



Research Report

An Assessment of Ethiopia's Innovation Systems in Relation to Green Industrialisation

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Abbreviations

BA	Business Angel
BERD	Business Enterprise Research and Development
CCS	Carbon Capture and Storage
CRGE	Climate Resilient Green Economy
EBRD	European Bank for Reconstruction and Development
ECID	Ethiopia Climate Innovation Centre
EDRI	Ethiopian Development Research Institute
EIA	Environmental Impact Assessment
EPA	Environmental Protection Authority
ETB	Ethiopian Birr
FDI	Foreign Direct Investment
FTE	Full-Time Equivalent
GDP	Gross Domestic Product
GERD	Gross Domestic Expenditure on Research and Development
GTP	Growth and Transformation Plan
HEI	Higher Education Institute
ICT	Information and Communications Technology
IMF	International Monetary Fund
IO	International Organization
IOT	Institute of Technology
IPR	Intellectual Property Rights
IS	Innovation System
LIC	Low-income Country
MEFCC	Ministry of Environment, Forests and Climate Change
MFEC	Ministry of Finance and Economic Cooperation
MoI	Ministry of Industry
MoST	Ministry of Science and Technology
NGO	Non-Governmental Organization
NSI	National System of Innovation
NSTIC	National Science, Technology and Innovation Council
OECD	Organisation for Economic Cooperation and Development
PEF	Private Equity Fund
PPP	Purchasing Power Parity
PRI	Public Research Institution
R&D	Research and Development
RSI	Regional System of Innovation
SCM	Supplementary Cementitious Material
SSA	Sub-Saharan Africa
SSI	Sectoral System of Innovation
STI	Science, Technology and Innovation
STIC	Science and Technology Information Centre
SME	Small and Medium-Sized Enterprises
TSI	Technological System of Innovation
TTO	Technology Transfer Office
TVET	Technical and Vocational Education and Training
UNESCO	United Nations Education, Scientific and Cultural Organisation
VC	Venture Capital
WBES	World Bank Enterprise Survey

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Executive Summary

The Federal Government of Ethiopia has over the past few years embarked on an ambitious economic modernisation and industrialisation strategy, as encapsulated in its first and second Growth and Transformation Plans. At the same time, the FDRE has committed the country to a low-carbon development trajectory by adopting a Climate Resilient Green Economy Strategy. Questions remain, however, as to how compatible these two policy visions are in practice and implementation. Such questions provided the motivation for the research project funded by CDKN, which seeks to enhance the understanding of the interaction between the emerging industrial policies and green economy strategies in Ethiopia.

The international development literature makes it clear that innovation – that is, the adoption and diffusion of new knowledge and technologies within an economy – is a critical driver and enabler of economic transformation and industrialisation. Furthermore, the literature on green growth and sustainable development also places a large emphasis on the role of ‘sustainability-oriented’ or ‘green’ innovations as a key mechanism for achieving improvements in resource productivity and reductions in wastes and emissions, including greenhouse gases.

Aim and methodology

In light of these findings from the research literature, this report aimed to assess the strengths and weaknesses of the emerging national system of innovation in Ethiopia, and to conduct an analysis of sectoral innovation systems in key industrial sectors, with a view to establishing the extent to which they are geared toward supporting green innovation and hence green industrialisation. The report drew on extensive secondary data to assess the framework conditions and functioning of the NSI. It also analysed primary innovation data collected from a survey of 117 firms in the cement, leather and textiles sectors. Thirdly, the report drew on interviews with key actors in the national and sectoral innovation systems. The major findings are summarised below, following which recommendations are made for policies to strengthen green innovation systems in Ethiopia.

Main findings

The Federal Government has undertaken concerted efforts to bolster the national system of innovation in recent years, especially following the adoption of the national STI Policy in 2012. Key in this regard has been the rapid expansion of the education system, especially at the tertiary level, which has seen strong growth in enrolments. This has been accompanied by a rapid increase in state expenditure on research and development, and a substantial rise in the number of R&D personnel. Meanwhile, the macroeconomic environment, as well as the rapid expansion of transport and energy infrastructure, have been broadly supportive of business activity and innovation – although rising public debt is a possible cause for concern if the rate of economic growth should falter in the coming years.

Despite these positive developments, the NSI is still emerging and will require further commitment and resources to become fully fledged. Ethiopia’s indicators of research activity, such as publications and patents, are growing, but off an extremely low base. The bulk of government-sponsored research occurs in the agricultural sciences, with engineering, technology and the natural sciences garnering small shares of funding. ICT infrastructure is still severely limited, which inhibits firms’ ability to tap into global knowledge banks and to effectively network with innovation actors. Business enterprises are spending very little on R&D, and report that access to finance for innovation and for access to new markets is highly constrained, while costs are high. Many firms cite a lack of

appropriately skilled labour as a hindrance to innovation. Furthermore, there are weaknesses in the interactions among innovation system actors. For example, there appears to be insufficient engagement between the main ministries, particularly the MoST with the MoI and MEFC, regarding green innovation. Moreover, the links between universities and research institutes on the one hand, and private enterprises on the other, are generally quite weak.

The survey of innovation activities among enterprises in the cement, leather and textiles industries provided useful information about the extent of innovation (and specifically green innovation), the main drivers and inhibitors of innovation, and the linkages that firms have with other innovation system actors. The rate of product and process innovation was found to be low amongst cement and textile enterprises (less than 20% in each case). A large percentage of leather sector firms reported product innovation (65%), but only a moderate proportion (28%) engaged in process innovation. The extent of green innovation, defined as innovations that aimed to reduce energy, water and material inputs or solid, liquid and gaseous wastes, was substantially lower. Only 12% of firms reported green product innovations, and 15% engaged in green process innovation. However, according to the responses nearly half (46%) of all process innovations were undertaken to reduce inputs or wastes.

Results from probit regression models shed some light on the characteristics of firms that make them more or less likely to innovate. The following firms were more likely to engage in product innovation: those with smaller turnover; firms in the leather sector (relative to cement and textile sector firms); enterprises not located in an industrial park; firms that produce for export; state-owned firms; and enterprises that invest in internal R&D. In the case of green product innovation, the only significant explanatory variable was investment in internal R&D. The probability of (general) process innovation falls with increasing age of the firm, rises with turnover, is lower for leather sector firms, and is higher for exporting firms and those that invest in internal R&D. The same results were obtained for green process innovation, although in this case location in an industrial park was also significant, and reduced the probability of innovation.

For both leather and textiles producers, the most important drivers of innovation are increasing market share and improving the value of goods and services, while for cement firms it is reducing unit costs. Of concern is that “reducing environmental impacts” and “meeting environmental regulatory requirements” ranked amongst the least important motivators of innovation for firms in all three sectors. This is a clear indication that improved environmental policies and/or enforcement is needed to stimulate green innovations. 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. The cost of meeting government regulatory requirements did not feature as an important obstacle to innovation, which might indicate a lack of regulations or enforcement thereof. 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 in order to drive innovation.

When it comes to sources of information for innovation, firms generally relied more heavily on their own resources (within the enterprise or group), as well as on suppliers of equipment, materials, services or software, rather than on external sources such as universities, research institutes and government agencies. This implies that much more needs to be done to strengthen the linkages between public and academic innovation actors and firms to foster knowledge and technology transfers. This is further reinforced by the finding in the survey that the number of meetings between firms and most innovation system partners – especially universities – was very low. On the positive

side, the sectoral Industry Development Institutes appear to be playing a leading role in facilitating interactions and knowledge transfer.

Policy recommendations

Strengthening the national and sectoral systems of innovation requires measures to enhance the framework conditions and improve the functioning of the systems. Effective governance is key, and this requires strong leadership, a high degree of vertical and horizontal policy coordination, and monitoring and evaluation of policies. The fiscal and monetary authorities should maintain the stable macroeconomic policy environment, while the Ministry of Industry should ensure that trade policies are aligned with promoting innovation by encouraging competition and technology transfers. The federal government should continue to invest in the basic education system to build human capital, but it should arguably aim to consolidate the higher education system before expanding it further so as to ensure adequate quality. There is also a need to expand environmental education and training programmes in order to ensure sufficient skilled personnel who can devise, implement, monitor and enforce environmental policies. A rapid rollout of information and communication technology is required to support knowledge acquisition and diffusion. Measures such as incentives for commercialisation of research are needed to strengthen the linkages between universities and research institutes on the one hand, and firms on the other. In addition, government could provide additional resources to the industry development institutes to enable them to host collaborative events such as conferences and workshops to facilitate the transfer of knowledge and technologies to firms.

Promoting green innovation at an enterprise level requires a ‘carrot and stick’ approach. The ‘carrot’ refers to financial support and incentives for green innovation, including targeted grants for green R&D to young firms and possibly tax breaks for firms that improve their environmental performance. The ‘stick’ refers to enhanced implementation of environmental regulations, with effective monitoring and legal enforcement of compliance. While it seems that industrial parks are being used effectively to promote better environmental compliance among new entrants, especially factories set up through foreign direct investments, measures (such as limited-term rental subsidies) could be introduced to make industrial parks more accessible to domestic firms that face cost barriers to relocation. Otherwise, many existing enterprises may ‘fall through the net’ and have little incentive to innovate.

Final remarks

While each country has its own unique characteristics, and its own particular opportunities and challenges for green industrialisation, the analysis of the Ethiopian case is broadly relevant to other low-income countries that may be considering embarking on a sustainable economic transformation trajectory. Strong leadership from the top is imperative, as is coordination across spheres of government. A green industrialisation strategy has much better chances of success if it is twinned with a science, technology and innovation policy that explicitly targets environmentally beneficial innovations and backs these up with appropriate incentives and regulations.

1 Introduction

Ethiopia is a low-income country that has aspirations of becoming middle-income country within the coming decade, thereby lifting tens of millions of its people out of poverty. To give effect to this goal, the Ethiopian government adopted a five-year Growth and Transformation Plan (GTP) in 2010 (Federal Democratic Republic of Ethiopia [FDRE] 2010). At the same time, however, the Ethiopian government recognises the risks posed by climate change and has committed the country to a low-carbon development trajectory within a Climate Resilient Green Economy Strategy (CRGE) (FDRE 2011). The second phase of the Growth and Transformation Plan (GTP-II) largely stresses the facilitation of structural transformation through developing a dynamic domestic industrial sector. In contrast to its predecessor, the GTP-II explicitly targets the implementation of the climate resilient green economy strategy in industry and other sectors through leapfrogging to modern and energy-efficient technologies. A large and expanding body of literature argues theoretically and demonstrates empirically that innovation – the introduction and diffusion of new knowledge, techniques and products into an economy – is key to both economic growth and industrialisation (Organisation for Economic Cooperation and Development (OECD) 2012, World Bank 2010), and sustainable development and the green economy (OECD 2011a; UNEP 2011a; UNEP 2011b; UN 2011; UNCTAD 2012; World Bank 2012).

