonya et al., 2013) did not explicitly consider governance dynamics or the

impacts on capabilities. Ambidexterity is a high order capability that entails multiple capabilities for both exploring and exploiting innovation opportunities. In the case of multi-level networks of innovation platforms we expect the participation and facilitation by diverse stakeholders would foster family farms' organisational, knowledge-extension, technological, entrepreneurial and investment capabilities.

This paper therefore examines how, and to what extent, the network governance mechanism fosters other capabilities of the network. More specifically:

What network governance mechanism of innovation networks best enable family farms in developing countries to foster capabilities for exploring and exploiting innovation opportunities?

We test the following hypotheses:

- *Hypothesis 1. First-order governed innovation networks most adequately enable participating family farms to foster capabilities necessary for exploration of innovation opportunities;*
- *Hypothesis 2. Second-order governed innovation networks most adequately enable participating family farms to foster capabilities necessary for exploitation of innovation opportunities;*
- *Hypothesis 3. Multi-level innovation networks with meta-governance adequately enable participating family farms to foster capabilities necessary for exploration and exploitation of innovation opportunities.*

3 Data and Methods

We tested our hypotheses in the context of innovation networks in agricultural netchains in Sub-Saharan African countries. We used panel data of 2,562 households from two household surveys from 2008/09 and 2010, conducted in Uganda, the Democratic Republic of the Congo (DRC) and Rwanda. A longitudinal design allowed us to consider ambidexterity as a dynamic capability and to draw insights on how exactly innovation networks combined exploration and exploitation across family farms and across time (Simsek, 2009 pg. 889).

The panel data were from baseline and end line surveys conducted by the Sub-Saharan Africa Challenge Programme (SSACP). These surveys were designed to measure the impact of the Integrated Agricultural Research for Development approach (IAR4D) within the SSACP (Nkonya et al., 2013). The SSACP was designed to help family farms in Uganda, Rwanda and DRC foster capabilities to explore and exploit opportunities for innovation. The IAR4D organization structure consisted of managers at both the national and regional level. At the national level, managers coordinated activities aimed at improving family farms' market access, productivity and natural resources management. At the regional level, the IAR4D programme institutionalized innovation networks, coordinated by local IAR4D committees. The regional innovation networks' activities were closely monitored by national IAR4D management. For managing temporal challenges, the IPs had monthly meetings to discuss and adjust actions plans, and monitoring and evaluation committees to keep track of the innovation process.

The surveys were distributed among households located in both the 12 SSACP Action Sites (in which innovation platforms were established as a component of IAR4D) and their 12 counterfactual sites (Farrow et al., 2013). In 2008, immediately prior to the baseline survey, villages in all sites were characterised by the levels of participation in AR4D interventions. Villages in counterfactual sites were categorised as 'First-order networks' if they had little or no participation in agricultural development interventions, or 'Second-order networks' if they had active participation in conventional AR4D interventions. All villages in Action Sites had little or no previous participation in agricultural development interventions and were categorised as 'Multi-level networks' because they would receive the IAR4D treatment, with a networked approach to connect local, national, and regional networks. One hundred and eighty villages were selected randomly with equal numbers of village types, with approximately ten family farm households selected randomly in each village.

Table 1.
Number of family farms surveyed per country, by type of innovation network

	Uganda	**Rwanda**	**DRC**	**Total**
First-order networks	274	218	279	771
Second-order networks	266	220	291	777
Multi-level networks with meta-governance	271	224	190	685
Total	811	662	760	2233

3.1 Analytical approach and operationalisation

We hypothesised that the governance of first, second and multi-level innovation networks helps family farms foster different types of capabilities necessary for exploring and exploiting innovation opportunities. We distinguished between organisational, knowledge-extension, technological, entrepreneurial and investment capabilities (Table 2).

Table 2.
Types of capabilities likely to be fostered per network type

Exploration/Exploitation	**Type of capabilities**	**Type of Network**		
		First-order network	**Second-order network**	**Multi-level network**
Exploration	Organisational	☑		☑
Exploitation	Knowledge-extension		☑	☑
	Technological		☑	☑
	Entrepreneurial		☑	☑
	Investment		☑	☑

We analysed the change in capabilities at the family farm level, thereby taking advantage of the longitudinal data structure. As a proxy for family farms' *organisational capabilities* to explore innovation we tally-marked participation of family farms in regional social (V1), production (V2), agricultural processing (V3), marketing (V4), cooperative (V5), and saving and credit groups (V6) (Table 4). Membership of differentiated groups indicated types of organisational relationships (formal-informal, for horizontal, vertical, cross integration in the netchain) and further enables the family farm to explore and exploit opportunities for innovation. These different organisational relationships are indicators of the management of structural challenges in multi-stakeholders innovation networks, as different types of relationships allow to explore and/or exploit those opportunities for innovation.

