THE ROLE OF SYSTEMS OF INNOVATION TO ADAPT TO CLIMATE CHANGE: 
THE CASE OF KENYAN COFFEE AND DAIRY SECTORS

ABSTRACT

Research on sectoral systems of innovation has paid little attention to adaptation to climate change, notably in agriculture. This article, therefore, explores the role of systems of innovation in adapting to climate change. It focuses on two case studies in the Kenyan agriculture, i.e. coffee and dairy sectors, which differ in terms of stakeholders and institutional setups. In the coffee sector, the actors’ system is highly centralized and the system of innovation is oriented towards technology development. By contrast, a diversity of actors makes-up the dairy sector, and its system of innovation is based on institutional building and marketing. The capacity to innovate and adapt, therefore, depends on institutional arrangements in addition to the technology development, suggesting that the dairy in Kenya could be an example for the coffee sector.

Keywords: Climate Change, Coffee Sector, Dairy Sector, System of Innovation, Central Kenya

JEL Code: 030, 031,033
1. INTRODUCTION

The impacts of climate change on economic growth are still under debate. Some consider that climate change could be an opportunity for economic growth, while others argue that it will lead to slow-growth economy or even de-growth. However, this debate must take into account regional differences: in the Northern hemisphere colder regions, climate change could have positive effect on production, while in the tropics it is expected to substantially reduce economic growth (IPCC, 2014). In Africa and Latin America, for instance, maize production is expected to decline, which would be a cause a loss of $2 billion per year as of 2055 compared to the current production (Jones & Thornton, 2009).

These impacts will be more important as the Green House Gas (GHG) emissions increase. However, in all cases, adaptation strategies are necessary. Decisions on adaptations need to take into account the ever changing climate because of two main reasons: first, future uncertainty challenges the use of available technologies as latter are designed for current challenges (Iglesias et al., 2011). Secondly, the rate of climate change calls for flexibility in new infrastructural development (Hallegatte, 2009), technical systems and economic organisations. In particular, impacts on agriculture vary with farming systems or sectors (Touzard et al., 2015), which differ in sensitivity and exposure to changes.

The adaptation capacity to climate change depends on many factors, such as the market dynamics, private and public investment in R&D, policy and institutions (Hallegatte, 2009), or even cultural aspects (Dunlap & Brulle, 2015). A key factor is the capacity of cooperation between actors in regions and sectors (Boyer, 2016). Touzard (2015), for instance, reports that climate change has systemic impact on both regional vineyards and wine value chains, calling for cooperative solutions between actors at these two scales. Hence, adaptation capacities depend on the type of sectors, actors’ interaction and coordination, notably in agriculture (Soussana, 2013). In the rainfed crops production, adaptation comprises practices, such as adopting drought resistant varieties or intercropping (Teucher et al., 2016), while alternative feeding strategies or building insulation are promoted in the livestock sector (Seo, 2010).

Innovation studies so far emphasises on the role of innovation to bring economic and social changes (Van Lancker et al., 2016; Temple et al., 2015), in particular in each sector, where knowledge and technology, demand structure, institutions and firm characteristics are different (Malerba, 2002). The concept of Sectoral System of Innovation (SSI) is thus proposed to analyze this set of factors that can strongly determine specific trends in innovation in each sector with possible effects on economic performance and adaptation to global challenges such as climate change (Malerba, 2007). Empirical studies are, however, insufficiently taking into account the sectoral differences in innovation for climate change adaptation, and the role that SSI could play (Touzard, 2014).

This article therefore aims at analysing the roles of SSI in the adaptation of sectors to climate change, focusing on the coffee and dairy sectors in Central Kenya. It provides an answer to two questions: (1) what characteristics of the systems of innovation are particular to each sector in the adaptation process to climate change? (2) How do such characteristics affect the adaptation process and competitiveness of the sectors?