Against this background, the Climate and Development Knowledge Network (CDKN) commissioned a research programme to develop a better understanding of the interaction between the emerging industrial policies and green economy strategies in Ethiopia, with a view to supporting concrete policy reforms that are congruent with Ethiopia's governance and innovation context. As part of this programme, this report investigates the character and drivers of the emerging national innovation system in Ethiopia and assesses the extent to which it is in line with nurturing and sustaining green industrial development in the country.

The broad methodology for assessing the suitability of Ethiopia's innovation systems for green industrialisation comprises four stages, following the scheme presented by Botta et al. (2015), which was adapted from Bergek et al. (2008). The first stage is to select the level of analysis, in this case the national system of innovation as well as the sectoral level for three prominent manufacturing sectors, namely cement, leather and textiles. These sectors were selected for the overall research project because of their comparatively large size in terms of manufacturing sector gross value added as well as their large contribution to greenhouse gas emissions and/or other pollutants, and because of their priority in the GTPs. The second stage is to analyse the structure of the innovation systems (both national and sectoral) by mapping their major elements and the interactions among them, as well as assessing the underlying 'framework conditions'. Third, the functioning of the innovation system (and its failures) is assessed, including existing technical capabilities and knowledge gaps. Finally, policy recommendations are developed that can strengthen innovation systems and foster green innovations by improving knowledge transfers and overcoming obstacles to innovation.

The report is organised as follows. Section 2 provides the conceptual background concerning innovation and innovations systems, and their contributions to green economic growth and development. Section 3 describes the empirical methodology and data collection methods. Section 4 analyses the current national system of innovation in Ethiopia in terms of its structure and functions. Section 5 conducts sectoral-level analyses of innovation systems in the textiles, leather and cement industries based on firm-level survey data and interviews with key role-players. The final section

presents the main conclusions and puts forward a number of policy recommendations for improving green innovation.

2 Conceptual Background on Innovation Systems

This section develops the conceptual background upon which the assessment of Ethiopia's innovation systems is based. The intention of this section is not to review the broad literature on innovation per se, but rather to elucidate the concepts and technical definitions that underpin the subsequent empirical analysis in sections 4 and 5, as well as the policy recommendations that following in section 6. First, we define more precisely what is meant by innovation, partly as a concrete basis for the firm survey reported on in section 5. Next, the notion of an innovation system is elucidated. Third, the key drivers and inhibitors of innovation are identified. Fourth, the importance of innovation for economic development and green industrialisation is briefly emphasized. Thereafter, some examples are provided from the international literature of environmental innovations in the cement, textile and leather sectors. Finally, several general principles for innovation policy are presented.

2.1 What is innovation?

Broadly speaking, innovation pertains to the introduction into a society of new knowledge, technologies and practices, or new combinations of existing knowledge, and their diffusion (i.e. dissemination and use) within an economy (Edquist & Johnson 1997:42; World Bank 2010:4). A more technical definition that is widely used internationally is provided by the Organisation for Economic Cooperation and Development's *Oslo Manual*: "An innovation is the implementation of a new or significantly improved product (good or service), a new marketing method, or a new organisational method in business practices, workplace organisation or external relations" (OECD/Eurostat 2005:46). To be defined as such, an innovation must have been *implemented*. In a developing country context, innovation is often something that is not new to the world, but is new to the society in question and can deliver significant economic, social, or environmental change (World Bank 2010). Innovation does not have to involve advanced technologies; in fact, development of low-technology industries and the exploitation of indigenous knowledge can yield substantial gains in economic growth and welfare (von Tunzelmann & Acha 2005; World Bank 2010). Innovation is a social process as it depends on society's willingness to accept new products and new ways of doing things. Both private and public actors have important roles to play in driving innovation. For example, while it is commonly believed that innovation is generally driven by entrepreneurs and implemented by business enterprises, Mazzucato (2013) argues forcefully that private sector companies often invest after innovations have already progressed significantly within government-sponsored programmes of exploratory basic research.

To give greater specificity to the concept of innovation, four distinct types of innovation have been defined: product, process, organisational and marketing innovation (see Table 1). Product innovations include new products, significantly improved products, and new uses for existing products. The motivation for process innovations can be "to decrease unit costs of production or delivery, to increase quality or to produce or deliver new or significantly improved products." (OECD/Eurostat 2005:49). Examples include "the automation of work that used to be done manually, the introduction of new software to manage inventories and the introduction of new quality-control measures" (European Bank for Reconstruction and Development (EBRD) 2014:13). In contrast to process innovations, organisational innovations mainly involve people and the arrangement of work flows (EBRD 2014:15). Marketing innovations may be intended to improve customer satisfaction,

create new or expanded markets, or reposition a product in the existing market (EBRD 2014:15). Another distinction is between technological and non-technological innovation. The former is normally related to product and process innovation, while non-technological innovations are usually associated with organizational and marketing innovations (TIPP 2013). Nevertheless, the two forms are often linked. This study focuses on product and process innovation, as these types of innovation are most relevant for greening industrialisation.

Despite these distinct definitions, some innovations may have characteristics that fall into more than one category. By way of example, the acquisition of new machinery for the purpose of introducing a new product incorporates both product and process innovation (EBRD 2014:13). Furthermore, not all changes constitute innovations. Changes that do not qualify as innovations include capital replacement or extension (where the machinery is of the same type as before), changes resulting from changes in factor prices, routine upgrades, customization of products, regular seasonal and other cyclical changes (e.g. a new fashion in the clothing industry), new pricing methods involving discrimination among customer groups, and trading of new or significantly improved products (e.g. in wholesale and retail distribution, transport and storage (TIPP 2013).

Table 1: Definitions of different types of innovation

Type of Innovation	Definition
Product innovation	A product innovation is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics.
Process innovation	A process innovation is the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software.
Organisational innovation	An organisational innovation is the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations.
Marketing innovation	A marketing innovation is the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing.

Source: OECD/Eurostat (2005)

At the firm level, innovations must involve a significant degree of novelty, i.e. the innovation must be new (or significantly improved) *to the firm*, but does not need to be new to the domestic market or global economy (although it could be). A firm that wishes to innovate “can invest in creative activities to develop innovations in house, either alone or in conjunction with external partners, or it can adopt innovations developed by other firms or institutions as part of a diffusion process” (OECD/Eurostat 2005:35). The adoption of existing technologies that were developed elsewhere is especially important for developing economies, where enterprises are often a considerable distance from the technological frontier (EBRD 2014:12). A pioneer of diffusion studies, Rogers (1983:5) articulates diffusion as “the process by which an innovation is communicated through certain channels over time among the members of a social system.” A more detailed definition sees diffusion as “the way in which innovations spread, through market or non-market channels, from their very first implementation to different consumers, countries, regions, sectors, markets and firms”

(OECD/Eurostat 2005:17). A firm is described as innovative if it has implemented an innovation during a particular period under review.

Diffusion is vital for innovations to have economic impact. The effectiveness and speed of diffusion depends on the innovation-decision processes of individuals who transmit information, the innovativeness – or extent to which individuals are early adopters – and the rate of adoption or acceptance of innovations within a system (Rogers 1983). Furthermore, the scale of the socio-economic impact often relates to how new and extensive the innovation is: radical or incremental (Fagerberg 2005). “A radical or disruptive innovation can be defined as an innovation that has a significant impact on markets and on the economic activity of firms in that market; while incremental innovation concerns an existing product, service, process, organization or method whose performance has been significantly enhanced or upgraded” (TIPP 2013). Incremental innovation is the more common form and arguably yields the most of the economic benefits (Fagerberg 2005). The various effects of innovations on enterprise performance varies from impacts on sales and market share to improvements in productivity and efficiency (OECD/Eurostat 2005:19).

Innovation activities are defined as “all scientific, technological, organisational, financial and commercial steps which actually, or are intended to, lead to the implementation of innovations” (OECD/Eurostat 2005:47). Specific innovation activities include both research and experimental development (R&D) and non-R&D activities. R&D is defined in the OECD’s *Frascati Manual* as “creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge” (OECD 2015a:44). R&D includes basic research intended to acquire new knowledge, applied research that is directed towards a practical objective, and experimental development, which includes testing and modification of new product or process concepts. R&D is mainly an input into the innovation process, and is neither necessary nor sufficient for innovation. Non-R&D activities can include: identifying new concepts for products, processes, marketing approaches or organisational modifications; acquiring technical information; developing human capital resources through hiring or training; and purchasing new equipment, software or intermediate inputs that embody innovations (OECD/Eurostat 2005).