We observed the type of support provided by the extension services supporting the innovation network. The family farms' *knowledge-extension capabilities* were assumed to improve for those farms that received agricultural extension visits (V7), those that had received a certain number of extension visits (V8), those that had participated in research demonstrations (V9) and those that had facilitation to access market information (V10) (Table 4).

We analysed family farms' *technological capabilities* by measuring the use of different technologies. Based on SSACP data analysis, we considered the use of soil and water technologies (V11), the use of soil fertility technologies (V12), the use of crop management technologies (V13), the use of improved crop varieties (V14) and the use of improved livestock breeds (V15), as indicative of the farms' adoption of technological capabilities necessary for exploitation (Table 4 in the appendix).

We assessed *entrepreneurial capabilities* by the farms' existence of marketing contracts with groups or traders for consolidating as business networks (V16) and whether the farm has successfully arranged deals on the sale of cereal crops (V17), legume crops (V18) and roots and tubers (V19) (Table 4). These variables indicate the consolidation of innovation networks as business networks exploiting capabilities to give an economic benefit.

As to *investment capabilities*, we used the farms' borrowing activity from informal sources of credit (V20) and borrowing activity from formal sources of credit (V21) to observe whether there was a change in their saving and credit status over time, which would indicate their investment capabilities (Table 4).

For every single farm we calculated the change in the values of the variables V1 to V21 between the baseline (2008) and end line (2010) surveys. We use paired samples t-tests to establish statistically significant changes in the mean values between 2008 and 2010.

We tested whether first-order networks prove more efficient in improving family farms' organisational capabilities relative to second-order and multi-level innovation networks.

We expected second-order networks to improve the farmers' specialised knowledge, technological, entrepreneurial and investment capabilities. Multi-level networks with meta-governance were expected to help family farms build the combination of capabilities.

We used radar diagrams to plot the mean values for variables V1 to V21 for both the baseline and end line surveys. Changes in these variables can be read as pathways or cycles of innovation (Nooteboom, 2000, Van de Ven, 1999). Radar diagrams allowed us to consider ambidexterity as a dynamic capability by tracking changes in capabilities for exploration and exploitation over time.

4 Results

4.1 Baseline and End line capabilities comparisons

The mean change in scores for organisational, knowledge-extension, technological and entrepreneurial capabilities between the baseline (2008) and endline (2010) surveys are shown in Table 5 in the appendix.

We observed a general improvement in family farms' *organisational capabilities* (Table 5). There were significant changes in the membership of social (V1), production (V2) and saving and credit groups (V6). Changes in membership of agricultural processing (V3) and cooperative groups (V5) were not significant. The only significant deterioration in organisational capability was for group marketing (V4).

For *knowledge-extension capabilities*, Table 5 shows that there were a significantly higher number of farms receiving extension visits (V7) in 2010 compared to 2008. The number of visits (V8) for each farm also increased significantly and more farms participated in research demonstrations (V9), which may be attributed to improved facilitation of extension services. However, overall fewer family farms had access to market information (V10) in 2010 than in 2008.

Contrary to expectations, family farms' *technological capabilities* (V11-15) decreased significantly during the 2008–2010 period. This result may be explained by the network already having completed the process of training in technologies in 2008. The changes in *entrepreneurial capabilities* were mixed, with small but significant decreases in group marketing contracts and sales of cereals (V16-17), but with larger and significant increases in sales of legumes and roots and tubers (V18-19).

There was a small effect on family farms' *investment capabilities*, with a significant reduction in formal sources of finance, but no change in borrowing from informal sources.

4.2 Types of networks and changes in capabilities

We hypothesise that improvement in organisational, knowledge-extension, technological and entrepreneurial capabilities differ by type of governance of the network. Results per type of network are shown in table 3.

