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Considerations on the role of institutions and networks in the bioeconomy: three case studies from Ghana and Brazil

Lilli Scheiterle and Regina Birner

Abstract

An increasing number of governments around the world have developed a bioeconomy strategy. These strategies have important implications for the agricultural sector, technological innovation as well as sustainability and food security. The cross-cutting nature of the bioeconomy demands synergies and links between value chains to create innovations for optimal use of biomass for industrial purposes without creating competition for food products. Institutional networks are pivotal for the sustainable production and use of biological resources, as well as for the development of innovative processes to exploit the potential of biomass. This working paper uses three cases studies to explore aspects that need to be addressed to take advantage of the considerable untapped potential of the bioeconomy. The first case study highlights determinants of persisting low maize yields in northern Ghana, despite the introduction of a fertilizer subsidy program. Input subsidy policies are largely regarded as an instrument to increase crop productivity and contribute to food security. The second case study explores the role of female-led market institutions in Ghana. Markets are central to the development of the bioeconomy and as such, trader organizations have a key role to play in the value chain. The third case study investigates how well Brazil, the world leader in sugarcane production, is positioned to realize the shift from a fossil-based to a bio-based economy (bioeconomy). Subsequently, the role institutions and networks play in the development of the bioeconomy in two countries at different points of the value chain are discussed. We conclude that strengthening efforts to tailor site-specific solutions that consider the interdisciplinary nature of crop production, marketing, and development of processes is crucial to the bioeconomy. Overall, more attention to innovation networks is required to master the challenges of the bioeconomy and take full advantage of its opportunities.

Keywords: Biomass-based value web, governance, maize productivity, collective action, coordination.

1 Introduction

This paper explores the policy and institutional environment required to foster the emerging bioeconomy using three case studies from Ghana and Brazil. Each case addresses an essential aspect in the development of the bioeconomy: productivity, markets, and institutional networks. Increased productivity is central to the development of a sustainable biomass-based economy. In Ghana, the conventional cropping system still suffers from high yield gaps, despite the implementation of a fertilizer subsidy program, widely accepted to be a compelling policy tool to increase yields. On this premise, we explore the factors affecting low maize productivity in the Guinea savannah. The second case study investigates the role of traders, who as market agents operating between producers and consumers form an important link in the value chain and the broader biomass-based value web. In particular, we focus on the role of female-led market institutions that are considered monopolizing agents in Ghanaian markets. Third, the overall institutional arrangements and innovation forces along the biomass-based value web in the sugarcane sector in Brazil are explored to identify the accomplishments and challenges faced in the development of the bioeconomy.

The aim of this paper it to investigate key issues that can enable the development of a sustainable bioeconomy tailored to local ecological, social and institutional conditions. Understanding existing policies and the institutional environment are essential to develop the emerging agro-biomass sector while ensuring food security. Embracing the bioeconomy depends on the ability to produce increasing amounts of biomass, to adopt new technologies and entails new institutional arrangements along the biomass-based value web.

Following this introduction, we take on the definition of bioeconomy and how it fits within the SDGs as well presenting the context of the data collection and the rationale for the chosen case study countries. Section 2 explores the role the bioeconomy can play as a game changer; we focus on the role of institutions as outlined the New Institutional Economics (NIE) and explore the governance challenges to advancing the bioeconomy. In section 3, we focus on three pivotal aspects in the development of the bioeconomy: production, marketing, and the overall innovation system. It is against this background that we summarize findings based on case studies in Ghana that analyse challenges in crop production and a peculiar marketing institution and we investigate the overall innovation system based on the case study of the sugarcane sector in Brazil. Section 4, discusses the findings from the three case studies focussing on the role of institutions and governance. The study ends with concluding remarks in section 5.

1.1. Background and problem statement

The growing world population, increasing demand for products and the production of evermore waste and greenhouse gases (GHG) demand a sustainable use of limited natural resources. In this context, renewable resources including biomass have gained importance, as an alternative to fossil fuels, in the production and processing of the "four fs" (food, feed, fuel and “fun” where fun refers to products such as ornamental plants) (Birner and Pray 2018).

In recent decades, the role of biomass in the transition to a more sustainable economy has undergone dynamic changes. As its societal and economic importance has grown, use of biomass has become a popular subject in the political discourse as well as academic debates. Historically, biomass has been used for a range of purposes; its price changes influenced political decisions and had global repercussions. This became evident during the economic crisis in 2008/09 when food prices increased substantially due to crop demand for biofuel production and related agricultural land speculations, which had tremendous impacts on the food supply in many developing countries. The “food vs. fuel” debate grew and the topics of land and agriculture speculations entered the public discourse.

The concept of “bioeconomy” was first developed in the mid-21st century to address the envisioned scarcity of fossil resources, but after new technologies for oil extraction developed and oil prices dropped, the major argument for bioeconomy switched to one of climate and environmental protection (German Bioeconomy Council 2016). In recent years, different concepts have been developed with the common idea to improve resource use and efficiency to improve sustainability. Some of these concepts are the “green growth”, “green economy”, “circular economy”, and “bio-based economy.” Although no unified definition of “bioeconomy” exists, there is a common understanding of the concept as reported in the Communiqué of the Global Bioeconomy Summit, 2015. The report defines bioeconomy as “the knowledge-based production and utilization of biological resources, innovative biological processes and principles to sustainably provide goods and services across all economic sectors” (Global Bioeconomy Summit 2015 p.4). This definition is applied in this study, with the underlying idea being to use renewable biological resources sustainably to produce energy and industrial goods, in addition to food and feed. The crosscutting concept intersects pressing societal challenges while realizing sustainable economic development. The increased use of biomass as an industrial resource should not come at the expense of food security, environmental degradation or vulnerable populations. This new model makes use of the untapped potential of the biological waste and residual materials available from all sectors. The transition to a bioeconomy is expected to increase independence from fossil fuels by using, for

example, enzymes to break down plant components that can be used as building blocks for bio-based biodegradable plastic. Innovations that sustainably and significantly increase the value of agricultural produce, including the use of by-products, has the potential to transform agriculture-based economies dominated by small-scale farmers. Measures that aim to attract the private sector, increase collaboration between government and private institutions, and engage smallholder farmers in high value agribusiness and new technological frontiers are key for the development of a sustainable bio-based economy (Birner and Pray 2018).

However, a transition to the bioeconomy implies rethinking the current economic system, the structures that have developed over time to shape our lives. In the long-run it is expected to produce positive externalities, but until then, new technologies and processes need to be developed, market and competitive economic sectors need to be put in place, and collaboration between stakeholders need to be fostered. This requires comprehensive changes in the social and economic dimensions involving sectors as diverse as science, politics, industry and civil society.