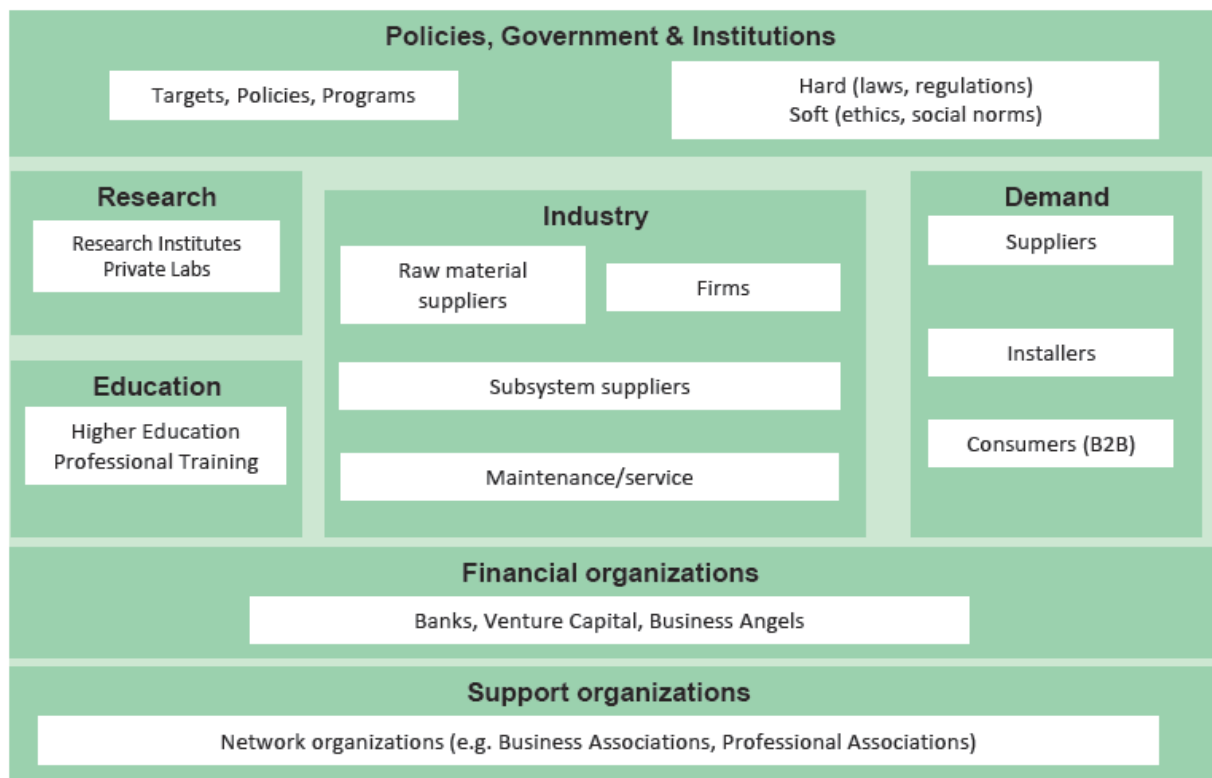
2.1.1 Green innovation

Innovations that result in improved environmental performance have variously been referred to as environmental innovations, green innovations, ecological innovations (or eco-innovations), and sustainable innovations (Schiederig et al. 2012). Building on the *Oslo Manual* definition of innovation quoted above, the OECD (2009) defines eco-innovation as “the creation or implementation of new, or significantly improved, products (goods and services), processes, marketing methods, organizational structures and institutional arrangements which – with or without intent – *lead to environmental improvements compared to relevant alternatives*” (italics added). Environmental improvements include reductions in resource inputs (such as energy, water and materials) and reductions in solid, liquid and gaseous waste products, including carbon emissions. Based on a review of alternative definitions, Schiederig et al. (2012) determine that the concepts of green, ecological and environmental innovation are generally used synonymously in the literature, while ‘sustainable innovations’ also encompasses a social aspect (i.e. greater equality or social inclusiveness). In the remainder of this report, therefore, the terms green/environmental/ecological innovations are used interchangeably.

2.2 What is an innovation system?

The analysis of ‘innovation systems’ or ‘national systems of innovation’ dates back to seminal works by authors such as Freeman (1987) and Lundvall (1992). Freeman (1987) 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”. Pioneering studies analysed the structure of innovation systems, which are comprised of networks of actors from the public sector (government agencies, regulators and policies), Higher Education Institutes (HEIs), Public Research Institutions (PRIs),¹ industry (firms), financial organisations, network and support organizations, and consumers (Edquist 2005). The flows of knowledge, information and technology among the various elements of an innovation system are key to the innovative process. Thus the interactions among these actors, including firms and other organisations, and the ways they share information, are critical for the transmission and diffusion of innovations in an economy (Edquist 2005). Figure 1 provides a schematic of a typical innovation system with its various components.

Figure 1: Structure of an innovation system



Source: Botta et al. (2015)

2.2.1 Levels of analysis of innovation systems

Innovation systems can be defined and analysed at four different levels: national system of innovation (NSI), regional systems of innovation (RSI), sectoral systems of innovation (SSI) and systems of technological (TSI). An NSI has been defined as “the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge, ..., and are either located within or rooted inside the borders of a nation state” (Lundvall, 1992). An RSI restricts the geographical scope of the innovation system to a specific region within a country (Cooke, Uranga, & Etzebarria, 1997). A sectoral system of innovation and production has been defined as “a set of

¹ These are also sometimes referred to as Public Research Organisations (PROs).

new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products” (Malerba 2002:250). Thus sectoral-level studies are restricted to innovation occurring within a particular sector (or subset) of the economy. Unlike the national and regional innovation systems, the sectoral innovation system may have local, national, and/or global dimensions, which often coexist in a sector (Malerba and Orsenigo, 1997). Finally, TSIs examine the networks of actors and institutions relevant to a particular technology, which may be applicable across a number of sectors or be a specific subset of one sector (Carlsson & Stankiewicz 1991; Bergek et al. 2008). These four levels of innovation analysis may overlap or intersect, depending on the local context in a specific country. The focus in the present study is on the national system of innovation in Ethiopia, as well as sectoral systems of innovation for each of the three case study sectors (textiles, leather and cement).

2.2.2 Framework conditions for innovation

The innovation performance of individual firms is influenced by a range of so-called ‘framework conditions’, which refer to the institutional and economic environment within which firms operate (Kuhlman & Arnold, 2001; Wiczorek & Hekkert 2012). These conditions include the following dimensions (OECD/Eurostat 2005:37; World Bank 2010):

- systems of basic education, universities and technical training;
- the science and research base;
- codified knowledge (e.g. publications, patents, technical, environmental and management standards);
- communications infrastructure (mobile phone connections; landlines; internet connectivity);
- innovation policies and other government policies that affect firm-level innovation;
- macroeconomic stability (e.g. GDP growth, inflation, public debt, budget deficit, current account balance, exchange rate);
- microeconomic and macroeconomic policy settings (e.g. patent law, taxation, openness to trade and foreign direct investment, corporate governance rules, competition policy, environmental laws);
- financial institutions (determining ease of access to finance);
- market accessibility (e.g. opportunities for the establishment of linkages with customers, market size and ease of access); and
- industry structure and the competitive environment.

2.2.3 Functions of an innovation system

The performance of any innovation system should be measured not by its structure but in terms of how it functions in a way that facilitates different types of interactions among the various components (actors, networks and institutions) in the system towards the goals of innovation systems, which are to develop, apply, diffuse and use new innovations.

The activities that contribute to the goals of innovation systems are called functions of innovations systems. Several studies list key functions that the system should perform, based on empirical case studies. Galli and Teubal (1997) emphasize the importance of making a distinction between organizations and functions of NSIs. They distinguish between hard and soft functions. Hard functions include R&D activities and the supply of scientific and technological services to third parties, while soft functions include diffusion of information, knowledge and technology, policy making, design and implementation of institutions concerning patents, laws, standards, etc., and diffusion of scientific culture and professional coordination. Liu and White (2001), in their

comparative analysis of Chinese innovation systems, focus on five activities of the system, namely: research (basic, development, engineering), implementation (manufacturing), end-use (customers of the product or process output), linkages (bringing together complementary knowledge) and education.

Jacobsson and Johnson (2000) outline eight primary functions for an NIS as follows:

- Guide the direction of the search process
- Supply resources, i.e., capital competence
- Supply incentives for companies to engage in innovative work
- Recognize the potential for growth
- Facilitate the exchange of information and knowledge and rate new knowledge
- Stimulate and create markets
- Reduce social uncertainty
- Counteract the resistance to change

In the context of technology-specific innovation systems, Hekkert et al. (2007) and Bergek et al. (2008) compiled the common features into seven distinctive functions of a system as follows: (1) knowledge development and diffusion, (2) entrepreneurial experimentation (3) influence of the direction of search, (4) market formation, (5) legitimation, (6) resource mobilization and (7) development of positive externalities. According to them, for a certain technology to evolve and perform well these seven functional requirements—in one way or another—must be fulfilled. The application of this approach to sectoral systems, rather than specific technologies, demonstrated similar features (Jacobsson and Bergek, 2011; Gebreeyesus and Iizuka, 2012). It should also be noted that the functioning of innovation systems depends heavily on the presence (or absence) and capacities of the structural elements and framework conditions discussed above (Wieczorek & Hekkert 2012). The main functions identified by Bergek et al. (2008) are briefly described below, bearing in mind that these were developed for the analysis of TSIs rather than NSIs. Nevertheless, an assessment of how well some of these functions are performed within the NSI can lay the foundation for policy recommendations.

Knowledge development and diffusion

The objective of this core function is to introduce new scientific and technical knowledge into the economy. This is achieved through basic research and technology development, as well as scouting for knowledge and technologies that are available in other countries and adapting them for local use. Knowledge sharing occurs through formal channels (such as publications, patents and workshops) and informally (via discussion forums and meetings). The principal actors involved in this function include HEIs, PRIs, firms and users, while governments in developing countries often assist in external knowledge scouting. The level of this function can be measured by metrics such as numbers of publications, research staff and patents (Bergek et al. 2008:415).

Guidance of the search/Influence on the direction of search

This function relates to the strength of pressures and incentives that induce firms and organisations to join the innovation system, as well as the factors that affect the direction of search within the innovation system (e.g. with respect to alternative technologies, applications and business models). The relevant factors include expectations of growth potential, changing factor and product prices, regulations and policy pressures, and the articulation of demand from leading customers.

Entrepreneurial experimentation

This function recognises the uncertainty that characterises the dynamic evolution of innovation systems, in terms of technologies, applications and markets. Entrepreneurial experimentation –

namely firms trying out different technologies and processes – is a way to reduce uncertainty and promote social learning. Empirically, this function is more tractable for TSIs rather than NSIs.

Market formation

Markets may be underdeveloped or even non-existent, especially in a developing country context. The purpose of this function is to both catalyse demand for new technologies and products, and facilitate their uptake in the marketplace. Key market failures and barriers must be identified and addressed, including international technical standards in the case of export markets. Relevant actors include government ministries, firms, NGOs and users' organisations.

Mobilising resources

The performance of an innovation system depends on the extent to which various types of resources are mobilised, including human capital (skills), financial capital and complementary assets such as complementary products, services and network infrastructure (Bergek et al. 2008). This function aims to supply the human capital that is required to underpin innovation, and entails education and training in both technical and business skills, as well as attracting qualified people from other countries. Actors involved include HEIs and private companies that offer on-the-job training. Governments have a role in setting the conditions for skilled immigration and assessing the match of domestic skills to the requirements of the labour market. In terms of financial resources, the goal of this function is to provide financial services to support innovation throughout its life cycle. This requires finance for RD&D, for business start-ups, and for firms to purchase machinery and equipment. The actors involved include various types of financial organisations as described earlier (BAs, VCs, PEFs, banks), as well as the government, which provides funds for basic research and R&D. Financial service providers must have the skills needed to assess new technologies and business models.

Creation of legitimacy

New industries and technologies need to be accepted by the society and conform with existing institutions (in the sense of social norms and regulations). Legitimation also feeds back positively to the mobilisation of resources and, by shaping managers' expectations, influences the search process (Bergek et al. 2008). The process of legitimation may face obstacles such as resistance from incumbent interests and friction with institutional frameworks.

Development of positive externalities

The entry of new firms into an innovation system may generate positive externalities that benefit existing members. This occurs through reducing uncertainties, enhancing legitimacy, building markets, and expanding the base of actors – which in turn promotes knowledge development and diffusion and entrepreneurial experimentation. This function is thus not independent of the other six functions, but rather augments them and relates to the dynamics of the system.

