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Actor roles and linkages in the agricultural innovation system: options for establishing a cocoa innovation platform in Ghana

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ABSTRACT

Innovation platforms promote interactions among actors in an innovation system. Given the importance of the cocoa sub-sector to the Ghanaian economy, having an innovation platform is imperative for increasing innovative performance. Using qualitative data collection tools we obtained in-depth information on the roles and linkages of actors to provide options for the establishment/strengthening of the cocoa innovation platform in Ghana. Findings from the thematic and social network analysis suggest that stimulating the participation of farmer groups, actors in research, extension, policy, and the private sector is important as they have the power to attract and sustain relevant actors to the network and hold the structure of the cocoa innovation platform together. The study contributes to the literature by being the first study that has applied the SNA tool to the cocoa innovation system in Ghana and also by emphasizing the prominent role farmers and private sector actors play in such networks.

KEYWORDS

Agricultural innovation system; social network analysis; linkages; actor roles; cocoa

1. Introduction

This paper seeks to provide options for the establishment and/or strengthening of innovation platforms in the agricultural innovation sector, specifically the cocoa sub-sector in Ghana. The crops sub-sector of the agricultural sector contributes the most – about 68% – to the agricultural GDP, and is further divided into industrial crops; food crops; and fruits and vegetables (MOFA 2017). Some of the key industrial crops include cocoa, oil palm, coconut, coffee, cotton, rubber, and cashew. However, cocoa remains the major agricultural foreign exchange earner for the country and the largest contributor to agricultural GDP (ISSER 2018). Currently, Ghana produces an average of 0.5 mt/ha of cocoa annually, which is far below its potential output of 1.0 mt/ha (MOFA 2017). Since growth in the agricultural sector is largely driven by growth in the cocoa sub-sector, improvement in the structures and systems in the cocoa sub-sector is vital to the entire agricultural sector.

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On the one hand, the productivity growth of Ghana's agricultural sector has been attributed to land expansion, institutional structures, and favourable policy changes (ISSER 2019; Leturque and Wiggins 2011). In addition to the institutional reforms and land expansion, the introduction of technological innovations such as improved seeds has also driven productivity growth in the agricultural sector (Nin-Pratt and McBride 2014). Interventions in the cocoa sub-sector have subsequently spurred growth in the overall agricultural sector of Ghana. For example, the government's cocoa hi-tech programme in the early 2000s saw the promotion of improved technologies such as improved seeds, agronomic practices, and fertilizer application to boost productivity (Aneani et al. 2012). The partial liberalization of the cocoa marketing system was accompanied by growth in the agricultural sector through revenue increases from the sale of cocoa beans (Leturque and Wiggins 2011). These highlight the importance of innovation and institutional reforms in the agricultural sector. Nonetheless, the success of any innovation largely depends on the functioning of a multitude of actors involved in the innovation value chain (Swaans et al. 2014). It is therefore imperative to understand and provide options for strengthening the network of actors in the innovation process through the establishment of functioning structures in Ghana's agriculture.

An innovation platform/network is one such structure designed to promote interactions among actors, which is the impetus of the agricultural innovation system concept. Innovation platforms ensure inclusivity as various groups – including local agents such as farmers who are typically marginalized in the innovation process – are brought together with more powerful actors (Cullen et al. 2014; Swaans et al. 2014). The ineffectiveness of an innovation system drives the formation of an innovation network/platform as actors may require an initial nudge to engage in knowledge sharing (Cullen et al. 2014). Innovation network building in an agricultural system is important for several reasons: It improves information flow, thereby reducing information asymmetry among actors within the network; facilitates the diffusion of innovation; provides access to resources for resource-constrained actors; and builds capacity and social capital of members. This is made possible by the constant interactions among actors, which also potentially encourages behavioural changes in order to meet the expectations of other influential actors (Brown and Roper 2017; Spielman et al. 2011; Weyori et al. 2018). Whereas bringing actors together in a coordinated network allows for improvement in innovative capabilities, Klerkx, Van Mierlo, and Leeuwis (2012) and Wieczorek and Hekkert (2012) posit that improvement is also largely dependent upon the presence of actors and institutions supporting their actions and behaviour.

As the major agricultural export earner for the Ghanaian economy and the greatest contributor to agricultural GDP, the cocoa sub-sector has received significant institutional and technological support from both policy and Research and Development (R&D) organizations. Together with allied institutions such as the Cocoa Research Institute of Ghana (CRIG), the Ghana Cocoa Board is a strong institutional structure created and backed by national policy to support the sub-sector in terms of research, development and innovation. Unlike mainstream research institutions mandated to carry out research and development of various crops, this is one of the few institutions created to address the needs of a specific crop. Yet despite the institutional framework governing the cocoa sub-sector, the structured innovation system in the sector is weak, as there is currently no innovation platform that ensures coordinated interactions among actors.

Without an innovation platform, power imbalances, resource access, inclusivity, and information flow will remain challenging, especially for farmers, the main end-users of innovation. It is therefore important to establish such networks for a sub-sector as essential as cocoa. To address these challenges, the Ghana Cocoa Board is undertaking efforts to establish an innovation platform for the sub-sector. This will also allow farmers to become a part of the decision-making process regarding innovation development.

By analyzing the roles and linkages of actors within the cocoa innovation system in this paper, we attempt to provide baseline information for the establishment of the cocoa innovation platform. Which actor plays which role and how the power relation in the linkages can be used to create and sustain a functioning cocoa innovation platform for increased innovative performance is the central question this study seeks to answer. In so doing, we offer policy options for the establishment of an effective cocoa innovation platform, thereby strengthening the innovation system within the cocoa sub-sector for sustained productivity growth. We also contribute to the body of literature on commodity innovation systems using both qualitative and quantitative measures. Few studies (Essegbey and Ofori-Gyamfi 2012) have been conducted on the cocoa innovation system in Ghana, and none has assessed the linkages among actors using the social network analysis, which makes this study original.

This paper is structured in four sections. Following the introduction in section one, section two presents the literature and conceptual framework for this study. In this section, we review the literature on the concept and application of the agricultural innovation system and situate the conceptual framework on which the study is based on. Section three presents the methodology, describing and elaborating upon the study design, data collection, and analysis methods. The final section (four) presents the results and a discussion of the study in three parts. The first part presents the actor roles; the second part discusses the nature of actors' interactions; and the final part presents the study's conclusions.

