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Innovation for green industrialisation: An empirical assessment of innovation in Ethiopia's cement, leather and textile sectors

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ABSTRACT

Ethiopia has recently committed to economic transformation and industrialisation through a low-carbon development trajectory. Existing literature highlights innovation as a critical driver of industrialisation, and the need for 'green' innovations to improve resource productivity and reduce pollution. However, empirical studies investigating the nexus between green innovation systems and industrialisation in developing countries are limited. Based on nine semi-structured interviews and a survey of 117 firms, this article assesses sectoral systems of innovation in Ethiopia's cement, leather and textile sectors, with a view to understanding their functioning toward supporting green industrialisation. Results revealed low rates of product and process innovations among firms in Ethiopia. The main inhibitors of innovation are high costs of technology, inadequate finance and limited information. Improving competitiveness is the main driver of firms' innovation, while reducing environmental impacts and meeting environmental regulations were among the least important motivators. Moreover, interactions among firms, government and other actors encourage innovation. The study therefore suggests enhancing coordination among key actors, providing financial incentives for firms, and enforcing environmental regulations.

1. Introduction

Ethiopia aspires to become a middle-income country within the coming decade, thereby lifting tens of millions of its people out of poverty. To realize this goal, the Ethiopian government adopted the five-year Growth and Transformation Plans (GTP-I, 2010–2015 & GTP-II, 2016–2020). At the same time, the country recognises the risks posed by climate change and has committed to a low-carbon development trajectory within a Climate Resilient Green Economy Strategy (CRGE). The GTP-II stresses the facilitation of structural transformation through developing a dynamic industrial sector. Unlike GTP-I, GTP-II explicitly incorporates targets for the implementation of the CRGE strategy in industrial sectors through leapfrogging to modern and energy-efficient technologies.

However, Ethiopia's industrial sector is currently at a nascent stage and has a high emissions growth rate. The sector contributed only 15% of GDP in 2015. In the 2000s, industrial sector production increased by about 9.1% annually and in the GTP I period (2010/11–2014/15) by about 19.6% (FDRE, 2010; NBE, 2016). As per the Business As Usual projection of the CRGE strategy, industry emissions were estimated to increase by 16% per year (FDRE, 2011). Hence, boosting industrial production while keeping GHG emissions low is a demanding task which cannot be achieved without spurring green innovation – defined as the introduction and diffusion of new knowledge, techniques and products that ensure resource efficiency and green growth. A large body of scientific literature since Schumpeter (1934) has theoretically identified innovation as central to socio-economic development (Dosi et al.,

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1988; Verspagen, 2005), economic growth and industrialisation (Freeman 1987; Hulten and Isaksson 2007; Organisation for Economic Cooperation and Development (OECD) 2012, World Bank 2010), and transitions to sustainability and a green economy (Jacobsson and Bergek, 2011; OECD, 2011; UNEP, 2011a; b; UN, 2011; World Bank, 2012). Hence, innovation has a vital role to play in realizing Ethiopia's low-carbon industrial development agenda.

Therefore, empirical analysis of innovation systems and their role in supporting green industrialisation is crucial to inform emerging policies. Although some studies (Talegeta, 2014; STIC, 2015; Beyene et al., 2016a,b; Kuriakose et al., 2016) report low rates of industrial innovation activities in Ethiopia, an assessment of underlying factors and systems of innovation is lacking. This study examines innovation systems and activities in three key industrial sectors in Ethiopia, namely cement, leather and textiles. These sectors were selected because they have been identified as significant growth industries for Ethiopia in the GTPs and make relatively large contributions to greenhouse gas (GHG) emissions and other pollutants. Specifically, the cement industry is the largest emitter of Ethiopia's industrial GHGs, contributing 50%, whereas textiles and leather account for 17% (UNDP Ethiopia, 2011). In addition, Ethiopia's leather and textiles industries cause significant water and soil pollution (Abera, 2014; Reda, 2015).

The overall aim of this paper is to assess the robustness and performance of the sectoral systems of innovation, and how well they support Ethiopia's green industrialisation agenda. It investigates the main drivers, barriers and performance of firms' innovation activities. The novelty of this paper lies in its analysis of innovation within the context of green industrialisation in a low-income country. To date, the vast majority of studies on green innovation focus on advanced economies or middle-income countries. The study hypothesizes that: (i) firms' interactions with government and development partners encourage innovation; (ii) firms innovate to gain competitiveness rather than to comply with environmental standards; and (iii) costs of technology and information inhibit firms' innovation. A mixed method is adopted, involving semi-structured interviews with key innovation system actors as well as a survey of firms.

The remainder of the paper is organised as follows. Section 2 provides the conceptual background and literature review. Section 3 describes the empirical methodology and data collection process. Section 4 analyses the structure of the sectoral innovation systems by mapping major elements and linkages. Section 5 analyses quantitative data on innovation activities while the final section presents the main conclusions and recommendations.

2. Conceptual background and literature review

2.1. Conceptual framework

Innovation broadly pertains to the introduction of new knowledge, technologies and practices, or new combinations of existing knowledge, and their diffusion (Edquist and Johnson, 1997:42; World Bank, 2010:4). The Oslo Manual provides a widely used definition: "An innovation is the implementation of new or significantly improved product and process, marketing method, or organizational method in business, workplace organisation or external relations" (OECD, 2005:46). Hence, four types of innovation can be specified: product innovation, which is the introduction of a new or significantly improved good or service; process innovation, entailing the implementation of new or significantly improved production methods; organizational innovation, representing the implementation of a new organizational method; and marketing innovation, implying the implementation of a new product design, packaging, placement, promotion or pricing.