2.3 Key drivers and inhibitors of innovation

The major motivations for innovation at the enterprise level are to improve firm performance and boost competitiveness. Specific objectives for innovation can vary by the type of innovation. For instance, “the objectives of product or marketing innovations will primarily relate to demand (e.g. improving product quality, increasing market share, entering new markets), while process or organisational innovations will tend to relate to supply (e.g. reducing costs, improving production capabilities)” (OECD/Eurostat 2005:106). Firms may also innovate in order to comply with environmental regulations, to reduce environmental impacts such as use of scarce resources and

pollution, and to improve health and safety standards. These are particularly relevant to the green industrialisation agenda. Table 2 contains a summary of motivations for innovation; these are used as the basis for questioning firms about the drivers of innovation in the firm survey reported on in section 5.

Table 2: Motivating factors for innovation among firms

Competition, demand and markets	<ul style="list-style-type: none"> • replace obsolete products • increase the range of goods or services on offer • maintain or expand market share • enter new markets
Production and costs	<ul style="list-style-type: none"> • increase production capacity • improve the efficiency and speed of production • improve the quality of goods and services • meet industry technical standards • reduce unit labour costs • reduce material and energy input costs
Environmental performance	<ul style="list-style-type: none"> • comply with environmental regulations • reduce environmental impacts • improve health and safety standards

Source: Adapted from OECD/Eurostat (2005:108, Table 7.1) and OECD (2012)

The firm-level drivers of innovation include both internal factors (such as characteristics of firms, and decisions they take) and external factors that influence the business environment (EBRD 2014:45). In terms of internal factors, characteristics of firms, such as age, size and ownership structure, are important potential determinants of innovation. Although young, small firms are often viewed as being major innovators, many start-ups fail and there are many small firms (e.g. in service sectors) that do not innovate much (EBRD 2014:45). Thus larger and older firms may engage more in innovation, which has been confirmed by survey data covering transition economies and the Middle East North Africa (MENA) region. This relationship might be partly explained by economies of scale, which allow large firms to spread the high fixed costs of innovation. Nevertheless, start-ups are more likely than larger, established firms to introduce product innovations that are new to the global marketplace (EBRD 2014:47).

The ownership structure of firms may also affect innovation (EBRD 2014:48). Foreign ownership and the participation of domestic firms in global value chains are expected to stimulate innovation. However, multinational companies that acquire local businesses might conduct all the R&D in the home country, thus reducing the local level of R&D spending. In the transition region, survey evidence indicates that the former effect dominates (EBRD 2014).

Various strategic decisions taken by firms also influences their propensity to innovate. First, firms that opt to produce for export markets and hence face international competition may need to innovate to stay competitive. Evidence supporting this hypothesis was found in surveys of transition countries and the Middle East North Africa region: the rate of product, process, marketing and organisational innovation was higher amongst firms that export their products directly than amongst non-exporters (EBRD 2014). At the same time, the larger market means that exporters “are able to spread the fixed costs of innovation over a larger customer base, so exports can support innovation”,

while “firms’ participation in global value chains... facilitates the adoption of foreign technologies” (EBRD 2014:49).

Second, firms that engage in R&D are more likely to succeed in innovating. For example, in its survey of firms in transition economies, the EBRD (2014) found that firms that invested in R&D were more than 20% more likely to engage in product or process innovation. Third, since skills are required to implement and operate new production processes, it is expected that firms that employ more personnel with tertiary education will be in a better position to innovate. However, a firm’s human resource decisions and profile will also be constrained to some extent by the availability of skills in the labour market.

External factors that affect the extent of innovation undertaken by firms include the business environment, the degree of market competition, customer preferences and the country’s openness to trade. For example, a poor business environment “can substantially increase the cost of introducing new products and make returns to investment in new products and technologies more uncertain” (EBRD 2014:51). Trade openness potentially contributes to innovation in several ways: (1) foreign competition reduces the market power of local producers; (2) open markets allow greater inflows of foreign knowledge and technologies; and (3) openness enables firms to achieve economies of scale and specialisation in sectors with a comparative advantage (OECD 2012:13-14).

A number of issues may inhibit (either prevent or retard) innovation amongst firms, including cost, market, knowledge and institutional factors. The main factors inhibiting innovation are summarised in Table 3.

Table 3: Factors inhibiting innovation among firms

Cost factors	<ul style="list-style-type: none"> • excessive perceived risks • lack of funds within the enterprise • lack of access to finance, including commercial bank loans and specialised financing from BAs and VCs • high costs of innovation, for example the search and acquisition of relevant information
Market factors	<ul style="list-style-type: none"> • uncertain demand for innovative products • high barriers to entry for new firms • competitors in the informal sector
Knowledge factors	<ul style="list-style-type: none"> • lack of suitably skilled personnel (e.g. engineering and technical skills), either inside the enterprise or in the labour market • lack of information about new technologies and potential innovations • lack of information on markets • difficulty finding cooperation partners
Institutional factors	<ul style="list-style-type: none"> • lack of reliable infrastructure, such as electricity and telecommunications • weak property rights, including intellectual property rights (IPR), implying that enterprises are not able to protect their innovations from imitation by competitors • high costs of doing business arising from the legal/regulatory environment (e.g. excessive red tape, corruption, difficulty in

	obtaining licences and permits, onerous regulations and tax rules)
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Source: Adapted from OECD/Eurostat (2005:113, Table 7.2) and OECD (2012)

2.4 Innovation as a driver of economic growth and industrialisation

A large body of academic literature spanning nearly a century since the seminal work of Joseph Schumpeter (1934) has established a strong theoretical foundation that identifies innovation as central to the socio-economic development of countries (Verspagen 2005). According to the World Bank (2010:6), innovation is “the main source of economic growth, it helps improve productivity, it is the foundation of competitiveness, and it improves welfare.” Innovation generates positive spill-over effects and is essential for enabling a transition to a knowledge-based economy (Botta et al. 2015:1). The diffusion of new knowledge can boost an economy’s potential to develop new products and more efficient production processes (OECD/Eurostat 2005:33). Empirical research has confirmed that an accumulation of innovation capacity has been a major catalyst of economic growth, job creation and socioeconomic transformation in successful developing countries (OECD 2012; Kraemer-Mbula & Wamae 2010). For example, “there is evidence that R&D played a key role in the take-off of Asian economies such as China, India and Korea” (OECD 2012:6). Furthermore, evidence from a survey of 26,000 manufacturing enterprises across 71 developed and developing countries “support the policy propositions that innovation is a powerful driver of employment growth, [and] that innovation-driven growth is inclusive in its creation of unskilled jobs” (Dutz et al. 2011).

2.5 The role of innovation in greening industrialisation

It is now commonly accepted that future economic development must proceed in a very different manner to historical patterns if it is to be socially equitable and environmentally sustainable. As the World Bank (2010:6) puts it, “adaptation to climate change, adjustment to limits of natural resources, and protection of biodiversity require fundamentally new patterns of production and consumption worldwide.” Each country needs to develop a ‘green economy’, which may be defined as “one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities” (UNEP 2011a:16).

Innovation is widely regarded as essential for the realisation of green economies and green industrialisation. For example, the United Nations Department of Economic and Social Affairs has called for a “Great Green Technological Transformation” that is driven by technological innovation and diffusion, with governments playing a central role to overcome market failures (UN 2011). This report “proposes mainstreaming sustainable development objectives into existing national innovation systems and situating those objectives at their very core so as to create what it calls Green National Innovation Systems (G-NIS)” (UN 2011:xi). Similarly, UNEP argues that “at the national level, any strategy to green economies should consider the impact of environmental policies within the broader context of policies to address innovation and economic performance” (UNEP 2011a:22). UNEP’s green economy programme has highlighted the relevance of greening for Least Developed Countries, and this in turn requires the transfer and diffusion of green innovations and technologies from more developed countries (UNEP 2011b). The OECD cautions that innovation is critical for green growth, since “without innovation, it will be very difficult and very costly to address major environmental issues” (OECD 2011a:51). More specifically, innovation is required to address market failures that impede green growth, such as knowledge externalities and capital market imperfections (World Bank, 2012). This needs to happen within a context of policies that shape markets and create enabling conditions for innovation and economic growth.

UNCTAD (2012) suggests that to solve the dilemma that developing countries face of needing to pursue industrialisation to improve well-being whilst limiting environmental damage, a strategy of 'sustainable structural transformation' (SST) is required. SST is defined as "structural transformation accompanied by the relative decoupling of resource use and environmental impact from the economic growth process" UNCTAD (2012:26). Decoupling, in turn, requires sustainability-oriented innovations that bring about improved resource productivity, as well as eco-innovations that lead to environmental improvements (UNEP 2011c). In sum, "innovation for green growth has the potential to tackle three challenges simultaneously: encouraging widespread development and poverty reduction; creating new and more vibrant economies based on clean technologies; and securing an increasingly greener world" (Haltman et al. 2012:2).

2.6 Examples of innovation in the cement, leather and textiles sectors

This section provides examples of product and process innovations in the three case study sectors, drawn from the international literature, in order to establish benchmarks of good practice for these industries in Ethiopia.

2.6.1 Cement

Cement manufacturing is a high-volume process and is amongst the most energy- and material-intensive industrial processes (Supino et al. 2016). The most common form of cement, known scientifically as 'calcium-silicate' cement and commercially as Portland cement, is produced by heating limestone together with small amounts of other materials (such as clay) in a kiln to temperatures around 1450°C. This produces small pellets called clinker, which, together with a small quantity of gypsum, is pulverised into a fine powder. Carbon dioxide is released from the chemical process (roughly half of the emissions) as well as the combustion of fuels (usually coking coal) to heat the kiln (about 40% of emissions); the remaining 10% of emissions derive from electricity that is used for grinding (if generated from fossil fuels or biomass), as well as transport of the raw materials and product (von Weiszacker et al. 2009:157).

Carbon emissions from cement production vary across different regions of the world. The average for Africa was 0.22 tons of carbon per ton of cement (tC/t) in 2001, the same as the world average, but below that of India (0.25 tC/t) and above that of Western Europe (0.19 tC/t) (von Weiszacker et al. 2009). These data indicate that there is scope to adopt international best practices to reduce cement-related emissions. According to von Weiszacker et al. (2009:157), "both the energy- and process-related CO₂ emissions from current methods of Portland cement manufacture can be reduced by at least 30 per cent globally."

To achieve greater emissions reductions than this, alternative forms of cement need to be considered, such as sulfo-aluminate cement, magnesium-phosphate cement and alumino-silicate (geopolymer) cement; these represent examples of **product innovation** in the cement industry.