We mobilize the SSI approach in order to explore conditions of adaptation to climate change in coffee and dairy sectors which are similar in terms of farmers’ objectives and shifting historical fortunes, but are different in terms of marketing, socio-political and technical
characteristics and policy. We would contribute i) to the SSI literature on the agricultural sector, still little studied (Touzard et al., 2015), and ii) to research on adaptation to climate change by focusing on the role of SSI. The next section discusses the use of SSI approach. In section three, we present the method which combines focus groups discussions and surveys of actors in the coffee and dairy sectors in Kenya. In section four we provide the results and finally, in section five, we discuss our results.

2. USING SECTORAL SYSTEM OF INNOVATION APPROACH TO ANALYSE ADAPTATION TO CLIMATE CHANGE

The concept of SSI basically provides a multi-dimensional, integrated and dynamic view of specific economic sectors, including different structural components and a set of actors carrying out market and non-market actions (Malerba, 2002; Edquist and Chaminade, 2006). The key structural components of SSI are the knowledge base and learning process, the technological base, specific institutions (rules, norms) and the evolution of demand, while the agents in the SSI are the individuals, firms and non-firm organizations who are involved at various levels of the production and innovation processes (Malerba, 2007). These actors have specific models of interaction, interdependencies and links, which depend on the evolving structure of each sector.

Sectors provide a key level of analysis for economists, policy makers or firm managers to analyze basic firm’s structure and concentration in the industrial economics literature. However, Malerba (2002) argues that SSI approaches are much richer empirically to analyze knowledge dynamics, learning competencies, networks, and interactions. Moreover, while, the SSI framework has been mobilized to analyze the economic development and the adoption of new technologies in many industrial sectors, agriculture has not been studied much explicitly with this framework. In agriculture a first line of research refers to the notion of ‘Agricultural Innovation System’ (AIS) or ‘Agricultural, Knowledge and Innovation System’ (AKIS) (Klerkx & Jansen, 2010), which shares many aspects of the Malerba’s SSI approach. But SSI, AIS or AKIS have not been mobilized until now to analyze climate change adaptation in agriculture (Boyer, 2016). This article, therefore, makes an initial attempt at developing a framework to apply the concept of SSI to analyzing adaptation to climate change in the agricultural sectors and sub-sectors. It assumes that their performance and capacity to adapt depend on how the actors and institutions make up the system. Evolutionary concepts, such as interactions, learning, knowledge and competence are also included in our proposed framework in addition to other notions coming from industrial economics, innovation economics or literature on adaptation to climate change in agriculture (Soussana, 2013). Our approach considers three analytical dimensions:

The first dimension is the understanding of the sectoral changes, which result from the combination of internal and external factors. Internal factors of change rely on the evolutionary life cycle of the sector (Utterback, 1994), the emergency of internal crisis, the endogenous development of innovative culture, or the expression of economic interest of actors (Hallegatte, 2009). External forces are potentially various (political, economic, technological, ecological...), one of which may be climate change. Climate change may be considered as a double pathway: impact pathway and adaptation pathway. From the impact pathway, climate variability and change may increase the frequency of drought and thus impact the innovation to adapt to changes (Figure 1). Due to the direct relationship between
Crop production and climate, agriculture is the sector most affected by climate change (Howden et al., 2007; Angeon and Bates, 2015). Hence, the link between impacts of climate change and innovation to adapt will strongly determinate the dynamics of agricultural sectors, directly through the evolution of productivity, and indirectly through changes in land use (Hannah et al., 2013). As temperature and rainfall patterns are expected to continue to change, impacts will be more severe.

The second dimension of our SSI approach focuses on the interdependencies between different sectors and their actors. The boundaries of sectors are not fixed but dynamic, which provides mechanism of emergence, growth, changes and innovation (Touzard, 2014). For instance, over the last 35 years, coffee in Kenya have moved up to higher altitudes, while food crops have been grown at the altitude once reserved for coffee production (Asayehegn et al., 2017). The land use competition between sectors creates a mechanism of interaction among actors. In the coffee agroforestry systems of Kenya, the emergency of the dairy sector generates new interactions between actors, creating new links between coffee, tea and dairy systems. In such cases, links and boundaries could be in a competitive or complementary advantage. The links and interdependencies among actors could be within a sector and/or across sectors.