The bioeconomy has the potential to address the grave environmental challenges faced by humanity and is in line with the Sustainable Development Goals (SDGs). The International Committee on the Bioeconomy illustrates how the principles of the bioeconomy are linked to individual SDGs. The five SDGs relevant to this paper are highlighted below, based on a commentary in the scientific journal "Nature" (El-Chichakli et al. 2016).

- SDG2: Zero Hunger: Food security requires increasingly more efficient food production with reduced GHG emissions and water requirements. Therefore, new processes in farming and the development of molecular diagnostics to reduce input use and provide nutrient-rich foods are needed.
- SDG7: Affordable and Clean Energy: The energy systems of many countries are based on scarce and vital resources, which are often unreliable and/or expensive. Alternative processes based on modern technologies have the potential to offer solutions that combine the generation of bioenergy with other renewables.
- SDG8: Decent Work and Economic Growth: Modern processes and alternative technologies to crude oil can trigger innovation that supports inclusive and sustainable growth through full and productive employment and decent work for all.
- The terms 'inclusive' and 'for all' implicitly refer to gender empowerment and SDG5: Gender Equality.
- SDG15: Life on Land: The sustainable use of terrestrial ecosystems, despite the intensification of agriculture, must be guaranteed, which calls for bioeconomic solutions.

Agriculture must be disentangled from fossil fuels and excessive use of chemical inputs, while reversing land degradation through ecosystem friendly and locally adapted solutions (El-Chichakli et al. 2016; Virchow et al. 2016).

1.2. Study context

This working paper is an output of the larger research project "BiomassWeb", funded by the German Federal Ministry of Education and Research (BMBF) and supported with funds from the German Federal Ministry for Economic Cooperation and Development as part of the "GlobE – Research for the global food supply" program. The project's underlying assumptions are: (i) that sub-Saharan Africa (SSA) has a high natural potential to increase biomass production, (ii) the available biomass is underutilized.

BiomassWeb therefore aims at contributing to food security in SSA by focusing on biomass-based value webs. The project seeks to use a multidimensional approach to identify and quantify potential opportunities to extract or create value. Biomass-based value webs are complex systems of interlinked value chains in which food and fodder, fuels, and other raw materials are produced, processed and traded. The overarching goal of BiomassWeb is to conceptualize how SSA may increase availability and access to food through high-value biomass for both food and non-food purposes in the coming decades due to increasing demand for innovative biomass products from agriculture. This goal is perused by identifying biomass-based value webs and studying selected entry points to increase the overall system productivity through exemplary agronomic, technological and institutional innovations. This study is part of the work-package "Governance" which focuses on the policy and institutional environment required to foster the emerging agro-biomass sector; and at the same time ensuring food security for smallholder farmers by integrating them into the emerging international bioeconomy (FSC and ZEF 2013 p. 8 and 93). Of the three project countries Ghana, Ethiopia, and Nigeria, Ghana was chosen for this study. Brazil was selected as the second case for this paper.

1.3. Rationale and context of chosen case studies: Ghana and Brazil

The two countries selected for this study, Ghana and Brazil, have different institutional setups and their bioeconomies are at different developmental stages.

Ghana represents an interesting case as its knowledge institutions (in particular its agricultural research, extension and education systems), as well as its regulatory and policy environment have not yet developed a strategy for the development of the emerging agro-biomass sector. However, policies aiming to increase biomass productivity (e.g. fertilizer subsidy programs)

and locally important institutions (e.g. trader associations) are in place and can play a significant role in the development of the bioeconomy.

Crucial to the development of a sustainable bioeconomy is the satisfactory production of biomass; therefore, the increase in productivity of traditional cropping systems is an important precondition. In the first case study, we look at the determinants of maize production in Ghana. Persisting yield gaps and low crop productivity are a major concern across much of sub-Saharan Africa (Adjei-Nsiah 2012; Dietrich et al. 2012; GYGA 2017). To address this issue, input subsidy programs are a popular policy approach in the region. However, in the Ghanaian context, this measure did not ensure higher yields but rather contributed to high public expenditure (Scheiterle and Birner 2018). The underlying assumption of the BiomassWeb project is that income generation can be achieved not only through an increase in crop yields, but also through diversification of biomass-derived products to tap into emerging biomass-based markets (FSC and ZEF, 2013). The adoption of technical and institutional innovation in the bioeconomy requires well-functioning institutions coupled with supportive regulatory and policy environments. For this reason, we shed light on a critical market institution in the biomass-based value web. Understanding the role of traditional organizations and power structures in a collectivist society like Ghana will help incorporate this link in the development of a successful local bioeconomy strategy. In this regard, female-led organizations in the Ghanaian food crop value chains play a pivotal role, as they are well-integrated agents in the biomass-based value web and can leverage knowledge about alternative biomass uses along the value chain and value web.

The second case study, on sugarcane biomass in Brazil, analyzes the role of institutions, networks and collaboration. Brazil was chosen because of its early investment in alternative paths to fossil fuels and its success in taking important steps towards a more sustainable economy. Analyzing what it took for Brazil to largely incorporate sugarcane biomass into its energy matrix, which is about 17 percent of the total energy consumed in the country (Leão de Sousa & de Carvalho Macedo 2011), can help us understand how countries with similar goals can develop appropriate strategies. Brazil substitutes transport fuels with sugarcane biomass and recently started sourcing sugarcane biomass for electricity production too. Considering net primary productivity (NPP)[1], other parts of the world could have the prerequisites to theoretically achieve similar success rates. In the region of São Paulo where most of Brazil's sugarcane is produced, the NPP is comparable to large areas on the African continent (Figure 1). Furthermore, constraints to agricultural production are to some extent comparable in terms

[1] NPP quantifies the amount of atmospheric carbon fixed by plants and accumulated as biomass.

of climate, soil, and terrain slope (Figure 2). Similar conditions in the two regions can facilitate the identification of conducive and transferable interventions, which in turn can foster timely and efficient introduction of material and processes based on biomass. Leapfrogging in the use of technologies can support the prerequisite of the bioeconomy, namely efficient resource utilization and sustainable agricultural production (German Bioeconomy Council 2013a).

1.4. The biomass-based value web approach

The shift towards the bioeconomy is a complex process that entails many challenges and at the same time opens new opportunities. This is the case across all economic sectors: extraction of raw materials, manufacturing and processing, and the services sector.

The sustainable bioeconomy "involves systematic approaches (e.g. nexus thinking), particularly innovation policy measures that aim at optimizing Bioeconomy value networks and minimizing waste and losses" (Global Bioeconomy Summit 2015 p.5). This concept is in line with the "biomass-based value web" concept that recognizes the importance of the linkage between value chains through cascading use and the integration of non-food biomass when analyzing the use of biomass (Virchow et al. 2016). The ways and the period in which different countries can succeed in shifting towards the bioeconomy depend on their natural conditions as well as on current levels of biomass production and exploitation.