Table 3.
Most favourable type of network governance per capability

Type of capabilities	Variables	Most favourable type of network governance
Organisational capabilities	V1 Member of social groups	First-order
	V2 Member of production groups	First-order
	V3 Member of agric. processing groups	
	V4 Participate in group marketing	
	V5 Member of cooperative group	Multi
	V6 Member of savings and credit groups	Multi
Knowledge-extension capabilities	V7 Received agricultural extension visits	Multi
	V8 Number of extension visits	Multi
	V9 Participated in research demonstrations	First-order
	V10 Access to market information	
Technological capabilities	V11 Used soil and water technology practices	
	V12 Used soil fertility technology practices	
	V13 Used crop management technology practices	
	V14 Used improved crop varieties	
	V15 Used improved livestock breeds	
Entrepreneurial capabilities	V16 Have marketing contract with groups or traders	
	V17 Sold cereal crops	
	V18 Sold legume crops	Second-order
	V19 Sold roots and tubers	Second-order
Investment capabilities	V20 Borrowed from informal sources	Second-order
	V21 Borrowed from formal sources	

We hypothesised that innovation networks with first-order governance most adequately enabled participating family farms to foster organisational capabilities necessary for exploration. We confirmed that first order governed networks enabled organisational capabilities for exploration, but also exploitation of innovation opportunities. First-order governed networks had a major improvement on membership of social groups, membership of production groups and membership of agricultural processing groups, which indicate an improvement in the management of structural challenges, fostering different types of integration (i.e. more cross, horizontal, and vertical integration of innovation networks) for the exploration and exploitation of innovation opportunities.

Moreover, we found that organisational capabilities for exploration and exploitation of innovation opportunities (V1) were greater in first-order but also in meta-governance networks, than in networks with second-order governance. Meta-governance networks had an slight improvement on membership of cooperative groups and membership on saving and credits groups, which indicate also an improvement in the management of structural challenges (i.e. more cross, horizontal, and vertical integration of innovation networks) for enabling exploration and exploitation of innovation opportunities, although differently to first order governed networks. Meta-governed networks fostered the membership to cooperative groups and also the membership to credit and saving organisations, which are formal types of organisational relationships that can support the consolidation of business networks. In comparison, the first order governed networks fostered organisational capabilities by improving the membership to social groups in general, and the membership to production groups.

For participation in cooperative groups, both the first and second-order governance treatments experienced a significant decrease, while in the meta-governance there was a slight improvement.

Our second hypothesis was that larger innovation networks with second-order governance were more likely to foster specialised capabilities for exploitation (e.g. knowledge-extension, technological, entrepreneurial or investment capabilities) than networks with first-order governance. For the knowledge-extension variables (V7 – V10), the second-order governed networks were not more

successful at fostering capabilities than the other types of network governance. The most favourable type of network governance for extension visits was the multi-level network, whereas the first-order governed networks led to the most improved participation in research demonstrations. Access to market information was universally worse in 2010 than in 2008, significantly so in the case of meta-governed networks.

None of the three networks improved the technological capabilities of farms; instead there was a significant deterioration in the use of technologies (V11 – V15) in all networks between 2008 and 2010. Regarding *entrepreneurial capabilities* (V16 – V19) the network that indicated most improvement between 2008/09 and 2010 was the second-order governed networks, which improved most on the variables of sales of legume crops and roots and tubers (V18-V19).

Regarding *investment capabilities*, mean changes in households' access to informal sources to credit (V20) were significantly different among innovation networks with different governances. Second-order governance networks had an increase in borrowing from informal sources, with a smaller increase in the first-order governance networks and a significant decrease for farms in meta-governed networks. Borrowing from formal sources of credit (V21) decreased in all three networks, with a significant change for farms in first-order governed networks.

4.3 Multiple capabilities for exploration and exploitation

We hypothesised that innovation networks with meta-governance would be more likely to foster multiple capabilities compared to networks with other governances.

For *organisational capabilities*, IPs with meta-governance improved the membership of the family farm to agricultural processing groups, cooperative groups and member of savings and credit groups. Therefore, the innovation networks with meta-governance of multi-level networks did foster effectively organisational capabilities for both exploitation and exploitation.