The third dimension is the characterization of the innovation and adaptation processes. Innovations to adapt to climate change may be technological, such as the development of new varieties and new breeds, or institutional, such as implementing new rules, norms or organizations that improve collaborations to reduce the impacts of climate change (Figure 1). The development of new cultivars of cowpea in the Sahelian West Africa, for instance, helped farmers to cope up with the experienced climate challenges (Chhetri et al. 2012). In East and Southern Africa, scientists developed high yielding maize varieties, with the objective of reducing vulnerability to drought (Fisher et al., 2015). New agronomic practices are another line of innovations for adaptation. Cropping system diversification, conservation tillage, new fertilizer management have proved to be sustainable adaptation practices increasing farmers’ income and reducing agronomic risk (Teklewold et al. 2013). Institutional innovation may also exert influence on both impacts of climate change and adaptation (Figure 1). For example, the adoption of new varieties depends on both upstream and downstream organizations (dissemination of varieties and credits vs access to market). New institutions also may improve actors’ interactions in bringing solution for adaptation, by improving knowledge sharing and inter-organizational learning, complementary resource development, capacity building and efficient governance (Dyer & Singh, 2012). In agriculture, institutional innovation and collaborative projects involving farmer’s organizations play a key role in the dissemination of climate smart innovations and practices (Cerdán et al., 2012). A study from the dairy sector in Kenya for instance, shows that farmers’ innovation is pushed by the development of new technologies of information, new services for input access and infrastructural facilities for delivering their products to markets (Schreiber 2002). The performance and adaptation of agricultural sectors, however, depends on the roles and performance of multiple actors, their interaction and co-production of knowledge (Klerkx & Nettle, 2013).
3. DATA AND METHODS

3.1. Coffee and dairy sectors in Kenya facing climate change

The study area, Murang’a County in central Kenya, is one of the areas with diversified physical environments and extreme climate. The area is made up of three agro ecological zones, each corresponding to a different altitude range (low, middle and high) and farming systems (food crops, coffee and tea). The lower altitude zone of the County which is a food crops zone is has a semi-arid climate with a high potential for drought while middle and high altitudes are potential for coffee and tea production, respectively. Dairy production is also an emerging business across all altitudes. Climate change is, however, strongly impacted the study area. Long-term rainfall has declined and temperature has increased; previous potential coffee areas are transformed to marginal coffee or food crops; and favorable weather zones are transformed into arid and semi-arid zones.

Historically, coffee production was one of the main monetary incomes generating activity for rural households in Kenya (Carsan, 2014). Following the “Lancaster House Conference” after independence, most of large scale coffee farms were sold to local elites (Ratten, 1993) and local indigenous people were encouraged to invest in coffee. Due to the expansion of plantations and attention to coffee by farmers and government, the sector grew at an annual rate of 6.6% until 1987 (FAO 2013). However, since 1988, coffee production has declined by 62% (FAO 2013). During this period, coffee has moved up from the lower altitudes where it has been replaced by dairy and food crops, for two reasons: First, warmer temperatures and erratic rainfall (Asayehegn et al. 2017) induced the transformation of potential areas to semi-arid zones, where a unit minimum temperature increase is subjected to a yield decline of 137 kg per hectare (Craparo et al., 2015). Secondly, climate change fostered the infestation of Coffee Leaf Rust (CLR) and Coffee Berry Diseases (CBD) causing the transformation of previous potential coffee growing areas to marginal coffee or food crops areas (Jaramillo et al., 2014).