Innovations that result in improved environmental performance are referred to as environmental innovations, green innovations, ecological innovations (eco-innovations), and sustainable innovations. These are synonymously used in the literature, while sustainable innovations encompasses a social aspect (Schiederig et al., 2012). The OECD (2009) defines eco-innovation as "the creation or implementation of new or significantly improved products, processes, marketing methods, organizational structures and institutional arrangements which *lead to environmental improvements compared to relevant alternatives*" (italics added). This study focuses only on product and process innovations in cement, leather and textile sectors, and looks for those that cause reductions in resource inputs (such as energy, water and materials) and reductions in solid, liquid and gaseous wastes including carbon emissions.

Given the sectoral focus, the analysis is framed under the 'sectoral systems of innovation' (SSI) context, although innovation systems can be analysed at national, regional and technological levels. Freeman (1987: 1) defined an innovation system (IS) as "the network of institutions in the public and private sector whose activities and interactions initiative, import, modify and diffuse new technologies". On the other hand, a sectoral system of innovation and production is a set of new and established products and processes and the set of agents carrying out various interactions for the creation, production and marketing of those products (Malerba, 2002:250). The structure of an IS comprises networks of actors from the public sector, higher education and research institutions, industries, financial organizations, network and support organizations, and consumers (Edquist, 2005). The flows of knowledge, information and technology are key to the innovative process. Thus the study analyses the interactions among key actors in the selected manufacturing sectors because they are critical for the transmission and diffusion of innovations.

Furthermore, driving and inhibiting factors for firms' innovation is framed within The Oslo Manual and recent literature. The major motivations for enterprises' innovation are to improve firm performance and boost competitiveness, either addressing demand/competition factors (e.g. increasing the range of goods on offer, expanding market share, entering new markets), or by targeting production/cost aspects (e.g. increasing production capacity, boosting efficiency and reducing unit costs). Firms may also innovate in order to comply with environmental regulations, to reduce resource use or environmental impacts, and to improve health and safety standards. On the other hand, inhibitors of firms' innovation include cost factors (lack of funds, lack of access to finance and high costs of innovation), market factors (uncertain demand, barriers to entry and competition), knowledge factors (lack of skilled personnel, inadequate information about new technologies, and a dearth of market information) and institutional factors (weak property rights, high costs of doing business, and a lack of reliable infrastructure).

2.2. Review of literature on industrial innovation

Globally, various studies investigate industrial innovation activities and factors affecting them. Pratoom and Savatsomboon (2012), Sag et al. (2016) and Chen et al. (2017) studied determinants of firms' innovation. On the other hand, Chuluun et al. (2017) analysed effects of firm networks on innovation in the USA, while Karabulut (2015) investigated impacts of innovation on firms' performance. Kwon and Motohashi (2017) studied the role of institutional arrangements in national innovation systems in USA and Japan. Moreover, Andersen et al. (2014) demonstrated sectoral innovation systems' role in strategic foresight practice in Nordic facility management. Most existing studies focus on developed and middle-income countries and separately analyse innovation systems and industry-level innovation. However, firms' innovation can be influenced by interlinked factors in the innovation system and industry-specific conditions.

In Ethiopia, Gebreeyesus (2011) showed that larger firms and those in the manufacturing sector are more likely to engage in innovation activities, while vocational training positively affects innovation. Even within the same size and location, there can be variation in firms' innovativeness. This is confirmed by Gebreeyesus and Mohnen (2013), who found varying behaviours and innovation performance in a cluster of shoemaking firms in Ethiopia. On the other hand, Beyene et al. (2016a) indicate that the type of firm ownership and cultural factors influence innovation activities in leather and textile firms, while Beyene et al. (2016b) highlighted the role of firms' innovation strategies in product innovation performance, in addition to size and ownership.

Moreover, studies report low levels of innovation in Ethiopia's industry sector. For instance, Talegeta (2014) finds that there is a low level of technological innovation among small and medium enterprises, citing a dearth of government regulation, insufficient information, inadequate R&D, high costs of innovation; lack of skilled personnel; insufficient finance; and a lack of cooperation as major obstacles. Ethiopia's innovation performance is relatively poor compared to China, Kenya and a group of other low-income countries (Kuriakose et al., 2016). According to the same study, 68% of large firms, 49% of medium enterprises and 42% of small enterprises in Ethiopia reported product or process innovation. Similarly, only 60% out of 1200 mining and quarrying, construction, manufacturing and services firms reported innovations in the three-year period 2012–2014 (Science and Technology Information Centre (STIC), 2015). The major driver of innovation was the desire to enhance product quality, and the main mechanism used by firms was the acquisition of machinery and software, instead of R&D. The major hindrances to innovation were lack of funds and high costs of innovation. Legesse and Singh (2014) showed that the introduction of green process innovations (lean manufacturing system) in the garment industry can save resource inputs and waste outputs, and boost productivity.

However, research on industrial innovation and particularly green product and process innovation in Ethiopia is generally limited. Previous studies also fail to provide a mixed approach analysing both firm-level factors and sectoral innovation system performance. This study aims to address these gaps by investigating sectoral systems of innovation with a focus on green industrialisation.