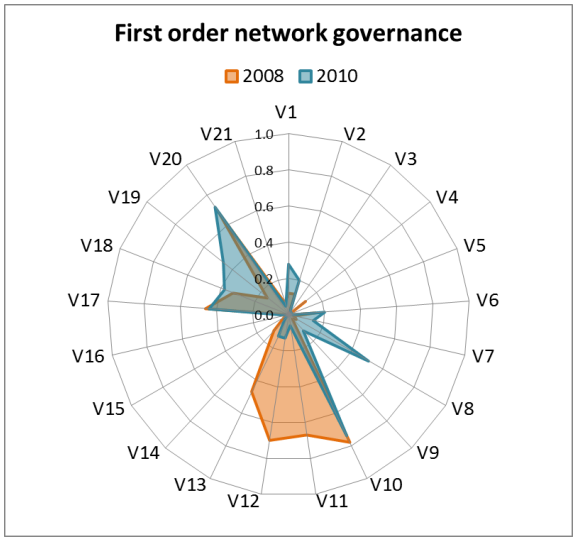
In relation to *knowledge-extension capabilities*, the IP meta-governed networks had the highest average positive change in the number of extension visits, followed by the first-order governance and second-order governed networks.

Regarding *technological capabilities*, in the period from 2008 to 2010 there was a mean reduction in the use of various technologies in all three treatments. For *entrepreneurial capabilities* the IP had marginally fewer households with contracts in 2010 than in 2008, whereas households in the first-order networks had marginally more households with contracts. For none of the other variables indicating entrepreneurial capabilities was the change in the IP households bigger than the other two governance types.

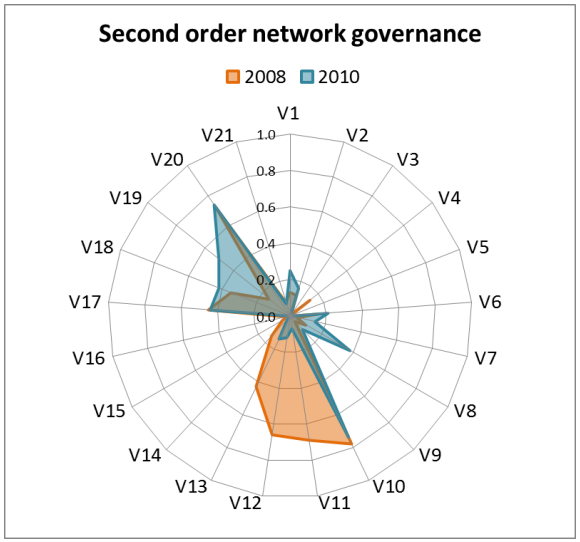
On *investment capabilities,* IP households had a smaller reduction in borrowing from formal sources than the second and first-order governance, and it was the only governance that reduced borrowing from informal sources. These changes could be due to cooperative affiliation or the loans provided by a partner of the IP in DRC to farmers in IPs in DRC, Uganda and Rwanda without the requisite of collateral. Informal sources of credit from family and friends are generally how farmers arrange their finances (Meyer, 2015), given that banks ask for collateral, a condition farmers find difficult to comply with.

5 Discussion and Conclusions

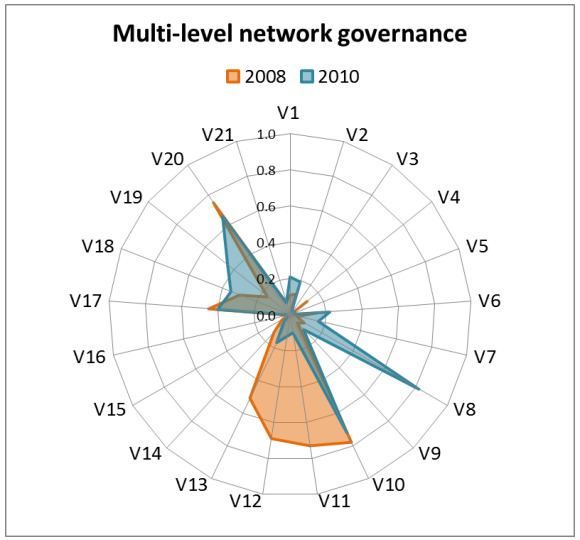
In this paper the results indicate that network governance does not have a significant effect on performance, in this case on fostering capabilities of networks to support family farms for exploring and exploiting innovation opportunities. The absolute values of the capabilities summarised in radar diagrams show the evolution of capabilities (figure 1). We observed that although the meta-governed networks had similar trajectories, this governance was more effective in combining multiple capabilities for both exploring and exploiting innovation opportunities rather in fostering specific capabilities.