The development of the dairy sector in Kenya had three main periods, i.e. the period of steady growth (before 1990), disruption (1991-2002), and the period of revival (since 2003). During the period of steady growth, indigenous smallholder farmers were encouraged to develop dairy production through training, infrastructural development and service delivery. Annual milk production grew from 75 million liters in 1964 to 392 million liters in 1990. During the period of disruption, dairy production declined from 359 million liters in 1991 to less than 150 million liters in 2002 due to the absence of efficient market and supply system. During the revival period, the dairy sector experienced a sharp increase in volume of production reaching to over 4.1 billion liters in 2014 (FAO 2011).

3.2. Methodological approach

Three types of data were used for this study: village and household data collected during nine Focus Group Discussions (FGDs), surveys with 240 household farmers and semi-directive surveys with other key stakeholders in the dairy and coffee sectors.

The FGDs were conducted with twelve farmers per group. FGD members were selected by local leaders after developing different criteria such as farming experience, extent of knowledge about the village, diversity of farming practices and perception of climate change.
We stratified the sample proportionally to the production systems. We then took random selection to get the first farmer from the list and then we calculated the sampling unit for list of sample farmers. The selection considers three groups: i) coffee specialized systems, including households production of coffee at high rate of intensification, ii) coffee-dairy diversification, where either the household’s attention is to both systems or households farm income is almost equally from coffee and dairy, iii) dairy specialized systems, where at least 80% of farmers’ income is from dairy.

The household survey was conducted via face to face interviews during May-October 2015 with heads of households. Farmers were asked about general farm and household characteristics, perceptions of climate change, livelihood means and income types, kinds of innovations they have introduced, where they had obtained necessary information, assistance, material, finance and the contribution of different actors to farming. This helped us to characterize the coffee and dairy farmers and understand how the systems of innovation in the coffee and dairy sectors are organized.

Data about other stakeholders were collected using individual semi-structured interviews with actors of innovation networks, who also shared their own experiences. A total of 23 such interviews were conducted with senior experts, technicians, managers, and heads of the following stakeholders: research, extension, private marketing, processing and input dealers, NGOs and CBOs, ministries: questions focused on what services each of them provided to farmers, and how they supported farmers. To analyze the contribution of different actors to the development of the sectors, a six scale measure (5=very high contribution, 0= not at all) was developed to analyze the views of farmers and stakeholders towards actors contribution.

4. RESULTS

4.1. Technological and institutional innovations to adapt to climate change: a case from the coffee sector of Central Kenya

4.1.1. Developing disease resistant coffee varieties

Between 1963 and 1987, national coffee production rose dramatically from 34,000 to 140,000 metric tonnes, benefitting from two technological innovations. In 1963, local farmers were encouraged and supported to use a new technical system including fertilizer and cultural practices such as pruning, in order to increase yields. The second technological change was the introduction of pesticides in the mid-1960s to prevent frost, Coffee Berry diseases (CBD) and Coffee Leaf Rust (CLR). Inputs and management supports were provided from the government directly through the cooperatives. For further improvement of production and quality, the Coffee Research Foundation (CRF) developed new diseases resistant varieties during the 70s, delivering in 1980 a new variety called “Ruiru 11” which was disseminated to farmers from 1985 onwards.

However, this SSI of developing new varieties, disseminating new practices and pesticides failed to increase coffee production or even maintain its level. Annual coffee production for example declined from 140 000 to less than 50 000 metric tonnes between 1988 and 2011 and production per hectare was reduced from 735 to less than 253 kilograms.

The claim that climate change impacted the coffee production is based on the evidences that:
• Analysis of long-term climate data showed rainfall has declined and temperature has increased (Table 1) which caused previous potential coffee-growing areas to be transformed to marginal coffee or food crops,
• Farmers’ perception of changes indicated seasons and weather patterns were changed (Figure 2). These arguments support the interpretation that changes in coffee production noted above were induced by climate change and that SSI in the coffee and dairy sectors were to tackle to the current challenges of climate change.