Brazil, for example, has achieved a comparative advantage in the production of sugarcane due to its favorable conditions, and its early development of supporting institutions, in particular cooperatives and research centers that have fostered the development of the sector (de Moraes & Zilberman 2014; Furtado et al. 2011; Hira & de Oliveira 2009; Ueki 2007). Political commitment and early investment in research for alternatives to crude oil have led to fundamental improvements in technical and economic efficiency. Brazil has shown that it is possible to substitute fossil with bio-based fuels, specifically with sugarcane-based ethanol, however many more substitutions are needed to build a sustainable economy.

Other countries, with similar factor conditions have the potential to reach comparable productivity levels and reach a comparative advantage in biomass production. As mentioned above, Ghana has similar natural conditions in terms of potential biomass production, soil and climate limitations (Figures 1 and 2). However, its political development and agro-biomass sector development are very different from Brazil.

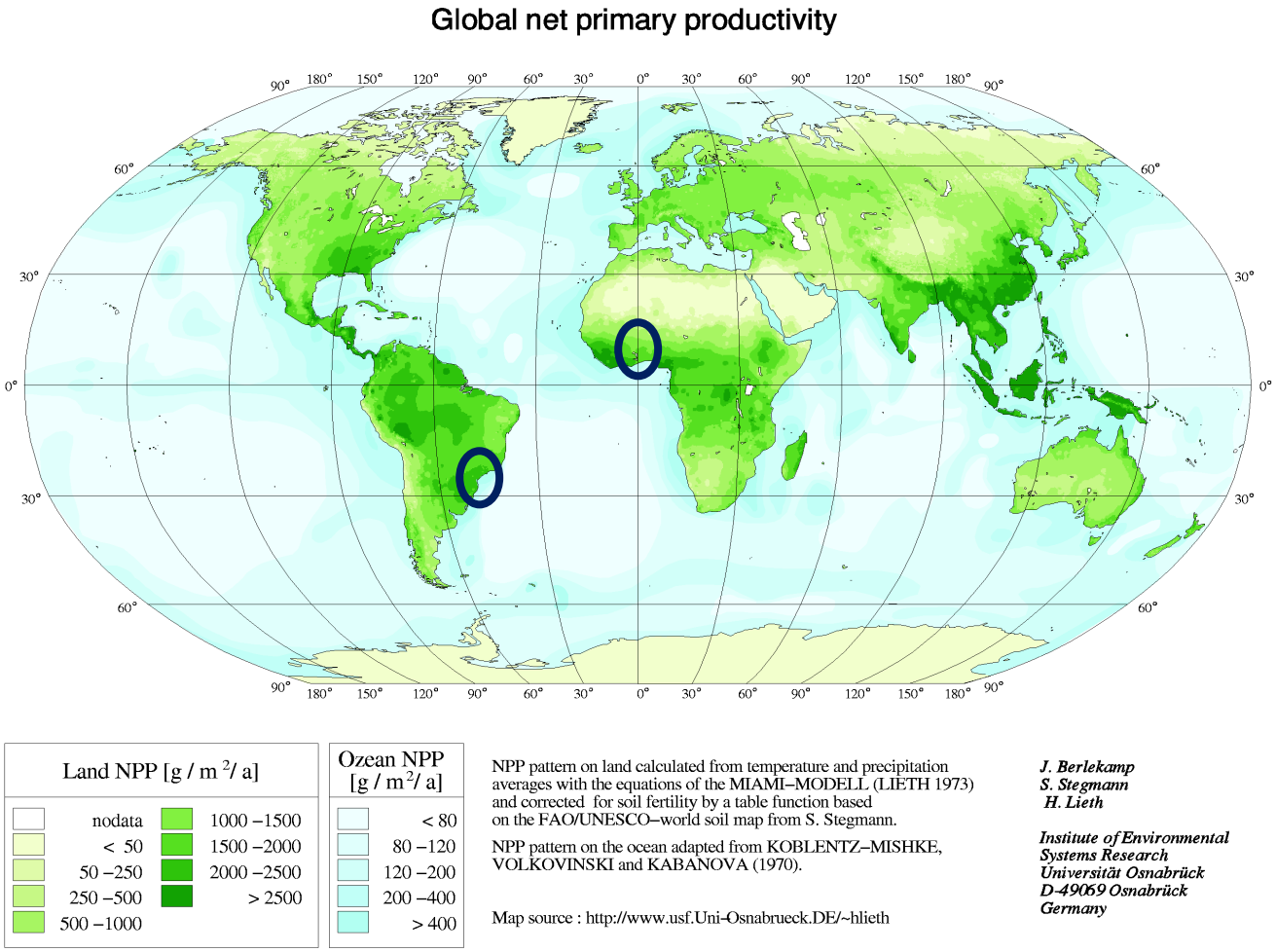

Figure 1: Global net primary productivity
Source: http://www.usf.Uni-Osnabrueck.De/~hlieth

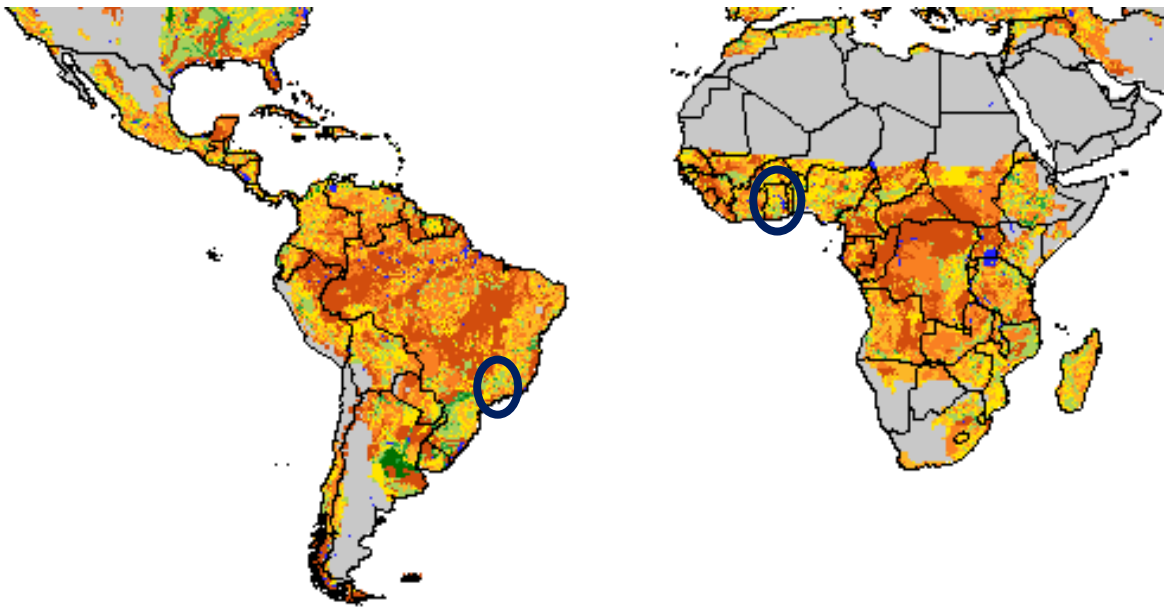

Figure 2: Climate, soil and terrain slope constrains to agriculture production combined (FAO)
Source: http://webarchive.iiasa.ac.at/Research/LUC/GAEZ/index.htm