3. Methodology and data

A mixed-method approach was adopted to analyse the sectoral systems of innovation in the cement, leather and textile industries. The first step was a survey of sampled enterprises to generate data on innovation activities and associated factors, sources of information and partnerships using the set of close-ended and open-ended questions. The survey questions were formulated using various factors that motivate and inhibit innovation among firms as listed on the product and process innovation sections of The Oslo Manual (OECD, 2005) and recent literature such as Andersen et al. (2014), STIC (2015) and Chen et al. (2017), with inclusion of additional questions about green innovation. The questionnaire was tested and validated through engagement of experts from respective industry development institutes and a pilot survey of six firms. The survey process involved numerous site visits to gather responses to the questionnaire. The number of respondents from the businesses ranged from one representative (usually the manager) in small firms to three (the general, production and marketing managers) in large companies. The sample selection was stratified based on sectors and geography. Accordingly, 141 firms were identified for the survey. A census of all firms was conducted among cement manufacturers, tanneries and integrated textile firms. A random sampling technique was used to select firms from downstream manufacturers of leather products and garments. Of the selected 141 firms, 11 refused and 13 provided incomplete responses, resulting in a response rate of 82%. The final sample of 117 firms comprised 15 cement, 40 leather and 62 textile firms.

The second step involved semi-structured interviews with key role-players in the sectoral innovation systems. The interviews employed a checklist of open-ended questions about existing innovation processes in the three case sectors. Questions also focused on linkages and communication channels among the actors, as well as drivers, challenges and opportunities for green innovation. Interviewees included prime ministerial advisors, senior government officials and experts from the Ministry of Environment, Forest and Climate Change, Ministry of Industry, Ethiopian Investment Commission, three (cement, leather and textile) industry development institutes, and respective industry associations, and leaders of think tanks. Nine interviews were conducted in June and July 2016, each lasting between 60 and 90 min. The information gathered was used to map the actors and networks in the respective SSIs.

4. Sectoral systems of innovation and the greening agenda

The sectoral systems of innovation in the cement, leather and textile industries are analysed from the perspective of the green industrialisation agenda, drawing on policy documents and interviews with prominent actors. Fig. 1 illustrates the structure of SSIs, drawing on Malerba (2005) "building blocks" of an SSI, namely knowledge and technologies, actors and networks, and institutions.

Several ministries and agencies are important actors in the SSIs, including the Ministry of Environment, Forestry and Climate Change (MEFCC), the Ministry of Industry (MoI), the Ministry of Science and Technology (MoST), the Ministry of Finance and Economic Cooperation (MoFEC) and the Ethiopian Investment Commission (EIC).

An interviewee in the MEFCC stated that his ministry plays a critical role in the implementation of environmental policy in general and the CRGE in particular. The MEFCC has introduced several national proclamations and regulations to control pollution emanating from various industrial sources, including an Environmental Impact Assessment (EIA) proclamation, a solid waste control proclamation, a pollution control proclamation, and industrial pollution control regulations. Furthermore, the MEFCC provides technical support both to strengthen regional agencies that enforce environmental regulations and to assist enterprises to comply with environmental standards and regulations. The MEFCC is therefore an important actor in the SSIs, especially by providing information and regulatory stimulus for green innovation.

According to an official in the MoI, his ministry is responsible for ensuring the implementation of the CRGE and environmental policies within the industrial sector. Although the MoI is active in the national and sectoral systems of innovation in general, its involvement in supporting green innovation specifically appears to be somewhat limited. The MoI has limited instruments at its disposal to foster innovation. For example, it does not administer grants or provide tax breaks or loan guarantees. Furthermore, there are no specific industrial sector policies and laws aimed at encouraging eco-innovations. The main route that the MoI uses to promote innovation is to gather information on best practices and forward recommendations to the CRGE Facility, a fund that