2. Literature and conceptual framework

Research on innovation and development processes within the agricultural sector in sub-Saharan Africa (SSA) is influenced by four main concepts: the innovation systems perspective (ISP); value chain and value-chain analysis (VCA); impact orientation; and integrated research for development (IR4D) (Anandajayasekeram 2011; Rajalahti 2012). Whereas some of these concepts have been popular for some time, the ISP is receiving increasing attention as recent studies by scholars researching various agricultural value chains have applied the concept (Adolwa et al. 2019; Kebebe 2019; Muilerman, Wigboldus, and Leeuwis 2018; Weyori et al. 2018). According to Rajalahti (2012), the ISP can incorporate other concepts and hence become a powerful tool in agricultural R&D. An innovation system is defined by Freeman (1987) as the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify, and diffuse technologies. Lundvall (2010) also highlights the critical role that learning and institutions play as components of the innovation system in the diffusion of knowledge. The concept can be specified at the national, sectoral, commodity, or intervention level (Anandajayasekeram 2011). Therefore, the Agricultural Innovation System (AIS) focuses on the interactions in knowledge generation, diffusion, and application within the agricultural sector (Aerni et al. 2015). The AIS also provides a framework

for analyzing complex relationships and innovative processes that occur among multiple agents, social and economic institutions, and technological and institutional opportunities (Aerni et al. 2015; Pound and Conroy 2017).

The multitude of actors and institutions that make up the Agricultural Innovation System have been categorized under various domains in the literature (Anandajayasekeram 2011; Rajalahti, Janssen, and Pehu 2008) depending on the role they play in the system as shown in Figure 1. They include innovation-providing institutions, bridging institutions, and value chain actors (Anandajayasekeram 2011). Rajalahti, Janssen, and Pehu (2008) also provide explicit components of the AIS domains, and these include the demand domain, the enterprise domain, the education and research domain, support structures, and the bridging domain. The demand domain comprises policymaking institutions and consumers of industrial raw materials and food products. These are the actors whose actions and preferences induce the creation of innovation by the supply

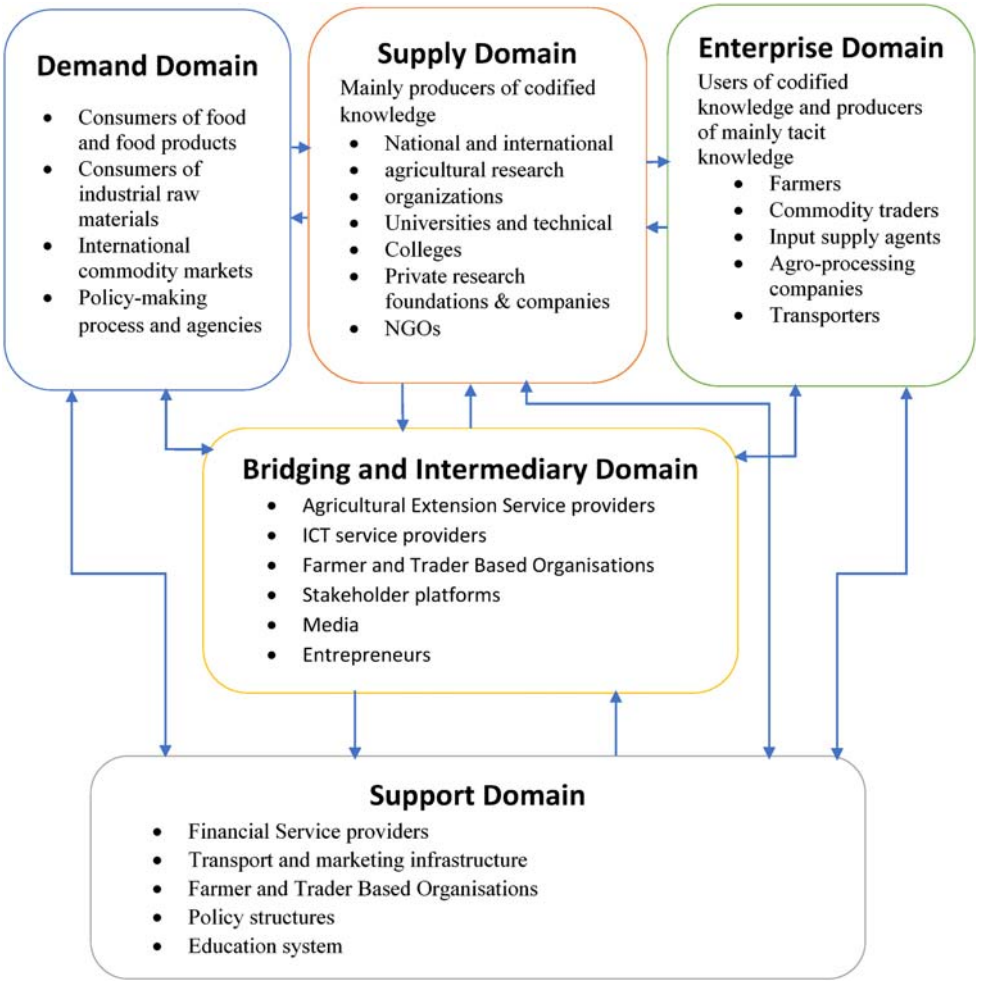

Figure 1. Domains of the agricultural innovation system. Source: Adapted from Anandajayasekeram (2011) and Rajalahti, Janssen, and Pehu (2008).

domain. Similar to the classification by Anandajayasekeram (2011), there is an education/research domain that is synonymous with the supply domain in Rajalahti, Janssen, and Pehu (2008)'s classification. This domain consists of the producers of innovation in a (usually) codified knowledge form.

There is also an enterprise domain where the actors may be both users of codified knowledge and/or producers of tacit knowledge. Key among the actors in this domain are farmers, agro-processors, transporters, input suppliers, and commodity traders (Rajalahti, Janssen, and Pehu 2008). The intermediary or bridging domains are also the actors who form links between all the other domains, and they have an equally important position in the AIS. Some of the actors within this domain include extension agents, stakeholder platforms, farmer and trade-based organizations, Non-Governmental Organizations (NGOs), other private enterprises, donors or development agencies, and ICT service providers. Finally, there is the domain that provides support and without which the functioning of the other domains could be weak and disorganized. The supporting domain actors are the financial institutions, transport and marketing infrastructural systems, educational system, farmer organizations, trade organizations, and policy structures, among others (Rajalahti, Janssen, and Pehu 2008). The unique characteristic about actors of this domain is that they can be both supportive and intermediary, concurrently. This study integrates the domain classification by Anandajayasekeram (2011) and Rajalahti, Janssen, and Pehu (2008) to ensure that the important components of the AIS are captured. The domain classification framework in Figure 1 was adopted in mapping out the roles of the actors in the cocoa innovation system in order to explore their positions and whether some could play an overlapping role in the effective functioning of the system.