A + Organisational, + knowledge, - technological, + entrepreneurial



B + Organisational, + knowledge, - technological, ++ entrepreneurial



c + Organisational, + knowledge, - technological, + entrepreneurial

V1 Member of social groups, V2 Member of production groups, V3 Member of agric. processing groups, V4 Participate in group marketing, V5 Member of cooperative group, V6 Member of savings and credit groups, V7 Received agricultural extension visits, V8 Number of extension visits, V9 Participated in research demonstrations, V10 Access to market information, V11 Used soil and water technology practices, V12 Used soil fertility technology practices, V13 Used crop management technology practices, V14 Used improved crop varieties, V15 Used improved livestock breeds, V16 Have marketing contract with groups or traders, V17 Sold cereal crops, V18 Sold legume crops, V19 Sold roots and tubers, V20 Borrowed from informal sources, V21 Borrowed from formal sources.

Figure 1. Tracking innovation pathways of innovation networks and network capabilities

Capabilities might evolve over time and complete a cycle; starting with organisational and knowledge capabilities (exploration), then more specialised capabilities: technological capabilities, entrepreneurial, and investment capabilities (exploitation), which make possible to continue the innovation process. The results indicate that organisational capabilities for exploration (V1) were greater in first-order networks and meta-governed networks than in networks with second-order governance. We also presented evidence of first-order governed networks enabling capabilities for exploitation, fostering organisational and entrepreneurial capabilities for consolidating business networks, with more marketing contracts with groups or traders. These results confirm similar findings of small networks in potato netchains (Pérez Perdomo et al., 2016) fostering exploration and exploitation (ambidexterity). Organisational and entrepreneurial capabilities of first-order and meta-governed networks could have been fostered with the increased membership of cooperatives and the provision of various services. Financial services provided by cooperatives (e.g. Saving and Credit Cooperatives [SACCOs] in Uganda) could have improved the investment capabilities of farmers and foster the emergence of small and medium size enterprises.

Second-order governed networks were significantly better for fostering just some few specialised capabilities for exploitation of opportunities for innovation (e.g. entrepreneurial and investment capabilities). Therefore, we could not confirm our second hypothesis. The results presented can be due to limitations of some sub-Saharan countries on the availability and/or coverage of specialised leading organisations that can contribute to exploitation of innovation opportunities by family farms (e.g. extension agencies, financial organisations and other specialised service providers). For instance, we observed a decrease in the provision of market information in all the cases, which is gap that could be filled by a lead organisation that specialises in offering this service more effectively and timely. Results can also be due to the emergence of collective roles and the diversification of roles played by organisations participating in collaborative innovation networks that are filling some of the gaps of the mentioned lack of specialised leading organisations.

With regards to our third hypothesis, our results indicate that while *meta-governed innovation networks* were not the most effective in building specific capabilities, they were effective at building multiple capabilities, enabling participating family farms to build a combination of capabilities necessary for exploration and exploitation of innovation opportunities. The IP was a social innovation for agricultural research and development that changed the traditional linear technology transfer approach for a networked approach. Multi-level innovation networks were governed through mobile hubs that coordinated the exploration and exploitation of synergies and complementarities of geographically dispersed networks that involved diverse stakeholders.

A factual limitation in our study was the difficulty of accurately measuring the effect of the IP, given that these were embedded in local governance mechanisms, and there might be a combined effect of the first and other governance network levels. The research design did not control for this effect, like taking a sample of people not members of the IP in the same place where the IP was established. The panel data did not track more systematically the influence of other possible interventions and dynamics. The second and first-order governance networks also might have had a strategy and facilitation of multi-level networks, but there was no tracking of such dynamics in a systematic manner in the panel data and complementary studies to compare. Another limitation is that the data did not specify the scale (local, regional, national or international levels) at which organisational relationships took place, perhaps underestimating the capabilities of meta-governed networks.

More monitoring and evaluation and longitudinal case studies in all sites would have given more in-depth data to track changes over time. According to the presented results, it is clear that fostering capabilities certainly takes more than two years to produce statistically significant changes. Further research is recommended to test capabilities using longitudinal data of at least a 10 year period (Alpkan et al., 2012) to measure the process of emergence of different capabilities over time. We provided the radar tool to show the results on capabilities as innovation pathways, which we hope would be useful as an analytical tool of innovation dynamics.