This research focuses on the institutions and networks needed to develop the bioeconomy in the two countries. It assesses natural conditions, identifies traditional institutions, current policies, and governance challenges that influence biomass production and utilization. As the Brazil case study reveals, the shift to a bio-based economy calls for economic and knowledge networks, transdisciplinary approaches and institutional collaborations. The case study applies a transdisciplinary approach to examine the role of the institutions and networks needed for the development of a sustainable bioeconomy tailored to local natural, social and institutional conditions. Understanding the existing policy and institutional environment is essential to foster the emerging agro-biomass sector and ensure food security for all actors involved in the value web. Embracing the bioeconomy depends, inter alia, on the ability of the agro-biomass sector to produce increasing amounts of biomass, adopt new technologies and farming practices, and to develop new, appropriate institutional arrangements along the biomass-based value web.

2 Governance challenges of the developing bioeconomy

This section aims to identify the governance challenges that can prevent the bioeconomy from developing its full potential. The climatic challenges the world is facing, the limited resource availability for an increasing population while safeguarding the health of the planet involves more than one industrial sector, scientific discipline or country. At first, we would like to bring the bioeconomy in the perspective of major revolutions in agriculture and highlight the role institutions and 'political-will' have played in fueling them. Action must be taken with governments, private sector and multilateral organizations in tow. The effectiveness of these measures resides in the collaborations and networks towards a common objective. Therefore, in the second part, we review the role of institutions and governance challenges that can arise. This is true for production, marketing, and the overall innovation system since they are crucial to the development of the bioeconomy.

2.1. Revolutions in agriculture

According to the Merriam-Webster dictionary, a revolution is defined as an "activity or movement designed to effect fundamental changes in the socioeconomic situation" (Merriam-Webster 2019). Such "fundamental changes" first occurred 10,000 years ago in the field of agriculture, today known as the Neolithic revolution, when plants and animals were domesticated, humans became sedentary, and had more time for handicrafts which improved their manual dexterity. A second agricultural revolution (around 1700 AD) paved the way for the industrial revolution (1760-1840). In Britain, the increase in land and labor productivity due to improved farming practices (e.g. drainage systems and selective livestock breeding) and technological innovations (e.g. cast-iron plow and seed planting instead of broadcasting) allowed more of the workforce to be available for activities such as manufacturing, which fostered competition, innovation, and efficiency. Change in land tenure systems, the development of national markets, and the improvement of transportation infrastructure, all contributed to foster innovations and increased agricultural productivity. Population increase in England and Wales and the decline in the labor force needed in agriculture laid the foundations for the industrial revolution (Overton 1996).

The most recent revolution in agriculture is the 'Green Revolution' (1960), which saw a massive increase in rice and wheat yields in Asia due to the introduction of new varieties and complementary chemical inputs. Similarly, a shift towards the bioeconomy entails "great societal transformation" (WBGU 2011). This definition introduces, aside from the technological innovations, the social aspect, which is pivotal to a successful shift from the

current fossil-based to the envisioned bio-based economic system. Banerjee (2013) sheds light on the role of institutional and political actors that accompanied the success of the green revolution. She finds that it is only possible to sustain long-term agricultural growth if functioning infrastructure and institutions are established and maintained. Furthermore, she emphasizes the role of leadership and political will. These elements are crucial for any larger transformations, and subsequently to achieve a sustainable and low carbon economy.

The debate on technological and demographic factors versus the role of politics and institutions is known as the "Brenner Debate", due to the seminal work of Robert Brenner in 1976 analyzing the pre-industrial European agrarian economies. He compares farms, which adopted agricultural technologies in independent family farms in Western Europe and the more restrictive system in the feudal structures of Eastern Europe. The latter institutional setup did not provide incentives for the uptake of productivity-increasing measures and led to an inevitable under-performance. Whereas, competition and rivalry fostered the readiness for innovation and improved productivity. The legacy of that period is still observable today.

The willingness to embrace and foster innovations will continue to shape performance. The development of an economic, environmental and socially sustainable economy calls for a fundamental change to the current economic and social structures. With regards to this, the literature often refers to a "great societal transformation" and sees "profound changes to infrastructures, production processes, regulation systems, and lifestyles, and extends to a new kind of interaction between politics, society, science, and the economy" (WBGU 2011 p.1). The bioeconomy could represent a necessary next revolution. However, certain critical components have to play their part: political will, engagement of institutions at local, regional and global levels, and innovations that foster an efficient and sustainable use of natural resources. The increasing number of countries across the world that have adopted 'bioeconomy strategies' tailored to local conditions and regional specializations, indicates a positive advancement towards the needed changes (German Bioeconomy Council 2015).

2.2. Institutions in New Institutional Economics (NIE)

Within New Institutional Economics (NIE), institutions are defined as "the humanly devised constraints that structure political, economic and social interaction. They consist of both informal constraints (sanctions, taboos, customs, traditions, and codes of conduct), and formal rules (constitutions, laws, property rights)" and their enforcement characteristics (North 1991, p.97). Formal and informal institutions catalyze interactions between actors. For the purpose of this study, it is useful to distinguish between institutions and organizations. Institutions are

defined as "the rules of the game" (North 1993 p.3), whereas an organization can be defined as a group of people working towards a common objective and sharing common regulations. NIE authors argue that both organizations and institutions have developed to reduce transaction costs and obtain higher efficiency in economic performance (Bardhan 1989; Coase 1984; Williamson 1979). Social benefits are undermined by transaction costs (e.g. screening and monitoring contract partners). The failure to exhaust any possible lucrative transaction is termed a market failure[2] (Coase, 1937; North, 1990).