Result from our FGDs converge to point out that: i) institutional conditions and extension services were inadequately taken into account for these dissemination and learning process, and ii) that climate change modified the conditions of technical innovation, and was not considered by organizations of the coffee SSI. In relation to variety selection, farmers were confronted with two main challenges. First, the new varieties which farmers in their words call them “heavy feeders” to mean the new coffee varieties particularly Ruiru 11 requires higher doses of fertilizer and frequent watering. This is linked with their physiological characteristics, where their root system is shallow. Second, the old varieties are good in nutrient intake due to their deep root system but are highly sensitive to CBD and CLR, where farmers were forced to invest on purchasing chemicals.

4.1.2. Institutional innovation in the coffee sector

We classified the actors in the SSI of the coffee sector in three main categories. The first category includes the national and county government organizations who were the direct administrative body of the sector. The second category covers the research and education institutions, such as Kenya Agricultural and Livestock Research Organization (KALRO), International research institutions linked to CGIAR (ICRAF, CIAT), ICIPE, CIRAD, or joint research programs and projects with AU and EU, etc. These organizations developed research projects for the Kenyan coffee sector. The third category gathers the development organizations and community based organizations such as DANIDA, AgroproFocus, SIDA, and USAID. Figure 3 shows two main results from the surveys with these three categories of the coffee sector. First, the coffee SSI is organized around a long value chain with few actors in the marketing system (oligopolistic structure) and a focus of the research and development organizations on the production scale. Second, the interactions and collaboration between the different actors in the coffee sector appeared weak, and dominated by business and administrative links.

Upstream, the coffee union was the monopoly institution providing financial, administrative, technical services until the coffee liberalization in 1992. It was mandated to supply inputs, control the application of rules and regulations on coffee production and supply. After the liberalization, the Coffee Board of Kenya (CBK), which was the regulatory body became responsible for defining the marketing rules. The coffee union and CBK had a direct link with the government institutions, CRF, milling companies (Coffee processing), auction and export agents (Figure 3). Downstream institutions and actors such as societies, local government agents (ministry of agriculture, cooperatives), national and international research centers (CRF, KALRO, CGIAR), and community based development organizations, were loosely linked to the upstream actors. These unconnected and uncoordinated SSI created an opportunity to private business oriented actors to higher input prices.

These led coffee farmers of the community to follow four main strategies to adapt to the challenges they encountered, according to our findings. The first strategy was a continued
specialization in coffee production by investing in inputs and chemicals. The second strategy was to intercrop food crops and fodder in coffee farms, which reduced coffee production. The third strategy was abandoning coffee management and shifting their livelihood source to off-farm and non-farm activities. And the fourth strategy was completely uprooting their coffee in order to plant other food crops and fodder for their livestock.

The findings from the FGDs also indicated that shifting from coffee to other activities, which caused land use change was mainly due to challenges encountered in service provision and the weak role played by actors in the SSI. The agronomic and breeding activities were provided by the downstream actors such as CRF and other research organizations which was loosely connected and coordinated to the upstream actors such as the Union and CBK.

4.2. Innovation in the dairy sector to adapt to climate change in Central Kenya

The SSI in the development of the dairy sector was mainly based on three broad categories of changes: technological development, extension and education on best practices for keeping dairy animals, and institutional building for marketing channels (Figure 4).

4.2.1. Technological innovation in the dairy sector

The focus of technological innovation was generic improvement of livestock breeds and sanitary supervision of livestock. It also involved using new grass, shrubs and commercial feed in order to solve the acute feed shortage linked to climate change. For its part, extension and education was mainly developed by applying a business oriented private sector approach. The breeding materials, health services and innovative new feed systems were primarily developed at the research centers or directly adapted from abroad.

Originally, local cow breeds in Murang’a were the Zebu, with medium performance in meat and milk productions. As farmers’ objective was mainly to improve milk production, continuous crossing of the best traditional breeds were done leading to higher milk performance crossbreeds cows. Artificial Insemination of improved breeds was used and farmers experienced the requirement of the new breeds’ in terms of feeding and housing. The other technological innovations in the dairy sector were mainly dedicated to improve safety and milk quality, such as the installation of 35 dairy cooling plants (each with 5 000 liters capacity) in the milk shed localities.