- Sulfo-aluminate cement lowers the greenhouse gas emissions of concrete by nearly 30 per cent, compared to Portland cement, as a result of lower process temperatures and reduced calcium oxide content (von Weiszacker et al. 2009:157). However, this process requires blast furnace slag as a feedstock, which may not be available in specific locations.
- Magnesium-phosphate cement is claimed to reduce GHG emissions by about 70 per cent relative to Portland cement, due to lower kiln temperatures and greater absorption of CO₂ by the concrete when it sets, but the evidence is not conclusive as yet (von Weiszacker et al. 2009:158). A few companies have devised magnesium-oxide based cements that have various environmental benefits (Hasanbeigi, Price and Lin 2012).

- Alumino-silicate (geopolymer) cement, formed by the reaction of an alumino-silicate powder with an alkaline silicate solution, can reportedly produce GHG emissions 80% lower than those of Portland cement (von Weiszacker et al. 2009:158). This is because it is produced at lower temperatures and does not result in direct process emissions of CO₂ since it does not require lime (calcium carbonate). Geopolymer cement can be produced using several industrial by-products, such as fly ash, mine tailings and bauxite residues, and is at least as strong as and more durable than Portland cement. An Australian company, Zeobond, began producing a geopolymer cement at room temperature in 2008.

However, there are various options for introducing **process innovations** to improve environmental performance, including improving energy efficiency, reducing carbon intensity, boosting materials efficiency, fuel switching, and carbon capture. Hasanbeigi, Price and Lin (2012) provide a review of 18 emerging energy-efficiency and CO₂ emission-reduction technologies for cement production.

- The amount of energy used in the production of Portland cement varies by country, depending on the technologies used. Specifically, some new kiln designs are considerably more energy efficient than older designs. Japan's cement industry is the most efficient globally, due to the use of dry kilns that include pre-heaters and pre-calciners (von Weiszacker et al. 2009). So-called 'wet' and 'semi-wet' processes are more energy intensive as well as consuming more water. In addition, energy efficiency can be improved in the grinding process.
- Some companies have pioneered innovative processes to reduce the carbon intensity of cement production. A company called "Calera takes captured CO₂, mostly from utility plants, and combines it with an alkalinity solution and calcium in the form of carbide residue to convert the CO₂ to calcium carbonate and water. Calera then uses that calcium carbonate to replace limestone in cement, thus making a lower carbon variety of cement" (Grady 2016). Another company called "Solidia Technologies... uses a process it calls reactive hydrothermal liquid phase densification, which uses the CO₂ as a binding agent" and uses less limestone, hence reducing carbon emissions (Grady 2016).
- Fuel switching involves the substitution of fossil fuels (coal or gas) with other fuels in cement kilns, typically waste materials such as used tyres, paint sludge, waste plastics, textiles and paper, sewage sludge, rice hulls, demolition timbers, used oil, carbon anode dust, aluminium spent cell liners and solvent-based fuels (von Weiszacker et al. 2009; Supino et al. 2016). However, there needs to be strict monitoring of air pollutants. There is also scope for recovery of waste heat from the exhaust gases emanating from cement production by using co-generation or combined heat and power technology. According to Supino et al. (2016:434), "the European cement industry has already replaced a large portion of its traditional fuel sources with waste or biomass, with these representing about 25% of total thermal energy consumption in 2011."
- Clinker production, which results in most of the CO₂ emissions during cement production, can be reduced through the use of clinker substitutes, referred to as Supplementary Cementitious Materials (SCMs) (Supino et al. 2016). These include materials such as ground granulated blast furnace slag, fly and bottom ash, steel slag, and natural pozzolans (Meyer 2009; von Weiszacker et al. 2009:169). The rate at which fly ash is used in cement production varies widely across countries, from 3.5% in India to 93.7% in Hong Kong (Meyer 2009). Fly ash can replace up to 60% of Portland cement (Meyer 2009). The use of SCMs is an important part of implementing a 'closed cycle economy', which requires innovative conceptions and management of production, consumption, and waste flows (Supino et al. 2016). Hasanbeigi et al. (2012) report that high-energy milling can be used to enhance the compressive strength of SCMs by mechanically increasing the reactivity of some of the materials, such as fly ash and slag. Carbide slag (or

calcium carbide residue), can be partially substituted for limestone, resulting in lower CO₂ emissions and reducing the amount of slag sent to landfills (Hasanbeigi et al. 2012).

- Materials efficiency of cement plants can be improved in various ways. Water usage can be reduced by retrofitting 'wet' Portland cement manufacturing plants into 'dry' plants (von Weiszacker et al. 2009). Suárez et al. (2016) investigated the lifecycle impact of using recycled gypsum (RG) in the production of Portland cement in Spain. They found that the substitution of RG for natural gypsum brought a range of environmental benefits – including 65% lower energy use and carbon emissions – when the waste gypsum was transported less than 30 kilometres to a recycling plant. Production efficiencies can also be enhanced by increasing the size of plants to reap economies of scale and improved quality (von Weiszacker et al. 2009). Further benefits can be attained through “optimizing and modernizing existing plants by installing state-of-the-art automation, process control technology, and auxiliary equipment” (Supino et al. 2016:435).
- Another possible approach to reducing CO₂ emissions is to implement carbon capture and storage (CCS) technology. At least one company in the United States is exploring possibilities for the capture and conversion of flue gas to biofuels, although this process innovation is still in undergoing commercialisation trials (Grady 2016). More generally, the adoption of CCS technologies is limited by technical challenges and high capital costs (Supino et al. 2016). Hasanbeigi et al. (2012:6229) suggest that “carbon capture technologies for the cement industry might not be commercially available until 2020.”

Important lessons can be learned from country studies (in addition to the examples cited above). In a study of the Chinese cement industry, Xu et al. (2014) found that using best available technologies would enable a 50% reduction in CO₂ emissions by 2050. Specifically, “the relative contributions of four technology measures (clinker substitution, carbon capture and storage (CCS), efficiency improvement and alternative fuel use) to emissions reduction are about 37%, 33%, 15%, and 15%, respectively” (Xu et al. 2014:592). Analysing the sustainability performance of German and Italian cement industries, Supino et al. (2015:430) highlight that “the co-processing of alternative raw materials and fuels, in particular, has played a pivotal role, producing a triple win: emissions reductions, decreases in the extraction of natural resources and fossil fuels, and enhancement of waste management operations.” Their conclusion is that “the top priority for the cement industry in future is decoupling its outputs from environmental impacts, creating a circular economy vision that is able to reinvent the traditional cement supply chain” (Supino et al. 2015:440).

2.6.2 Leather²

The leather industry is composed of the tanning sub-sector, which converts hides into leather, and the leather products sub-sector, in which leather is turned into leather products, principally by shoe and upholstery manufacturers. Leather production involves various stages, from preparing hides or skins through pre-tanning (trimming, soaking, liming, unhairing, reliming, fleshing, deliming, bating, scudding and pickling), tanning (chrome tanning, basification and piling), post-tanning operations (sammying, splitting, shaving, rechroming, neutralisation, retanning, fatiquoring, dyeing, setting, drying), and finishing operations (conditioning, staking, toggling, trimming, buffing, spraying/roller coating, plating/polishing and measuring) (Thanikaivelan et al. 2005). Although the leather industry can be portrayed as turning the waste from the meat industry into a useful product, it has a reputation for being highly polluting because of the chemicals used in the various stages of leather production (Thanikaivelan et al. 2005). Specifically, substantial quantities of water are used in the leather production process, and this poses significant environmental challenges because of the

² This section draws on material from a background report written by Alexia Coke for this project, entitled “Greening Industrialisation in Developing Countries: A Scoping Review”.

chemicals contained in wastewater (Thanikaivelan et al. 2005). The pre-tanning and tanning stages of leather production account for between 80% and 90% of the pollutants emitted, including salts, heavy metals such as chromium and toxic gases such as ammonia (Thanikaivelan et al. 2005). However, the post-tanning and finishing activities also involve emissions, including carcinogenic arylamines and volatile organic compounds, while sludge generated in a number of the stages of production is also potentially hazardous.

While possibilities exist for product innovations in the leather sector, especially in terms of the quality of hides produced and the range of finished leather products created, the major scope for environmental improvements lies with **process innovations**. Such innovations can improve efficiencies and reduce the levels of pollution created in the leather production process. In the first instance, process efficiencies can be enhanced through changing the layout of a leather-making factory (Hoque & Clarke 2013). A wide range of cleaner production methodologies can be introduced at various stages of the production process to reduce the levels of pollution generated by leather processing (see Hoque & Clarke 2013: 51).

- To avoid the use of toxic insecticides such as DDT, benzene hexachloride and arsenic which are used for preserving hides, raw hides can be brought directly from the slaughter-house.
- Chemicals (sulphides), salts and organic waste (sodium hydrochloride) used for soaking hides can be substituted with less polluting materials, such as enzymes (Ma et al. 2014).
- Lime-sulphide liquors that are used in the process of 'unhairing' can be recycled.
- Solar/freeze/micro-wave drying or use of substitutes to salt alternatives can be applied instead of wet salt curing exist, while several mechanical processes can be used to desalt hides before tanning (Thanikaivelan et al. 2005).
- Fleshing (the removal of flesh from hides) can be performed before de-hairing and liming to improve efficiencies.
- Carbon dioxide can be used instead of ammonium sulfate in de-liming. Hu and Deng (2016) suggest that supercritical carbon dioxide can serve as a potential alternative solvent for cleaner production of leather products.
- In the preparation of leather for tanning, mercury fungicides can be substituted with less toxic thiobenzothiazol to control fungal growth.
- There is scope for reducing or recycling the chrome used in the tanning stage. Alternatives to chrome in the tanning stage have been trialled too, with organic and apparently environmentally-benign vegetable-based tanning substitutes seen as holding promise.
- Considerable quantities of chromium containing splits and chrome shavings can be avoided by splitting the hides before tanning them.
- Optimising the use of post-tanning chemicals and choosing those that are most treatable appears to be the best option to reduce pollution in the leather finishing stage (Hoque & Clarke 2013). The use of water-based liquors in place of solvent-based liquors can reduce hydrocarbon emissions. Olle et al. (2014) describe a solvent-free patent leather process that uses combinations of carbonyl-functional resins, resulting in a 97% reduction in volatile organic compounds.
- Thanikaivelan et al. (2005) suggest a more radical approach to changing leather processing, such as processing 'green' hides to avoid the need for the soaking stage, and shifting from chemical processing to bioprocessing, utilising enzymes.
- Bacardit et al. (2014) describe a new tanning process (which they call Wet Bright) that produces white leather for use in the automotive sector, and which is free of chromium, aldehydes, aldehyde precursors and organic solvents.