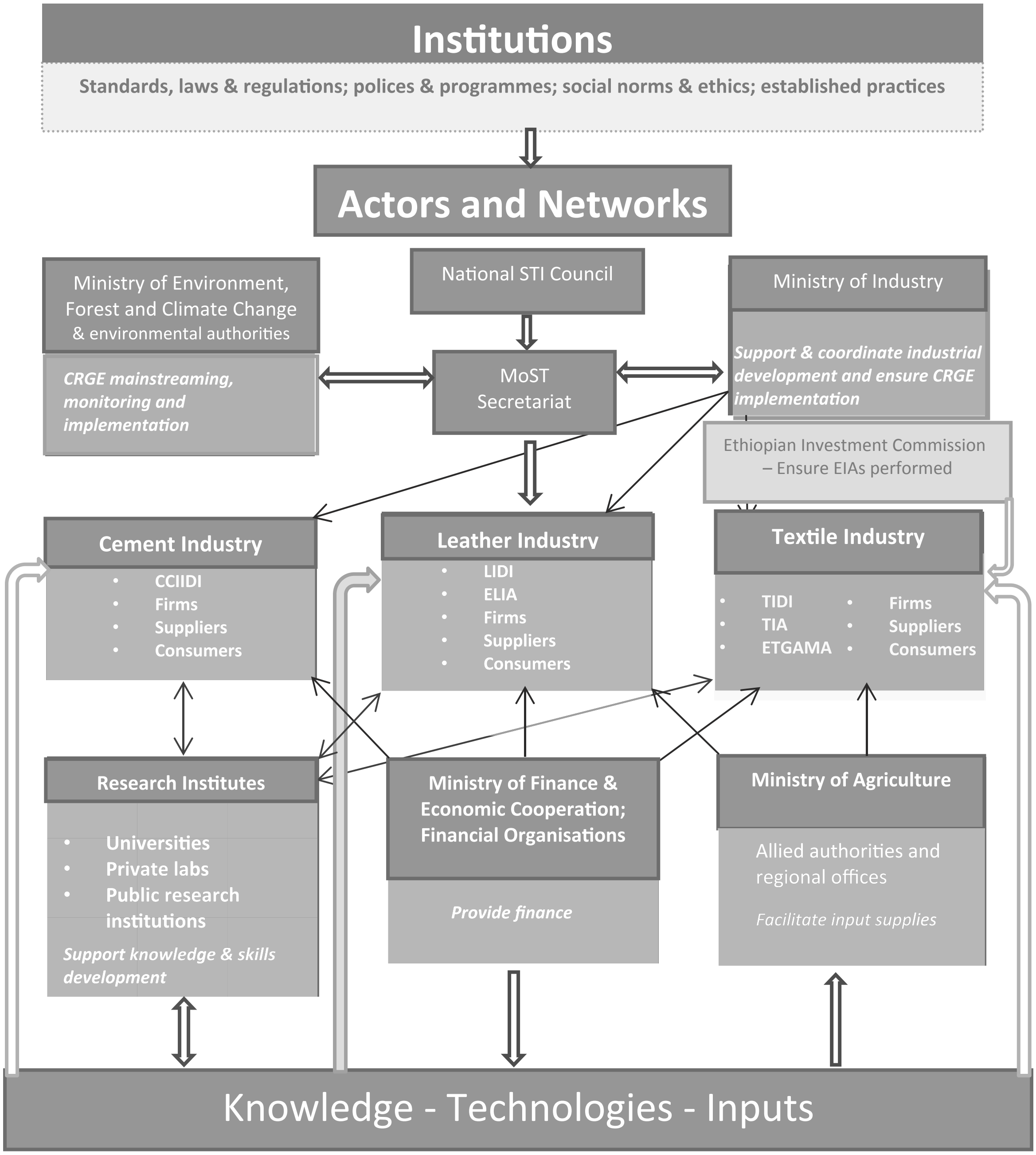

Fig. 1. Structure of the sectoral systems of innovation in Ethiopia.
Source: Authors

supports CRGE implementation projects. The interviewed official in the MoI described the connections among the main innovation system actors as follows:

> There are quarterly forums of the ministerial committee comprising line ministries involved in implementing the CRGE and a technical steering committee, which are co-chaired by the MoFEC and MEFCC. The MoI has regular communication with MEFCC, MoFEC and other ministries such as education and MoST. There are university-industry linkages, some with memorandums of agreement. The MoI gives support and direction to Industry Development Institutes, but responsibility for implementation and for liaising with universities is decentralised to the institutes.

Officials in the EIC stated that the environmental impacts of new entrants into the manufacturing industry in Ethiopia comes under considerable scrutiny, in contrast to established firms. Investors wanting to build new manufacturing facilities have to apply for an investment licence at the EIC. It then has to undertake an EIA, and submit this to the regional authority where they intend to set up operations. The regional authority forwards its recommendation to the EIC, which then decides whether to grant a business licence after checking compliance with environmental and social regulations.

According to officials in the EIC, many new industrial investments, especially textiles and leather, are being channelled into industrial parks, where centralised facilities are provided to optimise environmental performance. This recognises the fact that the major environmental challenge facing firms in these sectors relates to water pollution, while effluent treatment plants are prohibitively expensive for most firms to set up on their own. Thus, it appears as if the government's primary strategy for achieving greening in the textiles and leather sectors is to establish industrial parks. Firms locating in the industrial parks are forced to comply with environmental regulations, including EIAs.

Innovation, however, is also important in established firms that typically use older processes and equipment. Existing manufacturing facilities tend to be spread out geographically, which makes it difficult to establish common waste and effluent treatment facilities. In some cases, existing firms (e.g. tanneries) have been encouraged to relocate to industrial parks. However, the EIC official stated that many domestic firms in all sectors face a cost barrier to enter these industrial parks, as they cannot afford the rentals. Furthermore, there does not seem to be any mandatory EIA process for incumbent firms. Enforcement of compliance with existing environmental regulations has been weak, partly due to a lack of capacity and motivation of the regulatory bodies. According to the EIC official, there is a proposal for EIAs to be required for the expansion of existing manufacturing facilities. Therefore, from the regulatory perspective, the incentives for green innovation amongst existing firms are somewhat limited.

4.1. Analysis of innovation systems in cement sector

The MoI oversees the activities of the Chemical and Construction Inputs Industry Development Institute (CCIIDI), which is responsible for assisting the cement industry to meet the CO_2 emission reduction targets contained in the CRGE. According to the official in the CCIIDI,

> Every new entrant into industry must meet various environmental criteria, but especially CO_2 emissions in the case of cement. An Environmental and Social Impact Analysis must be undertaken before a firm can obtain a manufacturing licence. Enforcement of environmental requirements is ultimately the responsibility of the MEFCC, but in the case of the cement industry this is delegated to the MoI. The MoI, in turn, delegates to the CCIIDI.

The CCIIDI plays a coordinating role within the network of innovation actors in the cement SSI. This role is described as follows by an interviewee:

> There is a tripartite relationship between the CCIIDI, academia and industry. Research is demand-led, according to the industry's problems and needs. Regular meetings involving all partners are held every three months. CCIIDI also generates research agendas and has an advisory board involving professionals who advise on the research agenda, although this is still in a start-up phase. The CRGE strategy takes account of local people's needs, and how they can benefit from the programmes that are adopted to meet the targets (e.g. the biomass programme). This requires diversified knowledge and the CCIIDI, therefore engages with academics from diverse fields.