2.3. Governance challenges

Governance is described as the political processes that exist between organizations over a societal system. It defines "the processes of interaction and decision-making among the actors involved in a collective problem that lead to the creation, reinforcement, or reproduction of social norms and institutions" (Hufty 2011: 405). The challenge to develop a sustainable economic system through green innovations involves a complex network of activities in which a large number of actors are embedded and share knowledge through a fair process. This exchange needs to involve private sector, universities, think tanks, research centers and other knowledge institutions, as well as state-owned companies, the state as policy maker, multinationals and donors. This will facilitate the flow of information and strengthen collaborations to form a network, which is especially important to develop biotechnological processes for a heterogeneous primary material, like biomass. A number of processes may be needed to efficiently utilize it, depending on its compounds and the envisioned final product (Scheiterle et al. 2018). However, the needed collaborations and networks can suffer from governance challenges that hinder effectiveness and fairness. In this section, we discuss challenges that are likely to arise with efforts to build a sustainable bio-based economic system. Information asymmetries and related high transaction costs are one of the most prominent challenges which can lead to opportunistic behavior and create *'market failures'* (Akerlof 1970). Market failures are detrimental for the development of the bioeconomy, which is capital and knowledge-intensive, and thus dependent on information flows. Private sector investment might be discouraged due to high initial costs, and economies of scale can lead to monopolies (De Janvry et al. 1997). Therefore policies that foster the engagement of private firms, stimulate innovations, (e.g. start-ups) and strengthen institutions (e.g. collective action organizations),

[2] When resource allocation is suboptimal in the sense of Pareto, one can refer to a market failure. This implies that the welfare of one individual could be improved, without affecting the welfare of others (Bator, 1958). "Failures" of the public, the private and the third sector are also referred to as "governance challenges" (Birner and Anderson, 2007).

can help overcome market failures (Jayne & Tschirley 2009). However, the high initial cost of some innovations discourages the commitment of the private sector, calling for government investments or public-private collaborations. These collaborations are challenging since the private sector has economic goals to pursue whereas these partnerships should generate public goods.

When it comes to credit provision, asymmetric information and high transaction costs are a prominent market failure affecting most asset-poor actors who perform small transactions. This is an example of *'coordination failure'*, described as the failure to coordinate and reach a more desirable equilibrium among firms or price setters (Kydd & Dorward 2004). Local peer-to-peer savings and credit associations deliver a financial safety-net to asset-poor actors who perform small transactions, providing a service which is otherwise not available and thereby overcome both market and coordination failures. Coordination failure can have a particularly negative impact in an interlinked multi-stakeholder network. For example, the coordination along the value web could lead to breeding efforts of sugarcane with more leaves in the case of complementary investments, such as electricity production from by-products downstream (Kydd and Dorward 2004, section 3.3.).

'Network failures' are especially relevant in a knowledge-based bioeconomy where collaboration between actors are expected to drive innovations, as will be discussed in section 3.3. A well-connected network enables actors to gain access to resources and information, which decreases opportunistic behavior due to information asymmetry, and stimulates productive collaborations. Poor relationships between actors, due to limited trust and high (perceived) transaction costs are defined as network failures (Arnold & Thuriaux 2003). The same authors also define '*capability failures',* indicating that actors in the network are required to develop skills and knowledge to collaborate effectively. For example, poor managerial capabilities may inhibit optimal use of technological innovation for the interest of a firm or production. These aspects play a crucial role in developing a system based on coordinated networks of actors who jointly develop skill and knowledge to make up for weaknesses from one party.

Infrastructure and market stability are preconditions for the successful development of the agro-biomass sector, innovations and the overall bioeconomy. The lack of provision of public goods, merit goods, and services, which create positive externalities (benefits that can have a significant effect on social welfare), is a *'market failure'*. The problems highlighted in the case of the fertilizer subsidy program in Ghana (section 3.1.) reflect the lack of investment in extension services, capacity building of local institutions, and infrastructure to provide timely

subsidies. The German Bioeconomy Council also refers to the knowledge-based bioeconomy, highlighting investments in knowledge as one of the most powerful instruments governments have to develop the bioeconomy (German Bioeconomy Council 2013b).

Governments can promote the development of the bioeconomy through policy instruments, especially by strengthening the demand of bioeconomic products. Brazil has done this by investing in the development of flex-fuel cars, thereby creating a high demand for bio-based fuel. Support programs for industrial and research initiatives that foster transdisciplinary collaboration are pivotal. This also implies a high commitment and coordination between all stakeholders, including the private sector, government institutions and research agencies (de Moraes and Zilberman, 2014; Furtado et al., 2011; Hira and de Oliveira, 2009). This was observed in the development of Brazil's bioeconomy strategy. Government interventions can confront governance challenges at the public institutions level, namely *'state failure'*. These include: (1) *elite capture* intended as the capacity of "elites" to maneuver benefits from government programs towards themselves; (2) *clientelism* described as the allocation of resources to a specific group in expectation of political support; and (3) *bribes* in exchange for goods and services.

Organized groups of individuals, like communities or other formal and informal organizations, can play an important role in addressing market and state failures. Third sector organizations (non-governmental and community-based organizations) face their own challenges, including those referred to as '*community failure*'. A common challenges is the classic free-rider problem of collective action (Ostrom 1990). Moreover marginalized groups often face challenges in entering such organizations, due to gender norms or social status (Agrawal & Gibson 1999; Birner & Anderson 2007). Participatory approaches suffer mainly from poor management, capability and financial constraints as well as the above mentioned prominent elite capture problem (Platteau & Gaspart 2003). Coordination and monitoring by group members contribute to the good governance of the community or group, as seen in the example of female-led market organizations in Ghana (section 3.2.).

3 Three case insights on opportunities and challenges in developing the bioeconomy

The opportunities and challenges to realize a low-carbon economy vary across geographies and countries' technological development. Countries that have similar conditions can build on previous experiences to their advantage. We address three topics important to the development of a sustainable economy. In Ghana, we explore challenges to crop production, as biomass is the essential primary resource, and on a peculiar marketing context, that highlights the importance of local institutions. In Brazil, the overall innovation system of the sugarcane sector is considered, as the country is a forerunner in the substitution of fossil fuels with biomass-based products. The overarching aim is to review three aspects that are important for the development of the bioeconomy, namely local institutions, policies, and networks.

3.1. Increase biomass production: efforts to increase maize productivity in the Guinea savannah

Although strategies to achieve food security in rural Ghana have focused on increasing food production, the potential yields of the main agricultural crops have still not been achieved (Adjei-Nsiah 2012; GYGA 2017). Productivity increase remains an underlying requirement for use-diversification and the development of novel products to tap into biomass-based markets for both food and non-food purposes.

Fertilizer subsidy programs are widely accepted policy approaches to increase productivity and contribute to food security; however, the predicted effects have not yet been realized. Through the integration of socioeconomic and natural science-based data, the study by Scheiterle et al. (2019) investigates factors that are preventing smallholder farmers from overcoming persistent low productivity in the Guinea savannah of Ghana. Socioeconomic household survey data, qualitative data from focus group discussions and key informant interviews were combined with data derived from soil laboratory analyses. Furthermore, fertilizer samples were collected to control for adulterated or fake inputs and the spread of a parasitic weed in the maize fields was captured. Laboratory testing was used to analyze soil and fertilizer quality. The models revealed that the parasitic weed, Striga spp., and labile soil structure have profound effects on yield variability. The measured nutrient contents of the fertilizer samples reflected the composition indicated on the package labels. However, the results confirmed governance challenges in the distribution of fertilizers through the subsidy program, which included targeting (of the poor farmers in the country), timing (availability in the needed crop physiological time), and elite capture (better-connected farmers were treated preferentially).