Finally, effluent treatment plants are required to reduce residual end-of-pipe environmental impacts (Thanikaivalan et al. 2005: 46). Primary treatment options include anaerobic digestion based on lagoons, contact filter, upflow anaerobic sludge blanket (UASB) reactor, and high-rate biomethanation, sometimes with aerators, and wet air oxidation for primary treatment. Secondary treatment processes include chemoautotrophic activated carbon oxidation. Tertiary treatment can involve activated carbon filters, reed bed and root zone techniques, and reverse osmosis methods. Salt is often recovered from the soaking process using solar evaporation pans, but other high-rate transpiration systems have also been developed. Solid waste resulting from various of the processes can be reused or recycled (e.g. raw hide trimmings used in manufacturing glue, recovered salt in curing and pickling; recovered hair for low-cost carpets; and lime sludge in building construction). In addition, Kolomaznik et al. (2008) outline a 'new three-step hybrid technology' for dealing with chromium-treated scraps of leather and used leather products to create fertiliser and an 'inorganic pigment' that can be used in the production of glass and ceramics. Biological treatment of tannery effluent is seen as more environmentally-friendly than the use of chemicals, but is less effective (Lofrano et al. 2013). Joint treatment of wastes with another polluting industry, for example tanning and mining industries, have also been shown in some cases to reduce the load of heavy metals in comparison with separate waste management systems (Giannetti et al. 2004).

Ha Thanh and Duc Truong's (2013: 54) study of pollution control compliance in the leather tanning industry of Vietnam found that whilst large and medium sized enterprises tended to comply with regulation (submission of environmental impact assessment reports, wastewater treatment system installation, and wastewater fee payments), small firms did not, due to a lack of technical and financial capacities. In Mexico, it was found that the principle driver of clean technology adoption in a cluster of small and medium enterprises in the tannery sector was human capital, rather than firm size or regulatory pressures (Blackman & Kildegaard 2003).

2.6.3 Textiles³

The textile industry is among the most polluting industries in the world, with more than 8,000 chemicals used in the manufacturing of different types of fabric (Eryuruk 2012: 23). Large quantities of insecticides are typically used in the cultivation of cotton, which can cause environmental damage and harm the health of cotton plantation workers (Eryuruk 2012). Cotton processing also involves the use of chemicals that can be polluting, such as aqueous sodium hydroxide (used for dewaxing and mercerizing the cotton), bleaches and colourants (Loan 2011). Other forms of fibre, be they 'natural' (e.g. wool, silk, hemp, bamboo etc.) or 'man-made' ('cellulic' e.g. viscose; 'synthetic' i.e. based on petrochemicals, e.g. polyester, acrylic or nylon) or 'artificial' (i.e. based on inorganic materials such as glass or metals) (Stengg 2001), may also produce specific pollutants whilst they are being grown, extracted, treated and/or transformed [see Chen and Burns (2006)]. Different fabrics have different water use, energy use and CO₂ emission profiles; cotton is the most water intensive, synthetic fibres tend to be more energy intensive than natural fibres, while viscose and nylon produce the most CO₂ per kg of fibre and polypropylene (then wool) the least (Muthu et al. 2012). The manufacturing of garments is the least environmentally damaging of the various stages of the textile and clothing industry (Seuring 2004), although electricity is used for lighting and machinery. Waste fabric can contribute to landfill, unless recycled or used in other ways (Domina and Koch 1997).

Sustainability-oriented **product innovations** in the textile industry relate to choices regarding the type of raw material (fibre) that is used, how it was produced, whether it is biodegradable, and

³ This section draws on material from a background report written by Alexia Coke for this project, entitled "Greening Industrialisation in Developing Countries: A Scoping Review".

whether it can be recycled (see Chen & Burns 2006). Cotton is a renewable resource that is biodegradable and can in principle be recycled, although this is difficult in consumer products that have been dyed. Conventional agro-industrial cotton production, however, relies on fossil fuels and synthetic inputs such as inorganic fertilisers and pesticides. Organic cotton uses negligible quantities of pesticides and artificial fertilisers, thus reducing negative environmental and health impacts. A drawback of cotton is that its production requires large volumes of water. Wool is a renewable resource, is fully biodegradable and can be recycled. Rayon is derived from wood pulp from mature forests (a non-renewable resource on relevant timescales), and is biodegradable but not recyclable. Synthetic fabrics such as nylon and polyester are not biodegradable but can be made from recycled plastics instead of non-renewable petroleum resources. Based on a lifecycle assessment of several fibres, Muthu et al. (2012: 73) concluded that organic cotton (followed by flax) is the most environmentally sustainable of the fibres they studied (and acrylic the least), despite the amount of water required for growing cotton.

A number of **process innovations** can improve resource efficiency and reduce the negative environmental impacts of textile processing. Raising resource efficiency centres on ways of reducing consumption of dyes, water and energy. Loan (2011) explored an industrial ecology approach in relation to two textile factories in Vietnam to identify ways of reducing dye, water and energy consumption to generate \$1,000 per day worth of savings: this included reusing the waste water from rinsing processes, installing improved end-of-pipe technology and creating an external waste exchange network within the industrial zone to facilitate the utilisation of wastes from one factory by another. Rao (2004) cites a Malaysian dyeing company that was able to reduce water consumption by a factor of eight through replacing the dyeing machines with more water efficient technology, thus reducing both chemical and energy use in the process.

Venkatesh (2009: 412) identifies a number of potential energy-efficiency strategies for Indian textile firms: installing energy-efficient air-conditioning, boilers and steam distribution systems; introducing skylights that let in natural light but not heat, and use of LED lights at sewing machine needles, with 'high bay lights' only used when there is cloud; utilization of intelligent management systems for controlling humidity and carbon dioxide levels within the building; and improved management of air compressors and pneumatic systems, with monthly flue gas analyses. In a study of a Malaysian dyeing firm, Rao (2004) found that energy use could be reduced by replacing the boiler with a more efficient design and installing a heat recovery system that allows pre-heating of incoming reservoir water.

Angelis-Dimakis, Alexandratou and Balzarini (2016) identify several technologies to improve water use efficiency in a textile manufacturer. Smart pumping systems regulate water flow to meet system needs, resulting in fewer leaks and also reduced energy consumption. "Automatic dye and chemical dispensing technology involves automatic and semi-automatic weighting, dissolving and measuring systems that enable the precise delivery of dyeing chemicals and auxiliaries to production machines." resulting in less waste of additives and water. The use of low-liquor-ratio (LLR) jet dyeing machines "guarantees optimum dyeing results in very short times, enhancing energy saving and reducing the consumption of water and auxiliary resources'

A second approach is to substitute conventional inputs with less polluting inputs. Natural dyes, derived from plants (Indigo), animals (Cochineal) and minerals (Ochre), can reduce pollution caused by synthetic dyes (Angelis-Dimakis et al. 2016). Carvalho and Santos (2015) argue that "natural dyes obtained through engineered bacteria may contribute to a more ecological process to produce

natural dyes”. Specifically, they found that a natural dye derived from *Lycopene*, which is more biodegradable and safer than conventional dyes, could be applied to textiles.

Third, various techniques have been developed for reducing end-of-pipe pollutants. Processes to remove colour from textile water include a “combination of an activated sludge process, and a coagulation and ozone process” (Loan 2011), a special catalyst developed in the US, and a caustic recovery system that distils caustic and sulphuric acid for reuse (Chen & Burns 2006). “Advanced oxidation processes (AOPs) involve the generation and use of reactive but relatively non-selective free radicals (i.e. hydroxyl radicals), which in sufficient amounts oxidise most of the chemicals present in textile wastewater” (Angelis-Dimakis et al. 2016: 8). Membrane bioreactors (MBRs) separate solids from liquids and can reduce the amount of heavy metals in effluents (Angelis-Dimakis et al. 2016: 8).

Hoque and Clark (2013) list several process-related techniques that can be deployed to reduce pollution in the manufacturing of cotton textiles, including: replacement of starch-based sizing with synthetic sizing, and recovery of sizing agents; use of mineral acids instead of enzymes in a single de-sizing operation; use of less polluting detergents in the scouring process; substitution of hydrogen peroxide or ammonium salt for chlorine for bleaching purposes; recovery of caustic soda from mercerizing, and the use of hot instead of cold mercerization; the use of ‘pad-batch dyeing’ instead of conventional dyeing; and mechanical finishing processes to reduce the use of harmful heavy metal containing compounds. Pollution generated from the production of other fabrics can also be reduced, for example through the use of a non-toxic substitute for heavy metal catalysts used in making polyester from crude oil (Seuring 2004). Post-producer waste material can be recycled into new fibres or used to generate energy for manufacturing processes (Domina and Koch 1997).

Examples of developing countries where some of the foregoing eco-innovations have been implemented in specific textile factories include Thailand and Vietnam. In the case of Thailand, environmental improvements were made after the government introduced more stringent regulations on textile dyeing, printing and finishing industries in 1991 (Rao 2004). Since the late 1990s, the Thai textiles and garment industry has faced several challenges, such as competition from other Asian producers as well as stricter environmental standards enforced by the European Union. Brimble & Doner (2007: 1028-1029) report that:

Public and private officials have responded to these needs with a long list of initiatives, many within an increasingly active Thailand Textile Institute. The THTI has now established some 66 initiatives in areas such as supply chain management, garment and fabric design, dyeing and printing technology, and information technology. Some of these efforts have explicit linkages with universities or other institutions, such as a benchmarking project initiated by the TGMA [Thai Garment Manufacturers Association] in part through help from a Hong Kong polytechnic.

2.7 General principles for innovation policy

Several generic principles for the formulation of innovation policy emerge from the literature, and in particular from the work of a number of multilateral organisations such as the World Bank and OECD, which have been very active in promoting innovation in both developed and developing countries. Following a brief summary of important principles, a more detailed treatment of market failures that underlie the rationale for innovation policies is provided.