The cement industry contributes significantly to CO_2 emissions as the result of the calcination of raw materials and energy consumption. The key mitigation effort in the cement industry involves reducing emissions from energy use, because – according to the official – the industry cannot at this point reduce calcium carbonate inputs, which is more technically demanding and costly. This is supported by the finding by Ishak et al. (2016) that co-processing, kiln process improvement and carbon capture and storage can significantly reduce CO_2 emissions from cement manufacturing, but at a considerably higher production cost due to the required technology investments. There are two key process innovations for reducing energy-related emissions: improving efficiency and fuel switching. According to the CCIIDI official:

> Each firm must analyse its energy efficiency potential. For example, some firms are using hot gas emissions to capture heat for use in their processes. A two-stage programme of fuel switching has been undertaken by the cement industry, with assistance from the CCIIDI. The first is shifting from heavy fuel to coal. Energy inputs accounted for about 60% of costs before the switch, but this was reduced to about 40–45% with coal. This cost saving has allowed firms to exploit efficiency gains by investing in new equipment. Use of heavy fuel oil was highly inefficient and emissions intensive. All cement firms are now using coal.

The second stage of fuel switching will involve the partial substitution of biomass energy for coal. An invasive plant, Prosopis juliflora, is a significant problem for farmers in Afar region, having invaded 1.2 million hectares by 2013 and subsequently spreading to other areas. Research has shown that Prosopis has a high calorific value for biomass, so it is useful as a source of biomass energy for cement production. Technology is available for harvesting the plant, and a German company has developed technology to convert the plant to energy. According to the CCIIDI official:

> The plan is to shift all cement firms to biomass (40 per cent of their energy, with the balance being coal) over the next few years, starting in 2016/17. Mosobo is taking the lead, showing the way for other firms. By 2020, CCIIDI expects most cement firms to have adopted this measure. It is estimated that this project can meet the whole CO_2 reduction commitment for the cement industry stipulated within the CRGE.

4.2. Analysis of innovation systems in leather sector

The main actors in the innovation system in the leather sector are firms operating along the leather product supply chain, along with the Leather Industry Development Institute (LIDI) and the Ethiopian Leather Industries Association (ELIA). The LIDI has primary responsibility for assisting firms in the leather industry supply chain to meet the goals and targets of the CRGE and other environmental regulations. To achieve its mandate, the LIDI collaborates with relevant government ministries, domestic and foreign universities and research institutes, and local firms in the leather sector. According to a senior LIDI official,

> LIDI provides support to leather industries to use less emission technologies and monitor their activities. Our institute has environmental laboratory for testing. We do have model treatment plant facility. Moreover, the institute has established relevant department such as CRGE unit and environmental technology which work for environmental protection.

The ELIA represents tanneries as well as enterprises manufacturing leather products. An ELIA official recognized that one of its significant challenges is to help improve the environmental performance of constituent firms, especially tanneries. The official stated that as yet green certification for leather products has not been secured, and that this will require concerted efforts from other stakeholders including government ministries and agencies. While foreign direct investment (FDI) has been attracted into the leather sector, technology transfers are somewhat limited because such ventures remain fully-owned by foreign interests.

According to the interviewees, the impetus to undertake green innovations in the leather sector emanates from both external and internal sources. As the LIDI official put it, “There is also pressure from the buyers themselves. Buyers require compliance to environmental standards and social issues including child labor and safety.” Domestically, tanneries were initially given a five-year grace period in which to comply with new environmental regulations that came into effect in 2009, but this period expired in 2014. Since then, leather makers have come under increasing pressure from environmental regulators, with several tanneries having been forced to close, although some were able to reopen after making improvements. The LIDI official described some of the key initiatives that are supported by the government and private firms:

> Currently, we are taking initiative to establish leather city with common effluent treatment plant in Modjo town. Given substantial importance of clustering and building effluent treatment facility for leather industries particularly tanneries to greening the sector, the government is encouraging and support private sector to build their own industrial parks. In response to this, some private industrial groups are building their own facilities. These are the George Shoe Industry Zone in Modjo and the Huajan Industry Zone.

The ELIA regards the scale of investment and management required to create an effluent treatment plant to cater to so many firms as a significant challenge, but one in which it will be a major stakeholder. The leather city is envisaged as a joint undertaking between the private sector and government. According to the ELIA, tanneries will have to relocate to Modjo or build their own waste treatment plants.

Green innovation in the leather industry faces a number of challenges. One factor is the perception of private sector businesses, while incentives and enforcement of regulations are also lacking. As related by the LIDI official:

> Private investors become less responsible to environmental protection. They sometimes fail to comply with the environmental standards and focus only on making profit. Most of the private businesses consider greening activity as an expense and ignore benefits pertaining to green industrialization. Industries become reluctant and need push from the regulatory body … Adoption of environmental standards and technologies needs capacity and experience. Hence, taking standards from somewhere and experimenting it in different context is also challenging. Another challenge is the lack of strong market incentives particularly for the establishment of effluent treatment facilities. There are no separate incentives for those who developed their own effluent treatment plants.d

4.3. Analysis of innovation systems in textile sector

In the textile SSI, the main actors include the suppliers of inputs for cotton production, cotton plantation farms, manufacturers of textile products and garments, the Textile Industry Development Institute (TIDI), and the Ethiopian Textile and Garment Manufacturers Association (ETGAMA).