4.2.2. Institutional innovation

Kenya Cooperatives Creameries (KCC), equivalent to the coffee union was established in 1925 to support the production, marketing and processing of dairy and dairy products as a monopoly agent. The Kenya Dairy Board (KBD), equivalent to the CBK was created to regulate the dairy sector. The SSI in the dairy sector had mainly three periods. During the first period, cattle breeding was fairly organized and subsidized by the government. Breeding materials and artificial insemination were effectively used to upgrade breeds. KCC continued as sole agent for marketing and processing protected by policy. During the second period, the position of cooperatives and KCC weakened after the liberalization of the sector. Farmers’ milk delivery to KCC and other cooperatives declined due to irregular payments and delays in response to the liquidation of the KCC.
As a consequence of the dairy sector liberalization the services previously delivered from the government stopped. Public breeding and veterinary services was cut back and artificial insemination services became inadequate. Indeed private sectors were insufficient and not able to develop the insemination service, as well as the feeding function for the whole sector. Around the mid of 1990s, self-help groups and informal agreements emerged. Deregulation of milk prices created opportunity for different actors to participate in milk marketing. Three options for milk marketing thus co-existed: KCC as government agent, private companies such as Brookside Dairy Limited, and the informal channels (Figure 4).

During the last period new impetus gave corrections to previous administrative and technical failure. Alternative feed sources such as drought resistance grasses were developed and new commercial feed companies emerged. Pushed by an increasing national demand on milk, the prices increased, giving higher motivations to farmers to increase their production, in a new institutional context which allows stability availability of feed at homestead and commercial opportunities. KCC was privatized and County cooperatives emerged in a new way.

Five categories of actors played a role in the dairy SSI (Figure 4) : i) the government development agencies; ii) the national research organizations, particularly Kenya dairy research institute and Kenya beef research institute and international research organizations (ICRAF, ILRI, CIAT, CYMMIYT, ICIPE…) or joint research programs with AU or EU, iii) the development and community based organizations such as DANIDA, TechnoServe, SIDA, USAID and others, iv) organizations from the private sectors such as Brookside, KCC, Guthunguri, and v) finance institutions both public and private such as banks and microfinance institutions.

Regarding to the actors’ interaction in the dairy SSI, among the government agencies, KDB continued to control the quality and regulate dairy products from both the cooperatives and private firms. The dairy SSI also included demonstration and trail fields of higher education institutions such as the University of Nairobi, the Kenyatta University, and the Egerton University as important actors in research. The national and international research organizations participate in collaborative programs on breeding, production, feeding and marketing. The EADD program was best example implemented by a consortium of Heifers international, ILRI, Dairy cooperatives, TechnoServe, African breeders’ services and ICRAF, but also private dealers and banks had been providing credits to R&D initiatives and marketing organizations, including smallholders cooperatives. Such types of coordinated action open the options for farmers in terms of input supply, financial support and marketing access. The access to, and management of feed result from the coordination between private feed companies and dairy training institutes. Market arrangements and contract agreements were implemented between the county government, private milk processing companies and dealers. Access to insurance for cows was also one of the agreements included in the package.

4.3. Comparison of the contributions of actors in adaptation to climate change in the coffee and dairy sectors of Central Kenya

Our results show that the coffee and dairy SSI differ in both their structural components and the actors’ contribution to innovative and collaborative solutions in each sector. Coffee farmers were less supported in their access to material and inputs compare to dairy farmers. In the coffee sector, the cooperative societies, the county and the national government were participating in provision of material and input though it was not sufficiently provided (Figure 5a). In the dairy sector, the cooperatives, financial organizations (banks, credit and insurance
companies), upstream and downstream private firms (input dealers, market agencies) and international research institutes (CGIAR centers, ICPE) were collaborating for input and material supply.