Since the agricultural innovation system focuses on linkages/interactions of actors in the execution of their respective roles, the Social Network Analysis (SNA) was adopted to examine network linkages and their power relations in the cocoa innovation system. In this work, the SNA was used as an exploratory tool to gain insight into the nature of interactions among actors comprising the various domains in the cocoa innovation system. The SNA allows for the study of relationships among diverse actors by providing tools with which to visualize, measure, and analyse the relationships (Borgatti et al. 2009). Measures of centrality are used in the network analysis as they indicate the number of connections an actor has with other members, relative to the total number of connections in the network. The higher the scores of each of these measures, the better that actor is connected in the network; this is invariably indicative of how influential or prominent they are in the innovation system. The *in-degree* simply measures the interactions an actor receives from other actors, which also gives a measure of the prominence of an actor in the network. The *out-degree,* on the other hand, measures the extent to which actors can connect to other members in the network (Borgatti et al. 2009). For example, farmers may have a high in-degree score but might not have the same for out-degree, since they are mostly at the receiving end of interactions. Actors with high out-degree measures are considered influential (Borgatti et al. 2009). *Coreness* is the degree of closeness an actor is to the network core, while the measure of how big an actor is in the network is given by the *effect size*. The effect size measure identifies what is referred to as 'structural holes', which are weak connections (fewer interactions) between subgroups who are densely connected in the network (Borgatti et al. 2009;

Freeman 2004). *Betweenness* simply measures the degree to which an actor serves as a bridge in the innovation system. The level of unequal distribution of network influence and interaction is given by the overall network *centralization index*.

The AIS concept has been applied in varied ways, including assessing production efficiency, adoption decisions, value chains, and platform participation. Mekonnen et al. (2015), in examining the effect of AIS in developing countries' agriculture, found that knowledge production and transfer roles of actors increased the efficiency of agricultural systems. In studying the adoption behaviour of farmers, Weyori et al. (2018) found that closer linkages between farmers, research, and extension actors increased the adoption of improved practices. Adolwa et al. (2019) also observed that farmer-to-farmer linkages increased the adoption of integrated soil fertility management, compared to farmers with no linkages. In terms of its application to value chains, the work of Pietrobelli and Rabellotti (2011) emphasized the need to open up the innovation system concept to international knowledge. This, they projected, would reduce the transactional complexities in global value chain governance. Swaans et al. (2014) also note that innovation system actors (brokers) are vital in driving the innovation process, due to the weak linkages among livestock value chain actors in the countries studied (India and Mozambique).

In assessing platform participation using the AIS concept, Suchiradipta and Raj (2015) found farmers and extension agents to be the key stakeholders in a rice intensification system. Even though farmers were key stakeholders in the network, they were found to be excluded from decision-making at the top level, which is typically a characteristic of agricultural systems in developing countries. van Rooyen et al. (2017) however advocated for the inclusion of non-traditional stakeholders in such platforms to work on mutually agreed goals. The works of Essegbey and Ofori-Gyamfi (2012), and Spielman et al. (2011) have also provided an understanding of actor roles and linkages within the agricultural innovation system based on a commodity or an actor performing a specific role. Wood et al. (2014), in their study of farmer knowledge exchange, found that the call for specific actors, such as professional expertise, in any network should be carefully considered. This is because they may not necessarily play an overarching role in innovation systems when it comes to the flow of knowledge and connections. For example, in their study, farmers were more likely to share knowledge in networks in which they played an active facilitating role than in networks facilitated by other actors. This implies that it is important for the proper functioning of the system to assess each actor's strength and power in a given network before the assignment of lead roles. Swaans et al. (2014) similarly warn about the need to take into account different institutional structures in the assessment of network platforms.

The empirical evidence from these studies indicates how roles of actors are key in the functioning of the AIS. Whilst studies on AIS mostly apply the qualitative approach in both design and analysis, there have also been attempts to use both qualitative and quantitative procedures to analye the different dimensions of the system, as observed in Krishnan and Foster (2018); Aguilar-Gallegos et al. (2015); and Spielman et al. (2011). This study employs the latter and builds on the argument of Wood et al. (2014) and Swaans et al. (2014), who posit that certain actors may not influence the interaction in a network in the way that is presumed, and therefore specific institutional contexts should be carefully assessed. Assessing the cocoa innovation system through the use of

thematic and social network analysis thus offers specific options for the strengthening of the sub-sector.

3. Methodology

3.1. Study design and areas

The study design was qualitative with the use of qualitative data collection methods, including key informant interviews and focus group discussions. However, a mixed-method approach was employed to analyse the roles and linkages of the actors in the cocoa innovation system. The qualitative design enabled the collection of in-depth information, which is necessary for understanding actor roles in a network. The quantitative analytical approach was chosen in order to identify actors' power relations, given their respective roles in the cocoa innovation system. This was done using the Social Network Analysis by building relational data described further in this section.

Since the study involved multiple actors in different locations, the selection of study areas was based on the location of the various actors. For interviews with non-farmer actors, the Greater Accra, Ashanti, and Eastern regions were the areas visited. Most of the interviews, however, were conducted in Accra (Greater Accra region), since a majority of the key actors had their Headquarters or operational offices located in Accra. Interviews outside Accra included those with extension officers (Eastern and Ashanti regions) and the Cocoa Research Institute of Ghana (Eastern region). The Suhum Municipality in the Eastern region and the Sekyere Central district in the Ashanti region were selected as case study areas for the farmers' interviews. The Sekyere Central District and Suhum Municipality are known for their significant cocoa production (MOFA 2019a; MOFA 2019b). These sites were also selected based on their proximity to a key research institution in the cocoa sector. The reason for this was that the proximity of a key institution was assumed to influence its ability to trigger some level of actor interactions with farmers. The Cocoa Research Institute of Ghana (CRIG) is located in the Suhum Municipality, and so the Sekyere Central District provided a comparative case.

3.2. Data collection approaches

Interview guides were designed and used to obtain relevant data using key informant interviews and Focus Group Discussions (FGD) with actors. Questions asked in the interviews broadly pertained to actor roles, their mode of operation, and their connections. Where participants were not familiar with the AIS concept, an explanation was given before the interview proceeded. All interviews and discussions were recorded with the consent of participants, using a recorder, field notes, and memoirs. Actors identified in the demand, supply, bridging, and support domains, in addition to some from the enterprise domain (except farmers) were purposively considered for the key informant interviews. Farmers, as part of the enterprise domain, were included in focus group discussions. The choice of the data collection approaches used for farmers and the other actors was based on their respective functions. With the exception of farmers, all other actors performed different functions, and hence it was necessary to interview them individually in

key informant interview sessions in order to obtain in-depth information on each function. The selection of actors was generally based on the five main domains of the agricultural innovation system, as presented in the conceptual framework. At least two actors (or institutions) from each of the domains were selected for an interview. Before key informants were selected, request letters were sent to the Heads of the various institutions, who subsequently nominated personnel to grant the interview. A total of 12 key informant interviews were conducted for the study, with details shown in Table 1.