According to a senior official, ETGAMA represents interests of members in capacity building, creating market linkages, investment promotion and policy advocacy. The ETGAMA works closely with the TIDI, which was established under the Ministry of Industry to support the sector's development. The ETGAMA official stated that two recent international conferences on sustainability helped raise awareness and created opportunities for links with other stakeholders so as to improve competitiveness in the international market. The association also holds quarterly meetings with the MEFCC and TIDI to discuss issues of environmental compliance. Consumers are exerting pressure on factories to comply with environmental standards. The ETGAMA monitors the activities of its members and supports their compliance with international standards pertaining to environmental sustainability and social issues.

The ETGAMA official described some of the government initiatives towards greening of the textiles sector as follows:

> Government has set several incentives including tax holidays and building the industrial parks having sheds for ‘plug and play’ type of industrial establishments which is important for attracting investment. In addition to attracting investment, industrial parks help to ensure greener production and environmental sustainability. Previously all the factories were scattered and this makes compliance to the environmental standards challenging. This is because effluent treatment plant requires high investment which is costly.

In pursuit of capacity building, the ETGAMA collaborates with various development partners. According to the interviewee, the ETGAMA initiated a three-year project, funded by the Dutch government, which has engaged a consultant to assess the sustainability gap in the sector, including social and environmental compliance in the case of more than 20 factories. After identifying the sustainability gap, the project will support the firms to address issues of cleaner production, environmental and social aspects, health and safety.

In general, the SSI analysis indicates some innovative activities such as ongoing fuel substitution initiatives in cement firms, joint ventures to build a leather city with effluent treatment facilities and the textile sector's eco-industrial parks, and sustainability projects undertaken by firms in collaboration with government and development partners. These findings support the study hypothesis that interactions among firms, government and other partners encourage innovation.

5. Empirical analysis of sectoral innovation activities

5.1. Extent and types of innovation

The firms were asked about the extent of product and process innovations undertaken during the 2013 to 2015 period. Table 1 displays the results. Of the 15 cement firms, only 7% reported one product innovation. About 13% of cement firms reported process innovations; the average number of process innovations was 1.5. Of the 40 leather firms, 65% engaged in product innovation. The reported number of product innovations varied from as few as two to as many as 90, with an average of 18 per innovating firm. Process innovation was conducted by 28% of leather enterprises, ranging between one and five innovations per firm and averaging 2.4. Just 11% of the 62 textile firms reported product innovations, with the number of individual innovations per firm varying between one and 28, and averaging 10 per firm. On the other hand, 18% of textile firms engaged in process innovation, with the number of such innovations varying between one and five, except for one firm which claimed to have introduced 28 process innovations. Aggregating all firms across the three sectors, 29% and 21% reportedly engaged in product and process innovations respectively, with an average of 15 product and 4 process innovations per innovating firm. This finding of a low innovation rate among firms is consistent with the results of Talegeta (2014), Beyene et al. (2016a) and Kuriakose et al. (2016).

Given that the cement industry by and large produces a single

Table 1
Occurrence of product and process innovation by sector.

Innovation Activity	Cement	Leather	Textiles	All firms
Percentage of firms engaging in product innovation	7%	65%	11%	29%
Average number of product innovations per innovating firm	1	18	10	15
Percentage of firms engaging in process innovation	13%	28%	18%	21%
Average number of process innovations per innovating firm	1.5	2.4	5.5	3.7

homogeneous product (Portland cement), it is not surprising to find a low rate of product innovation. By contrast, leather, and textile and garment manufacturers deal with a much larger range of products, which also tend to change more frequently, which can offer freedom for product innovation.

Firms were also asked about the extent to which product and process innovations were introduced in order to reduce various kinds of inputs (energy, water, chemicals and materials) and waste products (solid, liquid and gaseous wastes). The results for 'green product innovations' are reported in Table 2. The cement firm that reported one product innovation responded with "do not know" to the question of how many innovations were adopted to reduce inputs or wastes; thus Table 2 reports no green product innovations in the cement sector. In the leather sector, 3% of enterprises reported product innovations intended to reduce chemical inputs and solid wastes, while a quarter of firms said they introduced product innovations to reduce material inputs. Considerably more green innovations were reported in the textiles sector, but only between 3% and 6% of firms engaged in such innovations. In aggregate, less than 5% of firms introduced product innovations to reduce most categories of inputs and wastes, with the exception of material inputs (12%). Overall, 21% of all firms reported at least one green product innovation.

Table 3 shows the reported extent of 'green process innovations' per sector. In the cement sector, only 7% of firms reported green process innovations to reduce energy use, solid wastes and material inputs. In the leather sector, the percentage of firms engaging in green process innovation varied from 5% to 15%, depending on the type of input/waste. Amongst textile sector firms, green process innovations were numerous (averaging between 2.7 and 4.9) and somewhat more common (adopted by between 10% and 15% of firms). Overall, only 15% of all firms reported at least one green process innovation. This result is consistent with the finding of Legesse and Singh (2014).