- **The approach to innovation policy should be both gradual and systemic.** The World Bank (2010:3) recommends an approach of “radical gradualism”, i.e. “a sequence of finely tuned small, specific reforms and successful outcomes that paves the way for broader, institutional changes.” Because there are many possible market and systemic failures, innovation policies need to take account of the systemic nature of innovation systems, and be designed so as to improve the performance of the whole system while ensuring that weak links are addressed (OECD 2011e:26).
- **Innovation policy needs to be informed by a long-term vision.** The OECD (2015b) suggests that innovation policy should be designed to address long-term challenges such as climate change. Innovation policy also needs to anticipate the changing nature of sources of growth, and its implications for industrialization.
- **The greening agenda should be mainstreamed in the national system of innovation.** The UN (2011), for example, recommends the creation of a green national innovation system (G-NIS) that coordinates the reorientation of sector-specific innovation systems towards green technologies. Process innovation is especially important in the green economy agenda, since efforts to reduce input use (e.g. water and energy) and reduce the amount of pollutants generated (including GHG emissions) often relate to manufacturing processes.
- **Heterogeneity across countries and context specificity matters.** If innovation policy is to be successful, it must take into account local conditions, such as demographic patterns, economic structure, social and economic inequities, and informal economic activity (Kraemer-Mbula & Wamae 2010). “There is a need to pay attention to context, history, path dependency, cultural considerations and existing political regimes of individual countries in the process of designing innovation strategies” (Kraemer-Mbula & Wamae 2010:33). In other words, the characteristics and status of the innovation system in each country will determine the priority given to various components, so that a ‘one-size-fits-all’ approach is not feasible (OECD 2011e:116). This, in turn, means that the optimal mix of policy instruments will vary across countries, according to factors such as the institutional landscape and capacities, the type and extent of market failures, the costs of monitoring environmental impacts, and so on (Botta et al. 2015).
- **Innovation policies should be as predictable as possible.** The more stable and predictable the policy environment, the more certainty is created for investors, who need to know that they will generate an adequate return on investments in new products and production processes (Botta et al. 2015).
- **Both supply side and demand side policies are required.** Supply side policies involve those designed to bolster the enabling conditions for innovation (see section 6.2). While many of these “are the same whether one is concerned with green innovation or innovation more generally” (OECD 2011e:46), the environmental policy framework is also critical for green innovation. Demand side policies address the uptake of (green) innovations by the market.
- **Innovation policy formulation and implementation should incorporate a learning process.** Proper monitoring and evaluation of innovation policies can provide feedback on how effective they are, and where remaining gaps lie. It can also generate learning from experience and allow policies to be adjusted over time, which can in turn maximise the cost effectiveness of government intervention (OECD 2015b).
- **The need for building functioning (green) innovations systems needs to be emphasized.**

2.7.1 Addressing market failures

The need for policies to support green innovation stems essentially from two main types of market failure: those that inhibit innovation in general, and environmental market failures that hinder green innovation specifically. The principal type of market failure relevant for general innovation is that it

has public good characteristics, i.e. firms cannot fully appropriate the returns on their investment in innovation; this results in insufficient private sector investment in innovation. Another market failure is uncertainty and incomplete information, which makes investment in R&D inherently risky (OECD 2011e:25). Barriers to entry, for example arising from the dominance of incumbent firms (e.g. monopolies), infrastructures and technology regimes, constitute a third market failure.

Environmental market failures essentially involve externalities, which arise when pollution costs are borne by the environment (and by implication society) and not directly by the private firm producing the pollution. In such cases, there is little or no incentive for firms to invest in green innovation (OECD 2011e:9). This means that policies are required that internalise externalities to the firms, thereby creating markets for green products and production processes. This effectively means the government needs to strengthen its capacity to monitor and enforce environmental law and policy.

Market failures, as described above, can be addressed in two main ways: through the creation of economic incentives, and through the enforcement of regulations. Incentives for innovation can take the form of tax breaks or grants. Adjusting the price mechanism to reflect environmental costs is often regarded as an effective way of creating incentives for green innovations, since it tends to minimise costs of achieving the policy goal. Price signals also demonstrate the government's commitment to achieving greener growth (OECD 2011e:10). A prominent example of a price mechanism to tackle greenhouse gases is a carbon tax, which has been introduced in several countries, including Sweden, Iceland, Ireland and Australia (OECD 2014). There is some debate over how desirable a carbon tax is in a low-income country context. The UN (2011:132) cautions that "higher energy prices due to carbon taxes can have the perverse effect of disrupting economic development in poor countries". However, Fey et al. (2015) have recently demonstrated that carbon taxation is a particularly progressive tax option, and can replace more distortionary and regressive sources of public revenue. Given the critical need of developing states for tax revenues, as well as the desire to chart a low-carbon course, a carbon tax could be a tool that promotes both environmental and developmental outcomes.

Setting an appropriate regulatory environment is the other main tool for addressing market failures. Product market regulations, which determine the extent of market competition, are important to reduce anticompetitive and monopolistic practices (World Bank 2010:13). The creation of intellectual property rights (IPRs) is another way to support the diffusion of innovations (OECD/Eurostat 2005:114; OECD 2011e:13). IPRs include patents, trademarks, copyrights, registration of design, confidentiality agreements and trade secrecy. Strong property rights ensure that firms have the incentive to invest in R&D, as they will be able to capture the returns on their investments.

Environmental regulations can be an effective way of reducing environmental impacts and stimulating green innovation. However, regulations should match the environmental objectives as strictly as possible and must be backed up by adequate monitoring and enforcement. This can be costly, and depends on adequate human and institutional capacity. "Given these constraints on conventional regulation, a promising strategy for controlling SME pollution is to promote the adoption of clean technologies that prevent pollution and either reduce production costs or do not raise them significantly. The hope is that firms will adopt clean technologies voluntarily or at least with minimal prodding" (Blackman & Kildegaard 2003). Where industrial standards are developed, "performance standards are usually considered more effective tools compared to technology-specific standards" because they afford firms a greater degree of flexibility (Botta et al. 2015: 27).

3 Methodology and Data

As mentioned in the introduction, this report adapts the methodology proposed by Botta et al. (2015), following Bergek et al. (2008), to analyse the functioning of an innovation system from the perspective of green growth. This involves four steps: (1) selecting the level of analysis (in this case both national and sectoral levels); (2) mapping the key elements of the IS and their interactions; (3) assessing the functioning of the IS; and (4) developing policy recommendations for improving the IS.

In order to operationalise these steps, the report utilised three research methods. First, it analysed secondary data on relevant variables (such as macroeconomic indicators, communication infrastructure, patents, educational enrolment, expenditure on R&D, etc.) drawn from international databases including the World Bank's *World Development Indicators* (World Bank 2016a) and the UNESCO Institute for Statistics database (UNESCO 2016) in order to assess current technical capacities and framework conditions that enable or hamper innovation.

The second research method entailed a survey of innovation activities amongst a sample of enterprises in the textiles, leather and cement sectors. These sectors were selected for the overall research study, which includes a benchmarking exercise with regard to the environmental performance of these firms, because they have been identified as significant growth industries within Ethiopia in the GTP. In addition, the cement industry is responsible for half of the industry sector's CO₂ emissions (UNDP Ethiopia, 2011), while the textiles and leather sectors are responsible for significant levels of pollution. The survey questions were based on OECD/Eurostat's (2005) *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*, although some sections were omitted (such as questions relating to organisational and marketing innovation) and extra questions were added about green innovation. The survey was carried out in March and April of 2016, and involved enumerators conducting site visits to enterprises and gathering answers to the survey questions from one or more representatives of each company. The same questions pertaining to innovation were used for each of the three sectors.

The sampling selection was stratified in the first instance according to sector (cement, leather and textiles) and geography. Within this scope, 141 firms were identified as candidates for the survey. In the cement sector, a census of firms was conducted. Within the leather sector, a census of tanneries was conducted, and a random sample was selected of downstream leather producers, including shoe manufacturers and firms making other finished leather products. In the textiles sector, all integrated textile facilities were included in the survey, as well as a sample of garment manufacturers. Of the 141 firms surveyed, 11 refused to participate in the survey and a further 13 provided incomplete responses, resulting in a response rate of 82%. The final sample of 117 firms comprised 15 firms in the cement sector, 40 in the leather sector and 62 in the textile sector.

The third research method consisted of interviews with key role-players in the national and sectoral innovation systems to gather qualitative information about the adoption and diffusion of innovations. The purpose was to identify the relevant innovation actors, establish the existing linkages and communication channels among these innovation actors, and identify the strengths, weaknesses, opportunities, and threats within the national and sectoral systems of innovation.

4 The National System of Innovation in Ethiopia

This section describes and assesses the national system of innovation in Ethiopia. Section 4.1 provides an analysis of the framework conditions for innovation, based on data drawn from international sources such as the World Bank, International Monetary Fund (IMF) and United Nations Education, Scientific and Cultural Organisation (UNESCO). Section 4.2 maps the main elements of the NSI. Section 4.3 assesses the overall performance of Ethiopia's NSI based on a recent national innovation survey as well as international comparative metrics. Section 4.4 evaluates the functioning of the NSI according to the dimensions outlined in section 2.2.3.

4.1 Framework conditions for innovation

As discussed in section 2.2.4, the innovation performance of a country is affected by a range of so-called 'framework conditions', such as the macroeconomic environment (including openness to foreign direct investment and trade), extent of infrastructure, human capital formation, expenditure on R&D, skills base, and regulations governing product and labour markets and environmental impacts. The strength and stability of policies relevant to innovation are discussed in section 4.2.

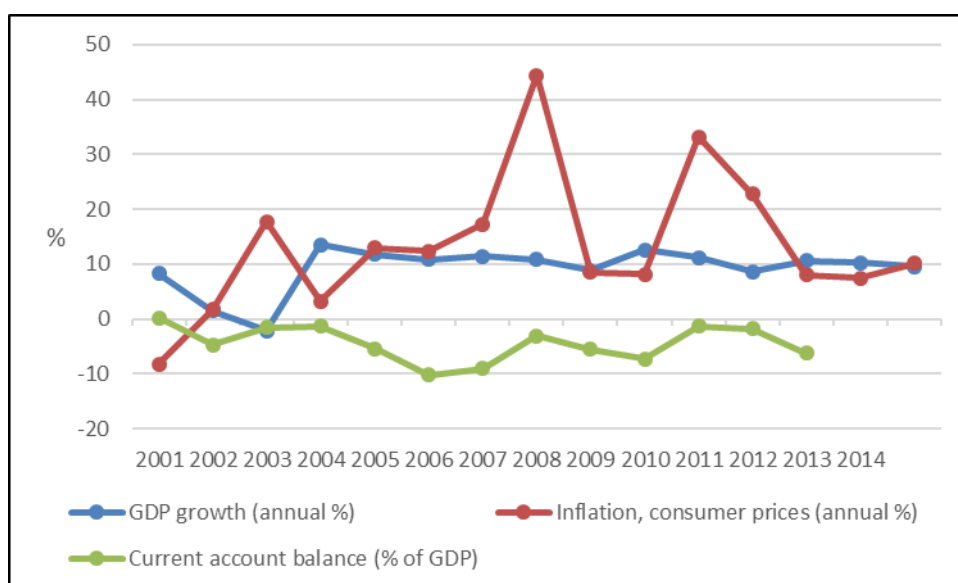
4.1.1 Macroeconomic environment

The general macroeconomic environment has been very positive in Ethiopia over the past decade. Most importantly, the rate of economic growth (GDP growth) has been consistently near 10% per annum since 2004, only dipping below that rate in 2008 (8.8%) and 2012 (8.6%) (see Figure 2). This strong growth environment has been conducive for the expansion of business activities, and the rapid growth of markets implies potentially good returns to innovation. However, in terms of structural transformation the only visible change is that since 2011 the services sector has overtaken the agriculture sector in terms of its share of GDP, reaching 43.6% in 2014/15 compared to 38.8% for agriculture. This is not, however, the desired direction of structural transformation for the country. Despite high annual growth over the two plan periods, the industry sector's contribution to GDP remained below 15%. Nonetheless, Ethiopia's economic growth has been inclusive, as evidenced by the decline in the share of the population living below the national poverty line from 44% in 2000 to 30% in 2011 (World Bank 2015a). According to the *African Economic Outlook: Ethiopia 2015*, the growth "has been inclusive, spanning different economic sectors and benefiting both urban and rural communities" ... "and a large number of new jobs have been created in both the public and private sectors" (Zerihun Wondifraw, Kibret & Wakaiga 2015:3).