On the other hand, focus group discussions were chosen for farmers, since they all played the same production role. The focal farmer criteria as used in Weyori et al. (2018) was adopted for sorting farmers into the groups. Focal farmers used in this context were the leaders of the various farmer groups in the areas visited. They were the 'go-to' farmers for information on innovation, since they represented farmers on platforms. Where triangulation of some of the key informants' responses was needed, the focus group participants were asked to provide that. The extension officers in the areas visited assisted the research team in identifying the members of the various farmer groups, since they worked directly with them. The farmer group members were then asked who their focal farmers were, which they identified. Each community had two farmer groups and each group had five leaders. Therefore, ten (10) participants were selected for each of the FGDs, bringing the total number of participants to 20. To allow farmers to express themselves without fear or favour, it was ensured that the FGDs took place in the absence of the extension officers. Data collection was conducted between July and September 2019, based on the availability of the key informants. The FGDs however lasted for only two days in the month of August.

3.3. Data analysis

Thematic analysis based on the AIS domain framework in Figure 1 was used to provide a descriptive analysis of the roles of actors in the cocoa innovation system. Data from the field interviews were transcribed and coded to generate the themes for the analysis of the actor roles as shown in Table 2. Where applicable, quotes from participants were used to support the discussion of findings.

Table 1. Details of key informants.

No.	Institution/Organisation	Position of Key informant	AIS Domain represented
1.	Ghana Cocoa Board	Research Manager	Demand/Support
2.	Cocoa Research Institute of Ghana	Principal Research Scientist	Supply
3.	Cocoa Health and Extension Directorate	Principal Technical Officer	Bridging
4.	Cocoa Health and Extension Directorate	IT Manager	Bridging
5.	Esoko	Content Manager	Supply/Bridging
6.	Forum for Agricultural Research in Africa	Lead Specialist: Innovation Systems and Partnerships	Supply/Support
7.	Yara Ghana limited	West Africa Agronomist	Supply
8.	Solidaridad Ghana	Programmes Manager	Supply/Support
9.	Agricultural Development Bank	Head, Agricultural Services Department	Support
10.	Crops Services Directorate, Ministry of Food and Agriculture	Assistant Director	Demand/Support
11.	Suhum, Suhum Municipality	Extension officer	Bridging
12.	Nsuta, Sekyere Central District	Extension officer	Bridging

Table 2. Codes and themes for the analysis.

AIS Domain	Themes	Codes
Demand	Policy support role	Setting development agenda, providing institutional structures
Supply	Innovation development	Cocoa hi-tech programme, development of improved seeds, improved agricultural practices, cocoa rehabilitation
Enterprise	Utilisation	Adoption of improved seeds and ICT services, practice of hand pollination and pruning
	Marketing	Input supply services Produce buying companies
Bridging	Liaison Dissemination	Extension services, farmer-to-farmer linkage digital services
Support	Funding Coordination/ regulatory	Assessment of innovations Financial support

In interpreting the qualitative information collected by means of interviews, the social network analysis (SNA) was employed in an exploratory/descriptive manner. This allowed us to characterize the attributes of actors, including their power relation in performing the roles identified in the system and their degree of connectivity with other actors. Data for the cocoa innovation networks were compiled in a square (nxn) matrix of actors. If there is a relation between actor i and actor j, the matrix element is given a value of 1; n_{ij}=1 or n_{ji}=1. However, if there is no relationship, it is assigned a value of 0; thus n_{ij}=0 or n_{ji}=0. The relationship is not symmetric, however, as n_{ij}=1 does not imply n_{ji}=1. This is important in establishing forward and backward linkages as a measure of who is influential or prominent in the network. In SNA, actors are referred to as nodes and the links between them are referred to as ties. The size of the node (actor) indicates the strength of the actor's connectedness in the network. The measure of centrality is important in network analysis as it indicates the number of connections an actor has with other members, relative to the total number of connections in the network. The Freeman degree of centrality (C_d) is measured in the equation as:

$$C_d(n_i) = \frac{\gamma_i(n_i)}{N-1}$$

where n_i is the node or actor of interest; γ_i is the number of ties to actor n_i; and $N-1$ is the size of the network, N, less the node of interest. The centrality indices used in this work included the in/out degrees, coreness, betweenness, and effect size as used by Weyori et al. (2018) and Spielman et al. (2011).

The UCINET software was used to draw the network maps and estimate the measures of centrality. A full network analysis was conducted since the focus of this study was not specifically one actor (e.g. farmers) but the entire network of actors in the cocoa innovation system.

4. Results and discussion

4.1. Thematic analysis of actors' roles and domains in the cocoa innovation systems

The key actors found in the cocoa innovation system are embedded within the conceptual framework of the study and presented in Figure 2. It can be observed that aside from

the Ministry of Food and Agriculture (MOFA) and the Ghana Cocoa Board (COCOBOD) who played roles in both the demand and support domains, all other actors played specific roles in their respective domains.

4.1.1. Policy support role (demand domain)

The Ministry of Food and Agriculture (MOFA) is the main policy institution responsible for promoting agricultural development in Ghana through the creation of an enabling environment for sustainable growth in the agricultural sector (MoFA 2007). However, although MOFA coordinates all agricultural policy issues, it was revealed that COCOBOD was specifically responsible for setting policy agenda in the cocoa sector. This was intimated by the Research Manager of COCOBOD: '… *management also set a policy agenda to be followed*… '. The agenda includes productivity and welfare enhancement which other agencies/departments in the cocoa sector are required to follow through on. With a very minimal oversight by MOFA, COCOBOD is solely