Furthermore, the study finds extension service delivery to be weak and not offering site-specific recommendations. The fertilizer subsidy program proves to be an ineffective standalone measure; quality seeds, as well as timely delivery, are essential to improve maize yields. Nannuru et al. (upcoming) find a popular maize variety Opatanpa sold at agro-input suppliers in Ghana have high genetic heterogeneity and about 11% are genetically not related to the variety they are sold for. Improving the involvement of research centers and universities to provide good quality inputs as well as deliver site-specific agronomic extension would strengthen the agriculture sector. In particular, the study emphasizes the need for incentives to foster collaboration among research, private sector and government institutions. Overall, it showed that both socioeconomic and biophysical parameters contribute to an improved understanding of site-specific challenges. Additional efforts to overcome governance challenges in fertilizer distribution need to be addressed to combat low maize productivity in the Guinea savannah of Ghana.

3.2. The role of collective action groups

The development of markets plays a key role for all actors in the biomass-based value web. In Ghana, markets are largely managed by female traders organized in groups based on the main commodity being traded and headed by a representative or leader. For example, one finds tomato groups, dry fish or roots and tuber groups. In the south of the country, because of this traditional institutional system, the leaders of the associations are called ‘market queens’ whereas in the northern regions they are called ‘magasia’. In the literature and the common narrative, female market leaders are portrayed as obstacles to the development of fair market prices for producers and consumers. Especially in the south of the country, the traders' associations are considered monopolizing agents. In the public narrative and limited academic literature, market queens are compared to “cartel” and “mafia” institutions (Katila 1997, Banful, 1998, Awo 2012, UNDP 2012). Scheiterle and Birner (upcoming) test this widely acknowledged discourse by looking beneath the surface and investigate the functions of the market associations. The study seeks to identify the role of female-led trader associations across markets in Ghana. The empirical findings challenge the negative representation of female traders’ associations and highlight the need to recognize them as valuable actors crucial in the value chain. The findings highlight that the female-led market groups are democratic, hierarchical, collective action institutions based on trust and mutual support offering savings, insurance, and credit services to traders. These services would otherwise not be available to them due to the risky activity they are exercising and the lack of collateral. The organizational

structure within groups varies between commodities, across regions, ethnicities, and market typologies throughout Ghana. However, in all instances, the female-led traders' associations are a crucial link to ensure all four dimensions of food security for urban and rural populations. The results do not show evidence of the female-led market groups leveraging their power to set market prices. Rather the study finds that traders' collective action provides vital safety-net measures for asset-poor women engaging in uncertain market activities. Traditional institutional arrangements can be catalysts in the development of the biomass webs and to achieve food security, therefore it is important to reconcile institutional arrangements to foster the participation of all actors in the value webs. These institutions should be integrated in public debates and their potential recognized to strengthen information flow between actors, develop community-based services and contribute to women's empowerment. They need to be integrated in the innovation system, as their role cannot be overlooked in the value web.

3.3. The role of institutions and networks in the development of new processes and products

To get an understanding of how collaborations between institutions and a network between heterogeneous actors can foster the development of the bioeconomy we have chosen the example of Brazil. The institutional arrangement in Brazil has showcased, first, how the successful exploitation of biomass-based value webs leads to a significant independence from crude oil; and second, how the commitment to develop the sugarcane sector led to a comparative advantage in sugar and ethanol production.

The most prominent step towards a bioeconomy was the substitution of conventional gasoline with sugarcane-based ethanol as fuel. The military government envisioned using ethanol as a substitute to imported gasoline and created research institutes (1972 Embrapa, the Brazilian Enterprise for Agricultural Research), implemented programs (1975 the National Alcohol Program), and promoted collaboration among stakeholders (de Moraes & Zilberman 2014). Through political will to foster a shift towards bio-based fuels, Brazil became independent of international oil price policy and developed a strong biomass-based energy sector. From this standing, it gained opportunities to become a front-runner in the future bioeconomy. However, existing collaborations within the county need to be expanded and new actors need to contribute to the innovation network. Identifying linkages that foster novel processes and products, based on knowledge and biomass, are crucial to detect entry points for the bioeconomy. Scheiterle and colleagues analyzed the current institutional arrangements that support the sugarcane sector and identified linkages that need to be strengthened to develop the bioeconomy. In general, the

results illustrate the importance of collaboration with national and international knowledge institutions, such as research centres and universities, by overcoming obsolete bureaucratic hurdles and creating incentives for exchange. In particular, the authors highlight the importance of integrating national and international private sector actors with national public institutions. Long-term consistent policies and funding opportunities for risky investments are also required to further strengthen Brazil's innovation network to meet the future opportunities and challenges of the bioeconomy. The paper discusses technical and institutional innovations needed, both to increase productivity and to develop novel processes and products (Scheiterle et al. 2018).

4 Discussion

According to the considerations presented in the introduction, and the empirical results of the case studies, this section emphasizes the roles of knowledge, cooperatives and networks, and multi-stakeholder participation. These topics are chosen because they result from the empirical studies and are considered pivotal for the bioeconomy's development.

4.1. The role of knowledge

Two paramount components of the bioeconomy are biomass and knowledge. The biomass production potential of Ghana and Brazil are largely recognized (Figure 1 p. 14), however, collaborations of national and international institutions, private, public as well as traditional institutions are necessary and differ greatly between the countries. The definition of bioeconomy used in this working paper stresses the importance of knowledge-based production and the utilization of biological resources. Considering earlier evidence from the green revolution in India as well as from the development of the sugarcane sector in Brazil, it is largely accepted that the inclusion of knowledge institutions fosters uptake and progress of innovations. Brazil is a particularly fitting example displaying how investment in knowledge generation and sharing can be successful, especially in the context of the bioeconomy. Its government's commitment and early investment in capacity building and research institutions led the country to independence from fuel imports and brought about the current comparative advantage in the production of sugar and ethanol (Scheiterle et al. 2018; Furtado, Scandiffio, and Cortez 2011; de Moraes and Zilberman 2014). The increase in sugarcane productivity was not driven by subsidies; rather the government invested in knowledge institutions and fostered collaboration with cooperatives to develop locally adapted and demand-driven solutions.

Ghana, in contrast, has not invested in knowledge institutions in the same way but rather relied on subsidies to close its yield gaps. The subsidy case study reveals that little success was achieved in raising maize productivity. State interventions, such as the fertilizer subsidy program, are justified by demand-side "failure" of smallholder farmers who are not in a position to make use of fertilizers. Common problems are the lack of financial resources (and access to credit and insurance), and/or the lack of knowledge on how to appropriately use the inputs (or perceive the benefits of them). On the supply side, challenges include the lack of economies of scale for the private sector to reduce high transport, stocking and distribution cost, which led to the justification of government intervention (Druilhe & Barreiro-Hurlé 2012). Empirical findings identified state failures that impede demand for fertilizer by farmers, such as targeting, rent-seeking and elite capture (Scheiterle et al. 2019). However, the study also emphasizes the

importance of site-specific interventions based on multidisciplinary research findings, to address low productivity challenges in the north of Ghana. Agronomic practices, such as improved soil carbon management and reduced mechanical stress through mulching, as suggested by integrated soil fertility management measures, are expected to greatly contribute to raising maize productivity in the study region.