Access to financial and credit services also differ according to each SSI. In the coffee sector, though it was not satisfactory, cooperatives and private agents were the main actors (Figure 5b), while dairy farmers were satisfactorily served by a wider range of financial and credit institutions such as government, cooperatives and farmers federations, private suppliers and buyers and pure financial agents (banks and insurance companies) (Figure 5b). Power imbalance among actors also affected the interactions and performance in the two sectors. Coffee was for instance, under the “political control” of the county and national government, while dairy sector was driven by a more distributed power structure.

Regarding market access and facilitation, the cooperative union was the sole and autonomous organization to process and sell coffee on behalf of the farmers but private marketing agents at the auction remained powerful actors (Figure 5c, Figure 3). The coffee export marketing was done by auction through an agent hired by the cooperative union (Figure 3). Prices were controlled by the top chain actors (exporters) and farmers were price takers, with a payment term of at least six month. Consequently, the information asymmetry in the value chain benefited the auction actors and the union, while farmers were disadvantaged and hardly knew the quality requirements.

In the dairy sector, cooperative unions and federations, private market agents, development organizations (USAID, Technoserve, SIDA..) and international research institutes were involved in facilitating farmers access to market (Figure 5c, Figure 4). These actors were more equally distributed throughout the value chain, resulting in more transparency and both competition and cooperation. All the dairy buyers organize and register farmers looking for the improvement in production, input service, and marketing.

Finally, our results on the knowledge base and learning process of the two SSI showed two contrasted situations: in the coffee sector, CRF, cooperatives and farmers federations were the primary sources of information and knowledge for coffee farmers, while there was limited contribution from international research institutes, County and national governments and other development organizations (Figure 5d). In the dairy sector, actors such as cooperative unions and farmers’ federations, the national and county governments, international research institutes, financial institutions, private suppliers and buyers and development organizations were all providers of knowledge and information (Figure 5d). The Coffee SSI was thus narrower and separated according to the different stages of the value chain, whereas the dairy SSI contributed to a more complex, diversified and extended learning process.

The main question here is, what were the consequences of the SSI in the coffee and dairy sectors to adapt to climate change. Thus, differences in structural arrangement and interaction of the actors in the coffee and dairy SSI brought different ways of farmers’ adaptation to climate change and adaptive capacity. According to the results from the FGDs, coffee farmers adapt to the changes either through diversification of enterprises such as diversify to food crops and dairy farming, while dairy farmers specialize in dairy investing on external input and feed. This is connected to the functions and contributions of the SSI of the different sectors.
5. Discussion and Conclusion

Macro level agreements, such as the Paris agreement of the UNFCCC should have to bring to discussion how to tackle climate change through the notion of SSI for both technological innovation and marketing issues. Technological innovation is indeed important, but it is not the only requirement. Enabling the SSI where some technological innovations contribute to adaptation to climate change should be a priority area for action. In the coffee and dairy sectors of Central Kenya, before the market liberalization, input delivery and marketing system were organized through monopoly cooperative agents. The two sectors experienced decline during the early years of liberalization, but later on they took different directional trends. While the coffee sector has continued to decline and enters in full recession, the dairy sector flourished. The main idea of this discussion is, therefore, to understand why these two sectors, and their SSI, took different trajectories and what these evolutions bring to understand and act upon farmers’ adaptation strategies to climate change.

Three main reasons contribute to the two sectors taking divergent trajectories. Firstly, the coffee SSI continued to push technological innovations such as disease-resistant varieties, following a very top down process focused on the production stage, whereas the dairy SSI was more driven by the demand side and involved various stakeholders in the learning process. Secondly, the two sectors followed different value chain policies: in the coffee sector, input and services were left to private firms with less attention to farmer’s empowerment, while the marketing of coffee is based on cooperative monopoly influenced by powerful top chain private export actors. The dairy sector on the contrary, was fairly liberalized and the cooperatives, private firms and informal dealers equally competed for the service delivery and milk marketing, building diversified collaborations with development organizations. The coffee sector is thus organized along a long vertical supply chain, while the dairy supply chain is shorter and more diversified and complex. Thirdly, the two sectors also differ in how actors interact around innovation: in the coffee SSI, actors are relatively few and focus on supporting the production technologies for the coffee plantation. In the dairy SSI, many actors are interacting for different kinds of innovations throughout the supply chain, at the production, collection, marketing and distribution stages.