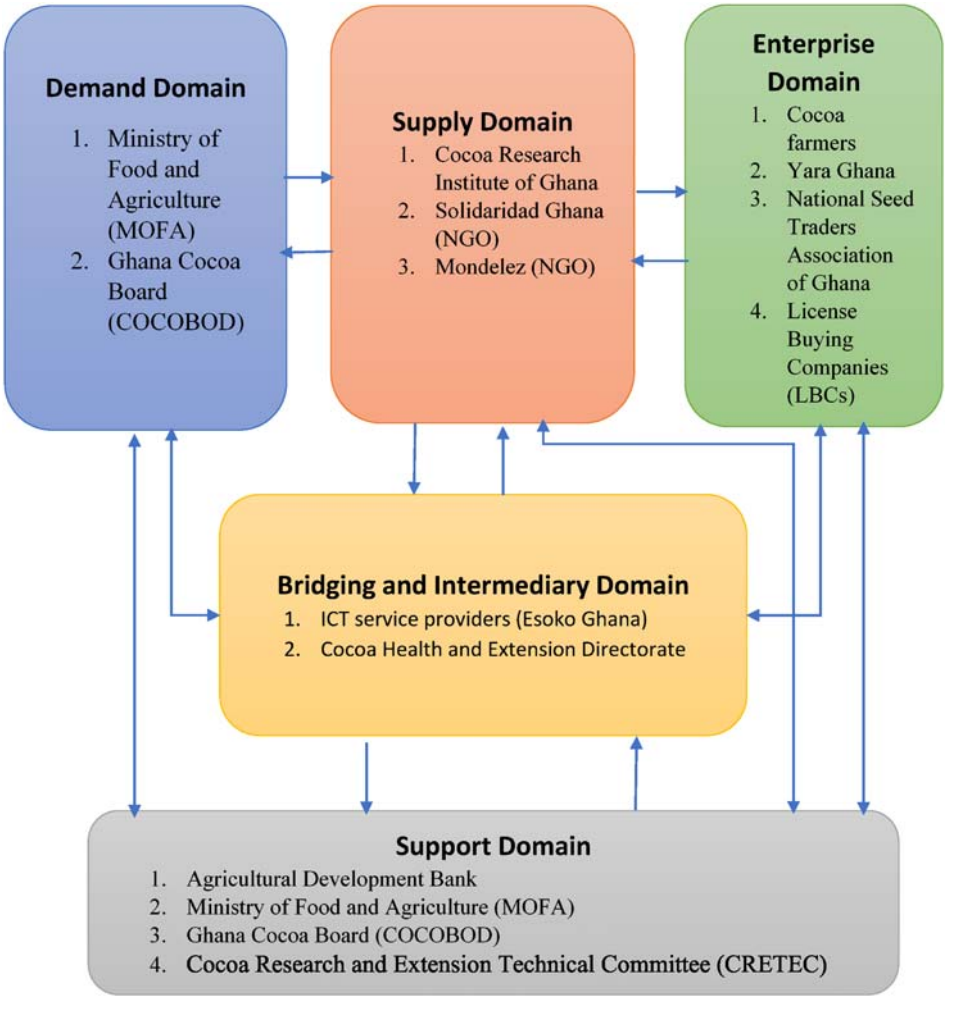

Figure 2. Actors and domains in the cocoa innovation system. Source: Field interviews (2019).

responsible for all policy directions, from the production to the marketing of cocoa. The autonomy given to COCOBOD positions them to play a pivotal role in the demand domain of the cocoa innovation system. With this autonomy, they can draw up sector-specific targets required for improving the innovative capabilities of actors and institutions in the sector, which has also been highlighted in the work of Essegbey and Ofori-Gyamfi (2012). From the interviews, there appeared to be considerable public sector support for the cocoa sector, compared to other agricultural sub-sectors, which has been noted by the farmers interviewed. '*If we take food crops like we take cocoa in this country, it will help all of us*'. One key informant also reiterated, *'Cocoa has been given a lot of attention and so we would have expected that they could set the pace for establishing innovation platforms in Ghana*' (Assistant Director, MOFA-CSD). The position and role of the Ghana Cocoa Board in setting policy agenda for the cocoa sector could be leveraged to lead in the establishment of an innovation platform to encourage interaction and build capacity for innovative performance. It was therefore encouraging when it was found that efforts are being made to establish a cocoa innovation platform as indicated by the key informant at COCOBOD. '*We need the platform so we are trying to operationalise the Ghana Cocoa Innovation Platform to begin working*'.

4.1.2. Innovation development role (supply domain)

The main R&D actor producing and managing innovations in the cocoa sub-sector was found to be the Cocoa Research Institute of Ghana (CRIG). They are mainly responsible for the generation of innovations with support from private and non-governmental agencies such as Solidaridad West Africa and Mondelez International as seen in Figure 2. Aside from developing improved varieties, CRIG has several programmes that support farmers in improving their agricultural practices. Some of these programmes include Cocoa Hi-Tech; the cocoa disease and pest control programme; hand pollination; pruning; and general best agricultural practices. CRIG had the sole mandate for developing new and improved seeds for farmers. CRIG can therefore be considered the backbone of the cocoa sector in the development of innovations. This was echoed by a key informant at the COCOBOD head office indicating, '*In the cocoa sector, the innovation system starts with the CRIG because they are our backbone*' (Research Manager, COCOBOD). Private sector actors, particularly NGOs, have been very instrumental in the supply domain. The role of these non-governmental actors was mainly the design of programmes in promoting the adoption and practice of innovations and best agricultural practices. The cocoa sector enjoys private sector participation, as a participant expressed, '*We have a long-standing relationship with CRIG through the cocoa rehabilitation programme. We also develop programmes for farmers focusing on adopting best agricultural practices*' (Cocoa programme manager, Solidaridad Ghana). Lambrecht and Ragasa (2018) also found active private sector participation in the agricultural sector of Ghana, especially under the contract farming schemes. The role of private sector actors in the innovation development role has also been acknowledged by COCOBOD, as the efforts towards establishing the cocoa innovation platform are in collaboration with the private sector. According the informant at COCOBOD: '*The proposed structure of the cocoa innovation platform has the private sector as a co-chair*'. This, he indicated, is to promote active private sector participation in building and sustaining the platform.

4.1.3. Utilization and marketing role (enterprise domain)

From Figure 2, cocoa farmers, input service providers, and buyers of cocoa were the main actors identified in performing the utilization and marketing role in the enterprise domain. In the enterprise domain, it was found that farmers interacted closely with input service providers and buyers of cocoa.

4.1.3.1. Utilization. It was found during the focus group discussions that several innovations were being used by farmers, including informational, production, and post-production innovations. However, production innovations were more frequently used by farmers than any other category of innovation along the value chain. Farmers used improved seeds and practiced hand pollination, seed selection, and improved pruning approaches, which they attested have been beneficial. Post-production innovation and informational innovation, however, were not commonly used by the selected farmers. Few (10%) of the farmers in all the focus groups indicated they had agriculture-related ICT services on their mobile phones. The challenge identified was the low level of awareness of ICT services by farmers. The farmers who were privileged to have access to such services were introduced to them through project interventions led by actors in the supply domain. The Coco-life programme by Solidaridad and Mondelez was repeatedly mentioned by the farmers as one of the interventions they have benefited from, again putting a spotlight on the role of the private sector in the cocoa innovation system. The intervention sought to promote sustainable cocoa production through innovative practices by farmers.