5.2. Drivers and inhibitors of innovation

In order to assess the relative importance of potential drivers and inhibitors of innovation, firms were asked to score a number of different factors on a scale of 0 (not significant) to 4 (a very strong factor). Fig. 2 reports average scores across firms in each sector and in aggregate for 11 drivers of innovation. There is comparatively little variation in the averages across sectors for most of the individual drivers. One exception is "reducing costs per unit produced", which is considerably higher for cement firms (3.9) than leather (2.8) and textile (3.1) firms. For both leather and textile enterprises, the most important drivers of innovation are "increasing market share" and "improving the value of goods and services". With regard to green innovation, it is noteworthy that textile firms cited "reducing environmental impacts" and "meeting environmental regulatory requirements" as the two weakest drivers of innovation. For leather firms, these two factors were the second and third weakest. These findings are congruent with those of Ortolano et al. (2014), who found that the need to meet environmental quality standards was not a major motivator for firms to adopt cleaner production processes in Pakistan's leather and textile sectors. For cement firms, the two environmental factors were the fourth and fifth weakest drivers. This indicates a need for improved enforcement of environmental regulations to stimulate green innovations.

Table 2
Product innovations adopted in the last three years to reduce inputs or wastes.

Innovations to reduce	Percentage of firms & average number of innovations per firm			
	Cement	Leather	Textiles	All firms
Energy use	0% (0)	0% (0)	6% (6.0)	3% (6.0)
Water use	0% (0)	0% (0)	6% (1.5)	3% (1.5)
Chemical inputs	0% (0)	3% (3.0)	6% (2.8)	4% (2.8)
Solid wastes	0% (0)	3% (4.0)	5% (3.7)	3% (3.8)
Liquid wastes	0% (0)	0% (0)	5% (1.7)	3% (1.7)
Gaseous emissions	0% (0)	0% (0)	3% (1.5)	2% (1.5)
Material inputs	0% (0)	25% (1.3)	6% (4.0)	12% (2.1)

Table 3
Process innovations adopted in the last three years to reduce inputs or wastes.

Innovations to reduce	Percentage of firms and average number of innovations			
	Cement	Leather	Textiles	All firms
Energy use	7% (2)	13% (1)	13% (4.9)	12% (3.7)
Water use	0% (0)	5% (0)	15% (2.7)	9% (2.7)
Chemical inputs	0% (0)	13% (2)	15% (2.7)	12% (2.5)
Solid wastes	7% (1)	10% (1)	13% (3.3)	11% (2.6)
Liquid wastes	0% (0)	8% (1)	13% (2.8)	9% (2.6)
Gaseous emissions	0% (0)	5% (0)	10% (2.7)	7% (2.7)
Material inputs	7% (1)	15% (1.5)	13% (3.9)	13% (2.7)

Overall, the results indicate that firms in Ethiopia engage in innovation activities to raise their market share and product quality rather than to meet environmental regulations. This supports the study's hypothesis that firms in Ethiopia innovate to gain competitiveness rather than complying with environmental standards.

Fig. 3 displays average scores across firms in each sector and in aggregate for 11 factors that inhibit innovation. A "high cost of new technologies" emerged as the strongest inhibitor for leather and textile firms and the second strongest for cement firms. "High cost of access to new markets" was also a major obstacle for cement and leather firms. The relatively high average score for "price competition" amongst cement firms could be due in part to product homogeneity in the cement sector. "Innovations by competitors" scored lowest for both cement (1.5) and textile (1.7) firms, while for leather firms, the least significant inhibitors were "lack of demand" and "dominant market share held by competitors". Lack of adequate finance was ranked as the second strongest inhibitor for textile firms and of medium importance for leather firms. The major policy implication appears to be that firms need financial support to meet the high costs of new technologies and to access new markets. Finally, the result of high cost of new technologies and information as a main inhibitor of innovation is partly consistent with Talegeta (2014) and supports the hypothesis that cost of technologies hinders firm-level innovation in Ethiopia.

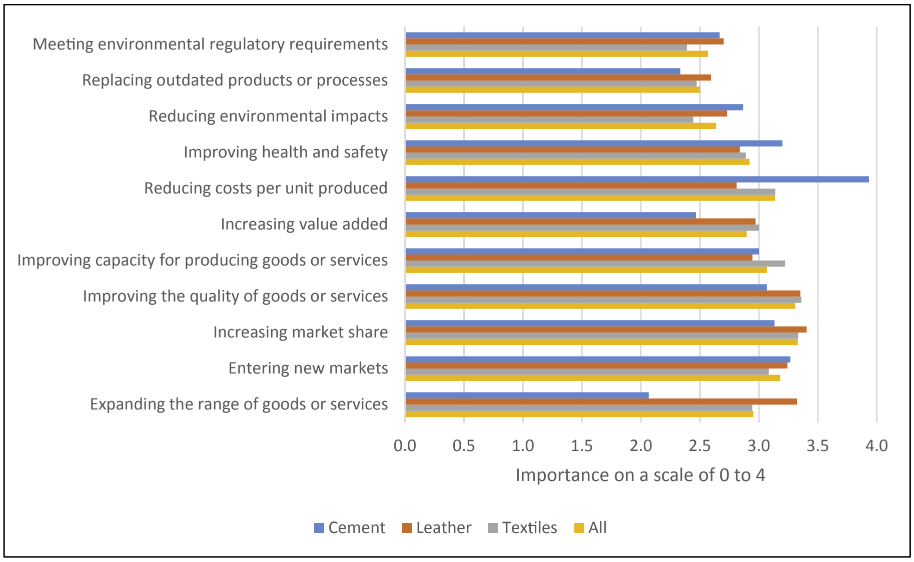

Fig. 2. Relative strength of factors encouraging innovation.