While network governance had an influence on the capabilities of the innovation networks in which family farms were embedded, the moderately significant results (95%) suggest that governance is not the most crucial factor enabling family farms in developing countries to foster capabilities necessary for exploring and exploiting innovation opportunities. Therefore, differently to how it is in organisations, governance is not *per se* a solution to the paradoxes that exploration and exploitation represent in practice (cf. Volberda, 1998, Stadler et al., 2014). In complex settings like innovation networks in developing countries, governance by itself is unlikely to solve other potentially complex barriers for exploration and exploitation. Therefore we should consider the interplay between network governance and multiple contextual variables over an innovation process. This would allow us to measure more accurately the effect of network governance on fostering capabilities over time.

Each country in our study has its own particular institutional dynamics that may have affected the management of multi-level networks, and therefore the effectiveness to foster capabilities.

In the province of North Kivu in DRC, civil war, lack of trust, limited financial and human resources, absence of a national agricultural extension policy and strategy (Ragasa et al., 2016), and poor basic infrastructure affect the fostering of financial, organisational and knowledge-extension capabilities of the innovation networks. The institutional-political arena—in which major decision making is made— can help or hinder network governance and its effectiveness to foster capabilities for exploration-exploitation. Uganda is characterised by decentralisation, which facilitates mobilisation, possibilities of self-governance, and a political arena created at the district level to participate in the 'politics of development' (Asiimwe and Musisi, 2007). However, this political arena also generates an environment of competition for leadership (Asiimwe and Musisi, 2007), which can undermine processes of fostering capabilities for innovation. For example (Pérez Perdomo et al., 2016) found that agreements made in an innovation platform were insufficient to resolve competing claims between potato growers and pastoralists. According to farmers, the negotiations failed due to a lack of involvement from higher (district) levels of leadership to make agreements operational. As with international organisations that aim to tackle global challenges, the findings of (Pérez Perdomo et al., 2016) indicate the importance of a dual decision making structures in multi-level innovation networks to couple the technical with the political agendas in an adaptive manner (Schemeil, 2013). In Rwanda there are also some counter-productive institutional dynamics that may have influenced the fostering of capabilities. The Rwandan government has been proposing macro-economic strategies, which are expected to eventually benefit a majority of small and poor farmers. However, the promotion of crop specialisation and fertilization associated with those strategies is contrary to the prevailing polyculture system practiced by Rwandan farmers (Dawson et al., 2016). This decoupling of the technical and institutional realms discourages the managerial efforts for fostering capabilities of family farms.

These insights echo other findings on the context sensitiveness of innovation processes, and the importance of institutional environments to foster innovation (Mueller et al., 2013). It is necessary to assess the different technical, institutional, physical and other multiple characteristics of the context, which effect might represent drivers of or barriers to foster ambidexterity of agricultural innovation networks.

We suggest further research on the management of structural challenges of innovation networks through different network governance mechanisms and the importance of context on capabilities for exploration and exploitation. We recommend looking at the context as a mediating factor between network governance and capabilities as outcomes of the innovation process. The context itself is a multi-dimensional concept, and needs to be redefined in order to assess accurately to what extent the context fosters or hinders the governance capability and other capabilities for ambidexterity of innovation networks. This is a key consideration for public management of increasingly international multi-level innovation networks that collectively tackle global challenges.