Interestingly, though farmers have been usually considered users of innovation, they also played a role in generating local knowledge for production activities. This could account for the increasing literature on farmer-led innovations, as seen in Tambo and Wünscher (2018), Baliwada et al. (2017); and Dolinska and d'Aquino (2016). With local knowledge and experience, farmers reported their ability to conduct seed selection as intimated by the FGD participants: '*When the tree fruits to 1–2 feet, the fruits below are exactly like the agric*[1] *ones, so you take those seeds and nurse them for production and it yields the same output as the agric ones*' (FGD Cocoa, Eastern region). Therefore, although the selected farmers served as users of innovation in the enterprise domain, they also served as potential actors in the supply domain using their local knowledge to generate local innovations for utilization. This suggests that when the innovative capacities of farmers are built, they could play several roles in the AIS domains. It also allows them to play an active role in the system instead of being primarily on the passive side as observed by Wood et al. (2014). This could lead to easy acceptance and use of innovations to increase productivity in the sector. Having an innovation platform of which farmers form an integral part can be a way to build their innovative capabilities.

The study further revealed trust and confidence between the selected farmers (enterprise domain) and actors in the supply domain as opined by the participants, '… *and we know CRIG has been working to give us good cocoa seeds, so anytime we are introduced to new seeds, we do not hesitate*' (FGD, Eastern region). '*we know the researchers will not give us anything bad that will harm our crops …* ' (FGD, Ashanti region). Trust is very important for the functioning of a system, as captured in the work of Webber and Labaste (2009) and hence knowing that the selected farmers have built trust in the supply

domain actors is encouraging. Thomas, Riley, and Spees (2020) also underscore how trust and social capital are important for knowledge sharing as evident in this study.

4.1.3.2. Marketing. The input and output marketing function is one of the solid pillars of the innovation system as it promotes exchanges within the system (Mekonnen et al. 2015). Input dealers were found to be playing key roles and were sometimes referred to as '*farmers' doctors*' by the farmers. The input supplied included seeds, fertilisers, agrochemicals, mechanized equipment and other tools. For output marketing roles, the Licensed Buying Companies (LBCs) were the main outlets for cocoa farmers. This provided guaranteed markets for cocoa farmers, which could potentially trigger the adoption of a productivity-inducing innovation generated by the supply domain actors. The issue of standards and measurement also arose as one of the weaknesses in the functioning of cocoa market actors, as expressed, '*They are cheating us with the scale they use. It is not accurate at all … '* (FGD, Eastern region). Efforts are consequently being made by the government to eliminate the manual scales from the system and replace them with digital ones, according to the extension officers interviewed. This will ensure the farmers receive what is due to them, further bridging the trust gap between farmers and marketers. In addition to the government's intervention in markets, private sector platform support towards market access is also encouraged, which is also emphasized in Liverpool-Tasie et al. (2020).

4.1.4. Liaison and dissemination role (bridging domain)

Knowledge management, primarily carried out by actors in the bridging domain, is essential for the proper functioning of any system as indicated by Kimble (2013). Extension agents, ICT service providers, and Farmer Based Organisations (FBOs) were the key actors identified in this role (Figure 2). Two categories of extension service providers were identified: the MOFA extension agents and the COCOBOD extension agents. However, only the COCOBOD extension agents under the Cocoa Health and Extension Division (CHED) handled cocoa farmers. It was revealed that the separation of cocoa extension from the general agricultural extension service provided by MOFA occurred to meet the specific needs of cocoa. This was found to have been necessitated by the prevalence of the cocoa swollen shoot disease bedevilling the cocoa sector. The role of extension in the innovation system was identified as the dissemination of new technologies, disease/pest control, and the provision of training on Good Agricultural Practices (GAPs).

Regarding the linkage of extension agents, farmers who were closer to actors in the supply domain expressed greater satisfaction with their level of interactions with extension agents than those further afar. For example, cocoa farmers in the Eastern region, where the Cocoa Research Institute is located, expressed great satisfaction with the extension services being received, as intimated by the participating farmers in the focus group discussions: '*… as for the extension officers, they are very effective. They come to the farms themselves and teach us … '* (FGD, Eastern region). The participating farmers in the Ashanti region, however, had this to say: '*we cannot say they are not doing much but they can do more by visiting and following up on us frequently*'. This suggests that the existence of certain actors in one domain could trigger the intensity of interaction with others from different domains for the effective functioning of the system. This

confirms the earlier assumption made in the selection of study sites, as the presence of the Cocoa Research Institute of Ghana is seen to trigger stronger interactions between farmers and extension service providers.

Farmer Based Organisations (FBOs) also served as links for the engagement of other actors with farmers. During discussions with the selected farmers, it was revealed that most of the FBOs they belonged to were formed either by an NGO or extension officers. There were also instances where the farmers themselves formed groups to benefit from an intervention, or for self-help activities, evident in the following quotes. '*The coco-life team and the extension officer put us together in groups*' (FGD, Eastern region) The challenge with this nature of farmer-to-farmer linkage is its sustainability, especially when the perceived benefits are realised or the intervention expires. It was also observed that due to the strong presence of extension service providers in the cocoa communities in Eastern region, the formation of cocoa FBOs was prominent. Extension actors, therefore, played a stronger linking role among the actors in the system. Taylor and Bhasme (2018) also note the benefits that the embedded relationship between extension agents and model farmers presents in terms of knowledge diffusion and provision of feedback loops. Farmers also served as a source of information on innovation as indicated by this quote: '*We share information amongst ourselves so if one of us hears about any innovation, he/she passes the information across'* (FGD, Ashanti region). '*when we hear something new has come, we tell our colleagues to also try it*' (FGD, Eastern region).