The question arises as to why governments, like Ghana, pursue this strategy even though it is apparently not successful. A possible explanation is that this intervention is more popular among policymakers. Fertilizer subsidy programs are less complex and show a higher impact on politicians' popularity than complex processes, like investments in agricultural extension, which have lower 'publicity power' (Jayne & Rashid 2013; Birner & Resnick 2010). Nevertheless, for the development of the fertilizer market it is necessary to invest in the knowledge of both extension service providers and farmers, leading to more efficient and productive fertilizer use (Druilhe & Barreiro-Hurlé 2012).

The importance of political incentives in Ghana can be seen in the case of cacao, for which the nation was able to increase productivity levels. Major financial investments, targeted at research and specialized extension services to develop solutions and address problems, were covered by the government and led to overall success in the cacao sector. This targeted intervention was instrumental in strengthening the sector but also in spurring private action (Kolavalli & Vigneri 2011). A similar effort would be needed to foster increased maize production. Investing in capacity building of local institutions, for example in equipping laboratories for soil fertility tests, fertilizer and seed quality control. Similarly, strengthening research institutions to develop locally adapted solutions, such as controlling Striga infestations, supporting extension services in delivering generated knowledge, and reporting back from the field on problems to be targeted, are all important measures to develop the agro-biomass sector. Good quality inputs are also fundamental: for example, maize seeds available for farmers at the agro-input dealers were found to have high genetic heterogeneity and some differed (genetically) largely from the variety, they were sold for (Nannuru et al., upcoming). Institutions should be capable of producing quality inputs for farmers and they should be made accountable. The budget for extension services are also expected to attract investments from the private sector, as the cases of sugarcane in Brazil and cacao in Ghana have demonstrated. However, it seems that local governments have not yet recognized the potential of the bioeconomy.

The role of knowledge was also highlighted in the second case study. Market queens in Ghana represent an important trade association, which has been overlooked in the value chain literature. The current public discourse has a strong impact on the public perception of these

market associations. However, their inclusion could contribute to strengthening governance, promoting transparency, developing community-based services and contribute to women's empowerment. Women's empowerment is pivotal for many tangible outcomes, including food security, education, child health, contraceptive use, and is imperative for achieving poverty reduction and human rights (Quisumbing & Maluccio 2000; Thomas 1990; Malhotra & Schuler 2005; Allendorf 2007; Doss 1996; Hashemi et al. 1996; Jejeebhoy 2002; Schuler et al. 1997).

4.2. The role of cooperatives and networks

The comparative advantage of sugar and ethanol production in Brazil draws attention to the role of cooperatives and their active integration in institutional networks. The coordination between institutions and farmers was facilitated by cooperatives, as they catalyze knowledge transmission among farmers and research institutions. Cooperatives and collective action initiatives have the potential to support small-scale farmers to compete in the bioeconomy. For example, commonly owned processing plants can play a major role in the participation of farmers in new markets. This could be the case of shared biomass digestions units to produce polymers used in the manufacturing of bioplastics or other resources needed in the production of materials. Addressing inefficiencies, coordination problems or barriers to accessing the market are particularly important in developing countries, and forms of collective action can help to address these market failures (Markelova et al. 2009). Collective organizations can foster the development of a well-functioning agro-biomass sector in different ways and from different standpoints in the value chain. The importance of credit cooperatives to overcome the governance challenges of small transactions by asset-poor actors (risky economic activities) is highlighted in the market queen case.

Transaction costs are the embodiment of barriers that prevent actors in the value chain from interacting. To address these challenges, forms of collective action, such as cooperatives (or market led-female institutions), are helpful in overcoming barriers of assets, information, and services (Jaffee 1995). Cooperatives have the potential to foster income opportunities by reducing transaction costs and facilitating input and product deliveries. They also function as a learning platform; information can be collected at one point and does not have to be retrieved or delivered to be dispersed among members (section 3.2). Moreover, forms of collective action can contribute to positive externalities such as reconciliations between actors along the value chain (Boudreaux 2011). However, there are narratives or myths that have been repeated so many times that they become institutionalized facts (Klein 2002); so much so that such discourses are then experienced as reality (Foucault 1972). This is the case of female-led credit

cooperatives in Ghana, held to be monopolizing market institutions by social consensus. Acknowledging the existence of this discourse and fostering experience exchange on neutral platforms to show different aspects of the role women's associations play can benefit all actors within the biomass-value web. To foster collaborations, however, strengthening collective organizations' intangible assets such as knowledge and agency, and uncovering the role played by market institutions in the value chain and society become the focus. Overall, the promotion of social reforms that lead to equity and justice are necessary for traditional institutions to unleash their potential.

Cooperatives channel knowledge and are therefore pivotal to vertical and horizontal information transmission. The accumulated experience in female-led market institutions can trigger other credit institutions to develop strategies to coordinate small transactions of their many members. Farmers' cooperatives improve access to input and output markets but often lack management skills. For instance, farmers' cooperatives in Rwanda have been an important avenue to enable smallholders to earn more money from coffee and develop additional products (Boudreaux 2011). Market queens in Ghana oversee well-functioning credit cooperatives based on strong management and entrepreneurship. The acquired skills and leadership features can serve as models for other cooperatives to address existing market failures.

4.3. The role of networks and multi-stakeholder participation

The shift towards a bioeconomy requires a type of revolution. The current resource pillars of the industrialized world will not only need to change substantially, but organizational and social aspects will need to undergo dramatic changes as well (WBGU 2011). The 'Brenner debate' as introduced earlier, has initiated the discussion on the role of political and institutional versus technological implantation of innovations. Brenner (1976) advocates the need to consider institutions when trying to understand what it takes to make an agricultural revolution happen. The green revolution in India highlights that in addition to technologies that were indispensable to improve yields in a very short time span, vision, leadership, institution-building and multilateral collaboration of diverse actors were crucial aspects for its success[3]. The involvement of research bodies, donor organizations, universities and extension service providers from various levels of global, state, regional, and community centers, made the green revolution a successful example of large scale multi-stakeholder collaboration (Banerjee 2013).

[3] Despite the successes of the Green Revolution, we acknowledge that there are of course also negative consequences to the green revolution as for example lack of biodiversity in the cropland, use of non-sustainable agricultural practices which impact human health and the environment as well as economic consequences for farmers.

The integration of farming communities in this context, as well as scale-neutral technologies that benefited smallholders in particular, were central to the revolution. (Akande et al. 2005; Hazell & Ramasamy 1991; Lipton 1988; Jewitt & Baker 2007; Yapa 1977). Similarly, the comparative advantage of sugar and ethanol in Brazil came about.