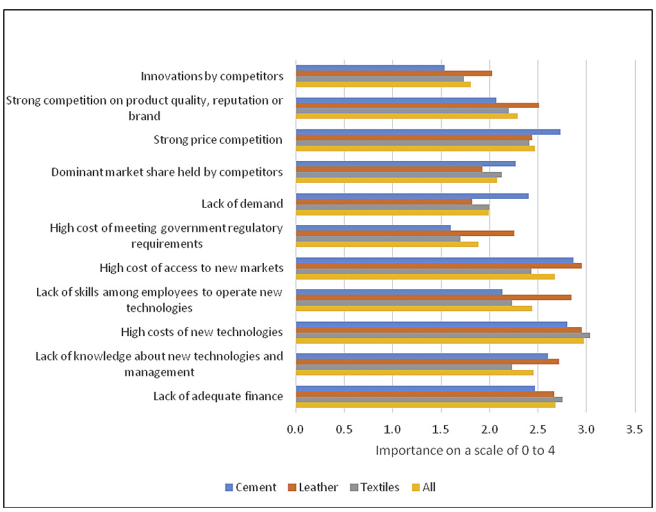

Fig. 3. Relative strength of factors inhibiting innovation.

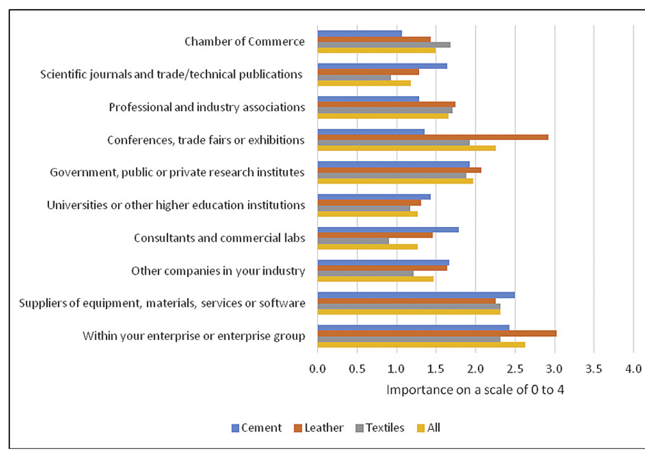

Fig. 4. Sources of information for innovation.

The sources of information and types of partners can determine how strong the innovation networks are and where the gaps lie. Fig. 4 shows the relative importance of 10 sources of information for innovation that firms rated. Information from within the enterprise or group was considered most important for firms in the leather (3.0) and textiles (2.3) sectors, and second most important for cement firms (2.4). The top category for cement producers was suppliers of equipment, materials, services or software (2.5). For leather sector firms, an important source of information was conferences, trade fairs and exhibitions (2.9). Government, research institutes and higher education institutions constituted a mediocre source of information for innovation, which implies reduced scope for knowledge and technology transfers.

6. Conclusions

This paper assessed the strengths and weaknesses of the emerging sectoral systems of innovation in key manufacturing sectors in Ethiopia. The evidence suggests that green innovation is not garnering the level of attention it requires to support a fully-fledged green industrialisation strategy. The MEFCC plays a critical role in the implementation of environmental policy, mainly by providing information and regulatory stimulus for green innovation. In addition, the MoI and affiliated sectoral industry development institutes are critical in supporting green innovation. The sectoral industry development institutes are playing an important role in the implementation of the CRGE strategy, and this includes facilitation of interactions and knowledge transfer among the innovation system actors. The major green innovation that is being adopted by cement manufacturers is the replacement of coal with biomass in order to reduce CO_2 emissions. The creation of industrial parks with centralised effluent treatment facilities is the main sectoral-level green innovation in the leather and textile industries.

The firm survey results revealed that the rates of product and process innovation among cement firms (7% & 13% respectively) are lower than among textile enterprises (11% & 18%). A significantly larger percentage of leather firms engaged in product innovation (65%) and process innovation (28%). Moreover, only 21% and 15% of firms in the three sectors reported green product and green process innovations, respectively. Increasing market share and reducing unit costs were cited as important drivers of innovation, while reducing environmental impacts and meeting environmental regulations were among the least important motivators. On the other hand, the most important inhibitors of innovation identified by firms were high costs of new technologies and high costs of access to new markets. Lack of adequate finance for innovation was also an issue for many firms. Concerning sources of information for innovation, firms generally relied on internal sources and trade fairs, rather than partnerships with universities, research institutes and government agencies.

Therefore, there is a need for greater support for green innovation to align the industrial policy with the desire for low-carbon development as motivated for in the CRGE. Green innovation also needs to be mainstreamed within the CRGE implementation process. Specifically, creating responsible units and improved environmental enforcement is needed to stimulate green innovations. Efforts are also required to educate firms about the need for green innovation. This needs to be supported by incentives and regulations that help to change the perception of private businesses to internalise negative environmental externalities. Financial barriers to innovation can be addressed with several financing mechanisms including debt financing, equity financing, government funding of R&D, co-funding by government and firms, and subsidies. A carbon tax also can provide incentives for firms to innovate to reduce their carbon emissions, and promote greening efforts. Furthermore, there is also a need to strengthen the interactions and linkages among key innovation system actors and firms to foster knowledge and technology creation and transfers.

The study has several limitations. First, 18 per cent of surveyed firms failed to provide responses, which somewhat restricts the representativeness of the results. Second, a statistical treatment of the survey results was not possible within the scope of this article. Third, the survey and interviews did not include detailed investigation of the types of green innovations that manufacturing firms have undertaken. These limitations indicate potentially fruitful avenues for further research.

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