The new digital age also provides a platform for interaction among actors. ICT digital platforms are created to bridge the gap among actors through the dissemination of information. In an attempt to solve the extension delivery challenges, Esoko and other related ICT firms have developed technologies that seek to serve as e-extension tools for farmers. The content manager of Esoko suggested, '*we break the scientific knowledge down and translate it into simple language so that absorption and understanding by the farmers will be easy*'. This they achieve through linkages with actors in the demand (MOFA) and supply (CSIR) domain by providing up to date information regarding new technologies that need to reach farmers. These linkages are key in bridging the demand-supply-enterprise divide in the innovation system to allow for lucid information flow. The promotion of digital platforms will hence go a long way to increase information access regarding innovation and speed up efficiency in extension delivery and productivity. This has also been observed in the works of Sørensen, Kateris, and Bochtis (2019) and Asenso-Okyere and Mekonnen (2012), where ICT played a key role in information delivery and subsequently increasing agricultural productivity. However, only about 25% of the participating farmers knew of these tools, whilst only 10% used them to access weather and market information. This indicates that more effort needs to be put into reaching out to farmers with these tools to help bridge the information asymmetry gap within the agricultural innovation system.

4.1.5. Funding and coordinating/regulatory role (support domain)

Actors in the finance function role included international development agencies; Ministry of Finance; MOFA; Agricultural Development Bank (ADB); and the rural and community banks (Figure 2). The study, however, revealed that most of the funding responsibilities for activities in the sector (including cocoa) were being handled by

government, international development and donor agencies. Local financial institutions played a minimal role in funding innovation activities. It was found that the government of Ghana established the ADB in a bid to improve access to agricultural finance. The bank's total lending portfolio to agriculture was reported to be about 30%, the highest among all universal banks in Ghana, as noted by one of the key informants; '*ADB's lending portfolio to agriculture is about 30%, which is far higher than any other commercial bank in Ghana*' (Key Informant, ADB). Farmers used in this case study, however, reported difficulty in accessing finance from lending institutions including the ADB because of the lack of proper collateral. Some key informants also had this to say: '*Funding has been a big challenge since it forms the core pillar innovation platforms* (Research Manager, COCOBOD). *A lot of these platforms have collapsed or remained dormant because of funding*' (Key informant, CRIG). However, it was reported that ADB supports innovative initiatives in the sector as they are currently in the process of establishing a platform with other financial sector players, farmers, aggregators, and other actors of the value chain. The Ghana Stock Exchange is also part of the platform, where they will run the warehousing and receipt systems. This, they indicated, will ensure product quality and generate higher value for the farmer.

In terms of regulation and coordination, the COCOBOD and the Cocoa Research and Extension Technical Committee (CRETEC) played this role. CRETEC provides a platform for scientists and extension officers to discuss problems and proffer solutions, as evident in this quote; '*In recent times, the major innovations are from the recommendations of CRETEC … '* (Research Manager, COCOBOD). For any technology developed by the supply domain actors of the cocoa innovation system, an assessment and recommendation from CRETEC are required before it can be released to the market. These regulatory roles are important in sustaining networks, especially regarding information flow and service quality as highlighted in the work of Hauck, Schmidt, and Werner (2016).

The next sub-section discusses the linkages and power relation of actors in the performance of their specific roles in the cocoa innovation system. The social network analysis complements the qualitative analysis and allows additional insight into the nature of the actors' interactions and their power relations, which are important to consider when setting up an innovation platform.

4.2. Actor linkages in the agricultural innovation system

4.2.1. Actor-network mapping in the cocoa innovation system

The network analysis presented in Figure 3 reveals that in the cocoa innovation system, extension actors from CHED had the highest number of ties with other actors in the system, confirming their important role in the bridging domain as discussed earlier. This implies that they provided more connections than any other actor in the cocoa innovation system.

FBOs (bridging domain) and international financial institutions (support domain) were the next set of actors that had many connections in the system, signalling their level of interactions. CRIG (supply domain), Licence Buying Companies (LBCs) (enterprise domain), COCOBOD (demand and support domain), and Solidaridad (supply domain), an international NGO also fulfilled some level of linkages in the

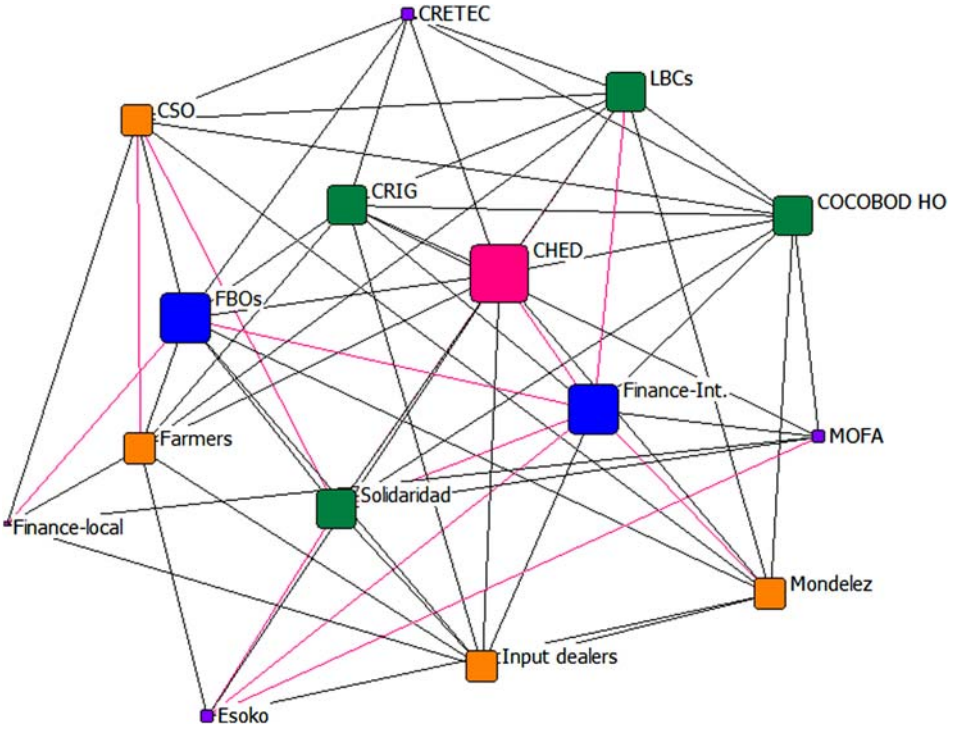

Figure 3. Network mapping in the cocoa innovation system. Source: Field interviews (2019).

system. On the other hand, some of the actors worth mentioning with the fewest ties were local financial institutions and the main agricultural policy support institution, MOFA. The weak ties of MOFA in the cocoa innovation system could be because the cocoa industry has been made to operate semi-autonomously, with full policy directions and strategies placed in the remit of COCOBOD. This therefore does not imply a weakness in the system, since COCOBOD plays that policy support role. CRETEC is an important body in the interaction of actors in the cocoa sector, but they only connected to a few of the core actors, which hence explains why they lie on the periphery.