Innovating for adaptation to climate change in the coffee and dairy sectors depends on the structure and evolution of each SSI, i.e. the evolving institutional, knowledge and collaborative environment that can improve a set of innovations including new varieties and breeds, good agronomic practices, better access to information, input and services, and efficient marketing systems. The coffee sector illustrates that this combination of innovations was lacking of, which correlates well with observed difficulties to adapt to climate change. On the contrary, the dairy sector shows that this combination of changes was tackled: institutional development, such as creating active and powerful cooperatives, was coupled with technological innovations such as new breeds or milk cooling machines, and better access to input, service and information. We argue that the evolution of the dairy SSI explains why the dairy sector was more resilient to climate change, something confirmed by other studies (Schreiber, 2002). Cooperative institutions are for instance known catalysts for decreasing production and marketing costs, developing new markets and better access to technical advice. The performance and efficiency of the sector, however, depends on how actors of these cooperatives are involved in interactions and co-production of knowledge with multiple actors, private business, community organizations and public agencies.
Economic and climate pressures are already major issues in most of sub-Saharan Africa. Policy actors have to look for micro studies on how using an SSI perspective could help farmers adapt to climate change. Impacts of climate change differ according to the sectors, the farming systems and the location. We show that sectors also differ markedly in terms of their SSI, and thus their capacity to adapt to climate change. In the traditional subsistence agriculture, farms that own both crops and livestock are more resilient to climate change than specialized farms (Seo, 2010). But specialized farms could provide higher profitability and income, as well as resiliency, under the condition of an adapted SSI able to offer efficient collaborative solutions for adaptation to climate change. The SSI perspective underlines the need for coordination or “alignment” (Geels, 2010) of both technological and institutional innovation processes. With respect to the coffee and dairy sectors in Central Kenya, we suggest that the dairy SSI could be an example for other agricultural sectors, in order to enable farmers to be climate-resistant. It may at least motivate the actors of the coffee sector to build a new SSI in which public and private actors would working together and invest in climate change adaptation strategies.

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### Table 1- Mann-Kendall test of significance of change in temperature and rainfall

<table>
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<tr>
<th>Variable</th>
<th>Mann-Kendall’s tau</th>
<th>p-value</th>
<th>Sen’s slope</th>
<th>Mean</th>
<th>SD</th>
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<td>&lt;0.0001**</td>
<td>0.043</td>
<td>25.75</td>
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<tr>
<td>T min</td>
<td>0.509</td>
<td>&lt;0.0001**</td>
<td>0.032</td>
<td>14.19</td>
<td>0.41</td>
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<tr>
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<td>&lt;0.0001**</td>
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<td>0.033</td>
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</table>

**indicates statistical significance at 5% level

Data source: Kenya Meteorological department
Figure 1 - Conceptual model illustrating interaction between climate change impacts, innovations and adaptation to climate change
Figure 2- Farmers perception of climate change in Central Kenya
Source: Authors survey data, 2015
Figure 3 - Smallholder coffee supply chain and actors’ interaction in Kenya
Figure 4- Supply chain of milk and actors interaction in Murang’a County, Kenya
a. Contribution input/ material supply

b. Financing and credit service

c. Market access and facility arrangement
d. Knowledge/information provision

Figure 5- Actors contribution towards the development of the coffee and dairy sectors
Note: 5= very high, 4=high, 3=medium, 2= low, 1=very low, and 0=no contribution at all