We argue that the development of the bioeconomy requires a similar effort. Political commitment and networks between institutions are as relevant as the development of bio-based products and processes. The Brazil case study emphasizes the importance of collaborations between national and international, as well as private and public sector actors. The results suggest that Brazil must overcome bureaucratic hurdles and create incentives to stimulate the innovation system. In the current innovation system in Brazil, coordination and network failures have been identified, for example, low intra-industry collaboration. However, these links are especially crucial when it comes to facing new challenges, such as technological and commercial uncertainty, and behavioral uncertainty of rival firms (Malmberg et al. 1996). Without links between industries, knowledge generation is slow, expensive and spillover effects might be missed (Buchmann & Pyka 2014; Pyka & Saviotti 2002). Suzumura (1992) identifies how collaborative R&D networks between rival firms foster spillovers, and that firms are also more likely to internalize knowledge spillovers, which enhances further investment in R&D. A recent analysis investigating innovation outcomes in industrial cluster projects in Japan found that indirect support programs are even more important than support for R&D. Indirect support programs (participation in meetings and events, and using coordination and advisory services) enhance firms' performance, specifically that of local firms and small to medium enterprises. Closer collaboration in public-private partnerships is also likely to contribute to overcoming current mistrust problems. To avoid crowding out effects, R&D supported by the government should address programs that seem more risky and with less potential for private returns, that would otherwise not be addressed (Hishimura & Okamuro 2011).

The exploitation of multiple types of knowledge is crucial for innovations to come about, as is the realization of complex multi-institutional links between research activities and the innovation process (Coriat & Weinstein 2002). In less developed industrial nations, "coordination mechanisms need to be given a much more prominent place in policy thinking" (Kydd and Dorward 2004 p. 967). In the rural areas of Ghana, for example, government intervention to address coordination failures can lower risk and raise expected returns. Intervention could also attract private agents to invest at multiple points along the supply chain; this might involve communications infrastructure, market information systems, commodity insurance, technical research, and extension. Additionally, support for trader and farmers'

associations to increase basic supply chain profitability should be supported (Kydd and Dorward 2004). The fertilizer study in Ghana identifies the low capacity of the extension service to provide knowledge on soil fertility management and support crop productivity with locally tailored solutions. Furthermore, the case study shows that the private sector is providing good quality fertilizer but that the distribution stage, carried out by the public sector, is failing. Similarly, the dominance of public sector institutions in Ghana's current seed system is facing comparable challenges, even if the context is more complex (Poku et al. 2018). Aside from political economy aspects, coordination and network failures prevent the exploitation of the complementary roles of the public and (national and international) private sectors. As indicated in the Brazil case, this plays an important role in the development of the bioeconomy.

As depicted in the Ghanaian and Brazilian cases, networks and coordination are crucial in the complex bioeconomy development arena. However, dominant narratives, as illustrated in the case of the market queens, affect the integration of important traditional institutions. Traditional female-led market institutions are effective in the distribution and circulation of information, within the market and among members, and they successfully coordinate with traditional and government authorities. If integrated into the local institutional network, they could act as agents to diffuse innovations and information on very diverse subjects. Due to the generally pejorative discourse and perception of such groups, their potential remains at a standstill.

4.4. Policy recommendations

This working paper has taken three case studies from two countries at different development stages of the bioeconomy. Both countries are endowed with natural resources and could theoretically sustain a shift away from the current fossil-fuel-based economy. The role of policies, institutions, and networks has been analyzed to identify underlying governance challenges that prevent better production and utilization of biomass-based resources. The broad policy implications identified in this research are as follows:

a. Fostering capacity-building of research institutions

All three studies clearly underline the need for capacity building of research institutions (see section 4.1. "The role of knowledge"). For example, provision of laboratory facilities to allow identification of site-specific problems would help in the development of locally adapted solutions. Site-specific data coupled with well-trained and well-equipped extension services, would help raise productivity levels of crops. Equally important are skill-training programs for staff members to foster collaboration and intensify networks between national and international

institutions. Policies and regulations should intensify knowledge flows and financially support the development of local research institutions. Allocating a higher share of public expenditures towards capacity building is expected to develop the agro-biomass sector and strengthen the bioeconomy long-term.

b. Strengthening extension services and addressing region-specific problems

The results from the fertilizer study provide evidence for the necessity of strengthening demand-driven extension services by addressing regional problems related to production, processing, and marketing. Training of extension officers on locally adapted strategies is pivotal, as well as increasing their budget and equipment availability to reach more remote areas. The development of a well-structured extension service provisioning system with specialized personnel is also expected to attract the private sector and provide wider country coverage, as demonstrated by the Brazil sugarcane case.

c. Fostering coordination between research centers, extension services and communities

The chosen case studies suggest that fostering collaboration between institutions would help overcome the challenges that affect the heterogeneous actors in the innovation system of the bioeconomy. The fertilizer and the sugarcane cases emphasize the importance of closer networks among research institutions and between research institutions and private and public sector actors. However, the work also highlights the need to better understand local institutions; successful integration of collective action initiatives could aid the development of solutions for widespread problems, and additionally foster innovation strategies that are important for the economy. For example, rural credit systems based on small transactions in a risky environment, as described in the market queen study.

d. Integrating collective action groups into institutional networks

The study suggests that cooperatives and other forms of collective action can serve as an effective link to communities in remote areas and possibly amplify the effect of extension service provision. Reinforcing traditional institutions can contribute to strengthening governance in rural areas by promoting transparent information delivery and decision making that represents various groups in society. Additionally, cooperatives can contribute to strengthening the monitoring of institutions and holding them accountable. The case study of Brazil depicted cooperatives as effective information channels between farmers and research institutions.

e. Supporting long-term investment schemes and revisiting bureaucratic measures

The provision of long-term incentives, as a strategy, can encourage stakeholder participation in innovation networks. Long-term policy perspectives encourage stakeholders to engage in more risky processes, which are vital for the development of the bioeconomy. To attract collaboration across research fields, obsolete bureaucratic processes, as identified in the Brazil case, need to be revisited. The cumbersome coordination dimension weakens networks and collaboration, therefore introducing coordination agents that support interactions within the network should be considered. This could greatly foster the development of the bioeconomy.

5 Concluding remarks

The case studies from Ghana and Brazil provide a range of insights into the complexity of shifting to a new economic system, from macro-level institutional dynamics to the very inputs that will grow the bioeconomy. Making the bioeconomy a reality will entail vision, leadership and crosscutting collaboration among diverse institutions. The role of knowledge institutions is paramount, as evidenced by the green revolution in India and the early achievements of the bioeconomy in Brazil. These case studies stress that knowledge-based development is vital to unleash the full potential of the bioeconomy to allow it to soar to unprecedented heights.

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