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Appendix

TABLE 4. BASELINE SURVEY DESCRIPTIVE STATISTICS PER NETWORK TYPE

Type of Network		Exploration / Exploitation	Type of capabilities	Variables	Baseline survey descriptive statistics					
					Type	N	Min 2008	Max 2008	Mean 2008	Sd 2008
Multi-level network	First-order network	Exploration	Organisational capabilities	V1 Member of social groups	Y/N	2207	0	1	0.12	0.33
				V2 Member of production groups	Y/N	2207	0	1	0.12	0.32
				V3 Member of agric. processing groups	Y/N	2207	0	1	0.01	0.08
				V4 Participate in group marketing	Y/N	1398	0	1	0.13	0.34
				V5 Member of cooperative group	Y/N	2207	0	1	0	0.05
				V6 Member of savings and credit groups	Y/N	2207	0	1	0.15	0.36
	Second-order network	Exploitation	Knowledge-extension capabilities	V7 Received agricultural extension visits	Y/N	2207	0	1	0.04	0.20
				V8 Number of received extension visits		2207	0	10	0.08	0.57
				V9 Participated in research demonstrations	Y/N	2207	0	1	0.04	0.20
				V10 Access to market information		1658	0	1	0.78	0.41
		Exploitation	Technological capabilities	V11 Used soil and water technology practices	Y/N	2207	0	1	0.70	0.46
				V12 Used soil fertility technology practices	Y/N	2207	0	1	0.68	0.47
				V13 Used crop management technology practices	Y/N	2207	0	1	0.47	0.50
				V14 Used improved crop variety technologies	Y/N	2207	0	1	0.13	0.34
				V15 Used improved livestock breeds technology	Y/N	2207	0	1	0.04	0.21
		Exploitation	Entrepreneurial capabilities	V16 Have marketing contract with groups or traders	Y/N	1398	0	1	0.01	0.11
				V17 Sold cereal crops	Y/N	2207	0	1	0.45	0.50
				V18 Sold legume crops	Y/N	2207	0	1	0.33	0.47
				V19 Sold roots and tubers	Y/N	2207	0	1	0.15	0.36
		Exploitation	Investment capabilities	V20 Borrowed from informal sources	Y/N	1726	0	1	0.71	0.45
				V21 Borrowed from formal sources	Y/N	1726	0	1	0.07	0.26

TABLE 5. CHANGES IN CAPABILITIES BETWEEN 2008 AND 2010 PER NETWORK TYPE

Type of capabilities	Variables	First-order network governance		Second-order network governance		Multi-level network governance		Most favourable type of network governance
		Mean change 2008 -2010	t-statistic	Mean change 2008 -2010	t-statistic	Mean change 2008 -2010	t-statistic	
Organisational capabilities	V1 Member of social groups	0.16	9.51*	0.12	7.16*	0.10	5.59*	First-order
	V2 Member of production groups	0.08	4.48*	0.03	2.04*	0.07	3.86*	First-order
	V3 Member of agric. processing groups	0.01	1.67	0.00	0.00	0.01	1.51	
	V4 Participate in group marketing	-0.09	-5.41*	-0.13	-7.54*	-0.09	-4.77*	
	V5 Member of cooperative group	0.00	-1.00	0.00	-1.42	0.01	1.89	Multi
	V6 Member of savings and credit groups	0.05	3.05*	0.05	3.10*	0.07	3.81*	Multi
Knowledge-extension capabilities	V7 Received agricultural extension visits	0.10	6.97*	0.10	6.73*	0.12	7.47*	Multi
	V8 Number of extension visits	0.46	6.54*	0.29	4.79*	0.73	5.07*	Multi
	V9 Participated in research demonstrations	0.08	6.32*	0.05	4.21*	0.05	3.39*	First-order
	V10 Access to market information	-0.02	-0.92	-0.05	-1.87	-0.07	-2.31*	
Technological capabilities	V11 Used soil and water technology practices	-0.62	-32.62*	-0.62	-34.13*	-0.63	-31.35*	
	V12 Used soil fertility technology practices	-0.57	-30.05*	-0.55	-28.35*	-0.57	-27.56*	
	V13 Used crop management technology practices	-0.34	-17.50*	-0.30	-15.32*	-0.34	-15.36*	
	V14 Used improved crop varieties	-0.09	-7.57*	-0.13	-9.69*	-0.09	-5.55*	
	V15 Used improved livestock breeds	-0.03	-4.25*	-0.05	-6.00*	-0.04	-4.95*	
Entrepreneurial capabilities	V16 Have marketing contract with groups or traders	0.00	0.82	-0.02	-2.91*	-0.01	-0.82	
	V17 Sold cereal crops	-0.01	-0.29	-0.02	-0.89	-0.06	-2.32*	
	V18 Sold legume crops	0.04	1.78	0.06	2.67*	0.05	1.98*	Second-order
	V19 Sold roots and tubers	0.28	12.00*	0.35	14.78*	0.28	11.78*	Second-order
Investment capabilities	V20 Borrowed from informal sources	0.03	1.06	0.04	1.63	-0.07	-2.56*	Second-order
	V21 Borrowed from formal sources	-0.03	-2.39*	-0.02	-1.20	-0.01	-0.94	

*significant 95%