There were more reciprocal than non-reciprocal linkages in the cocoa network. This implies that actor interactions in the cocoa innovation system have more forward and backward linkages, as opposed to a unidirectional one, which a merit for a dynamic system. Actors in the support, supply, enterprise, and bridging domains such as COCOBOD, CRIG, LBCs, CRETEC, and CHED, respectively had bi-directional linkages with each other, but the same cannot be said of financial service actors and ICT service providers (Esoko). It is important to note that though international financial institutions had a good number of linkages in the network, more of them were non-reciprocal, and hence weak bi-directional linkages. The position of local financial institutions at the periphery of the network, with fewer connections to other actors, confirms the findings of Nkegbe (2018) on how agricultural financing continues to remain a major challenge in Ghana's agriculture.

4.2.2. Power relation in the cocoa innovation system

Further analysis using the centrality measures revealed that extension actors (CHED) had the highest out-degree score, with FBOs having the highest in-degree score as presented in Table 3. This implies that extension service providers in the cocoa network are the most influential, as they initiated more interactions than they received from other actors. It can hence be inferred that extension agents in the bridging domain of the cocoa innovation system are a key source of information on innovations. FBOs (bridging domain) are also the most prominent in the cocoa network since most interactions from other actors come to them, rather than individual farmers. This finding supports the literature pointing to the important role that group cohesion and extension delivery play in the agricultural innovation system.

This suggests that group cohesion fosters interactions and linkages in networks, compared to singular actions, similarly observed by Uckert et al. (2017). This was also reinforced by the measure of betweenness, with extension serving as a bridge to all other connections. Weyori et al. (2018) in their study also found focal farmers serving as a bridge to other actors. The second bridging actor was COCOBOD (support and demand domain) which it is not unexpected, given their active involvement in the cocoa industry as described in the previous sub-section. This implies that policy actors in the support and demand domains, and extension in the bridging domain, could serve as a bridge connecting all other actors in the cocoa network.

Extension (bridging domain) and research actors (supply domain) also formed the core of the cocoa innovation system. This quantitative measure, therefore, supports the qualitative claim that the cocoa innovation system begins with the cocoa research institute. In the same manner, Essegbey and Ofori-Gyamfi (2012) identified the research role as central to the cocoa innovation system, but argued that it required a stronger linkage with policy actions and other actors. NGOs, local financial institutions, MOFA, and ICT service providers in their respective domains formed the network's periphery. The removal of Solidaridad (NGO) from the supply domain, extension services and farmer groups, both from the bridging domain, would create weaker connections[2] where actors may focus on their individual roles instead of a collective interactive role

Table 3. Network centrality measures in the cocoa innovation system.

Actor	Out-degree	In-degree	Betweenness	Coreness	Effect size
CHED	71.43	64.29	13.78	36.00	5.58
CRIG	64.29	64.29	9.72	35.00	4.77
COCOBOD HO	64.29	64.29	11.01	32.00	4.89
Finance-international	64.29	35.71	3.57	30.00	4.82
LBCs	57.14	57.14	6.19	29.00	4.84
Input dealers	57.14	57.14	8.07	28.00	4.50
FBOs	57.14	71.43	8.72	28.00	5.69
Farmers	57.14	50.00	9.07	26.00	4.73
Mondelez	50.00	57.14	7.01	24.00	4.67
CRETEC	42.86	42.86	1.58	23.00	2.50
Solidaridad	50.00	50.00	5.59	21.00	5.50
CSO	42.86	57.14	7.05	19.00	4.57
MOFA	42.86	35.71	4.88	18.00	3.91
Finance-Local	35.71	28.57	3.43	15.00	3.33
Esoko	21.43	42.86	2.33	11.00	4.06
Network centralization	20.92%				

Source: Field interviews (2019).

in the network, as suggested by their high effect size compared to other actors. This implies that these actors hold the structure of the cocoa innovation system together, and if they were absent, several other actors would be lost in the network. Farmers would therefore receive fewer interactions from other actors without their presence in the network. Spielman et al. (2011) also found farmers and NGOs to be potential sources of structural holes in the Ethiopian AIS. This implies that though farmers may not have a strong voice in the innovation system, they are central to the functioning of the system.

5. Conclusion

The study concludes that there are differences in the roles and positions of actors in the cocoa innovation system. Whilst most of the actors played specific roles in the cocoa innovation system, policy actors played a more heterogeneous role in the network. In setting an innovative development agenda for other actors to carry out, they also provide strong regulatory and coordinating support for the system. The role of government in providing policy support structures is therefore important for the functioning of the cocoa innovation system as Cullen et al. (2014) have indicated how powerful government actors are in a network. Since the Ghana Cocoa Board has a strong policy support structure, it is imperative to ensure that it has a lead role in the establishment of the cocoa innovation platform. ICT and extension services providers played a complementary role improving information access. It is also worth highlighting that farmers were found to be generating innovations using local knowledge, although they are mostly considered users of innovation. The local innovative capacity of farmers can further be developed with the establishment of the cocoa innovation platform if they are recognized as key actors that produce innovations, not just users. Therefore, the participation of farmers in the cocoa innovation platform should be keenly considered in the design of the platform's structure, as they could play roles in both supply and enterprise domains. They should also be allowed to play an active role on the platform, as that encourages both their acceptance and use of innovations and the diffusion of the local knowledge and innovations they develop.

In terms of overall governance, in order to create and sustain a stronger innovation platform towards the strengthening of the cocoa innovation system, extension and policy actors should be central, as they are identified as having the power to connect several actors to the network. Private sector participation, especially non-governmental organizations, also plays a governance role and should be stimulated as they (together with extension actors and farmer groups) have the potential to hold the structure of the cocoa innovation platform together. Thus empowering non-governmental organizations (private sector) as well as actors involved in research, extension, and policy, is important, as they all have the power to attract and retain relevant actors to the system. Since local financial institutions are at the periphery of the cocoa network, which confirms how the lack of finance is a major constraint on the developments of an AIS, bringing them fully onto the platform is imperative. This will promote engagement with farmers and other actors, since funding has been a challenge to innovative performance.

The study contributes to the literature as the first study that has applied the SNA tool to the cocoa innovation system in Ghana. The role and influence of farmers and extension actors in the innovation system, as established in previous studies, is emphasized in this study. This study has also brought to light the significant role private sector actors can play in promoting stronger and collective connections in the cocoa innovation platform. This suggests that as farmers are made an integral part of the platform, private sector actors should likewise be positioned on the cocoa innovation platform.

Notes

1. The term '*agric*' is used by farmers to refer to improved crop varieties developed by research institutions.
2. These weaker connections are referred to as structural holes in SNA.

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