Results from the World Bank Enterprise Survey (WBES) 2015, which was based on interviews of managers in 848 formal sector firms across a range of economic sectors, confirm that the business environment in Ethiopia was conducive for business expansion in the preceding four years. Annual employment growth averaged 8.9%, compared to 6% in Sub-Saharan Africa (SSA) and 5.4% in low income countries (LICs) (World Bank 2016b). Real annual sales growth in Ethiopia was 4.4%, considerably higher than in SSA (0.9%) and LICs (-0.1%).

On the other hand, inflation (measured by the annual percentage change in the consumer price index) has been volatile, reaching 44% in 2008 and 33% in 2012, although it more recently it declined to 10.1% in 2014 (Figure 2). These spikes coincided with global spikes in oil and food prices. The current account deficit – the gap between imports and exports plus net factor payments from abroad – has decreased since the mid-2000s, and has not presented a major risk to macroeconomic stability in recent years.

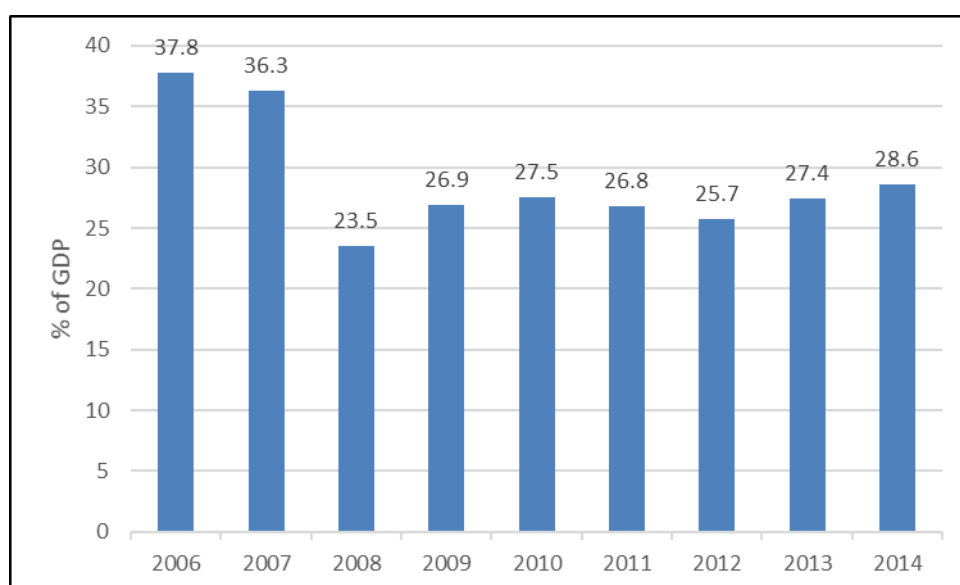
Figure 2: Macroeconomic indicators for Ethiopia



Source: World Bank (2016a) and International Monetary Fund (2016)

Ethiopia's public debt presents moderate risks to macroeconomic stability and sustainability. The debt to GDP ratio has fallen from over 35% in 2006 to 29% in 2014 (see Figure 3). However, the government has incurred substantial debt in recent years to finance its ambitious public infrastructure investment programme. Public investment rose from about 6% of GDP in 2000 to nearly 20% of GDP in 2011 (Moller 2016). According to a recent World Bank report, the public infrastructure programme has been one of the main drivers of Ethiopia's impressive economic growth over the past decade (Moller 2016). As long as this infrastructure lays the platform for future continued high growth rates, the debt should be sustainable, but risks are nevertheless presented by uncertainties surrounding foreign demand, including for Ethiopia's envisaged cross-border electricity exports (IMF 2015; Cuesta-Fernández 2015).

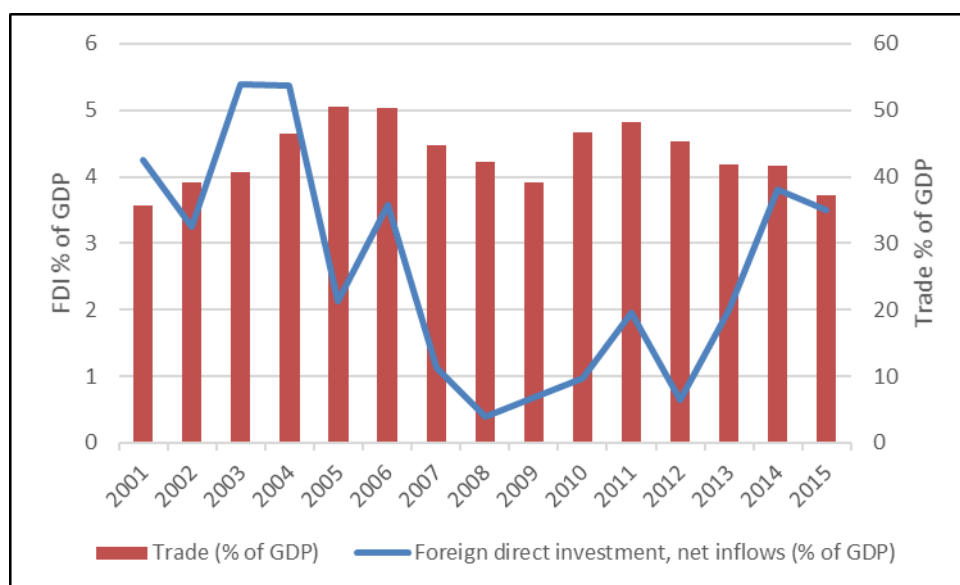
Figure 3: Ethiopia's public debt



Source: Trading Economics (2016)

Indicators of Ethiopia's openness to trade and foreign investment are shown in Figure 4. FDI has been rather volatile since 2001; it followed a notable declining trend between 2004 and 2008, but has since recovered to reach 3.5% of GDP in 2015. This level of FDI is still lower than the average FDI inflows of 5.5% of GDP for LICs,⁴ and therefore indicates that the related inflow of innovations embodied in technology (e.g. fixed capital equipment) is limited. International trade (defined as the sum of merchandise exports and imports) as a percentage of GDP is at a reasonable level, fluctuating between 40 and 50 percent of GDP since the early 2000s, although this is somewhat lower than the LIC average of 72% in 2014 (World Bank 2016a). Ethiopia's trade/GDP ratio has declined somewhat in recent years, mainly owing to the rapid growth in the domestic component of GDP (especially non-tradeable services), rather than a fall in external trade volumes, which have continued to rise.

Figure 4: Ethiopia's openness to trade and foreign investment



Source: IMF (2016) and World Bank (2016a)

The World Bank (2016b:7) cautions that “delays in clearing customs for exports and imports create additional costs to the firm, can interrupt production, interfere with sales, and may result in damaged supplies or merchandise.” According to the WBES 2015, it took 8 days on average for firms to clear their export goods through customs (compared to 10 days in SSA and 9 days in LICs) and 19 days to clear imports (compared to 16 days in both SSA and LICs) (World Bank 2016b). Thus Ethiopian firms face considerable inefficiencies in handling trade, but to a similar degree to their peers in similar countries. Certainly, Ethiopia's landlocked status further complicates international trade.

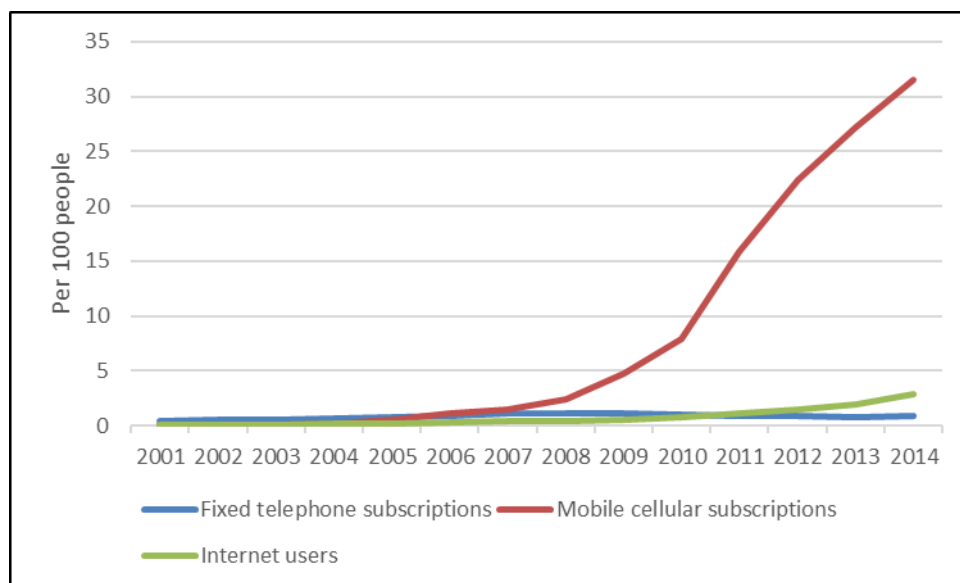
4.1.2 Infrastructure

Another important aspect of the framework conditions for innovation is the extent of ICT infrastructure. While fixed-line telephone subscriptions have remained at very low levels (0.8 per 100 people in 2014), mobile cellular subscriptions have grown spectacularly in recent years to reach 31.6 per 100 people in 2014. Although Internet connectivity has been growing, it remains at very low levels of penetration (2.9 users per 100 people). With the Internet in particular being a vital source of knowledge and electronic communications to support innovations and their diffusion, Ethiopian businesses are clearly very constrained in this area by the lack of ICT infrastructure. In the education

⁴ Calculated from data drawn from the World Bank (2016a).

sector, however, the government has made ICT infrastructure a priority as a platform for delivering quality education across all regions of the country (Kuriakose et al. 2016).

Figure 5: ICT infrastructure in Ethiopia



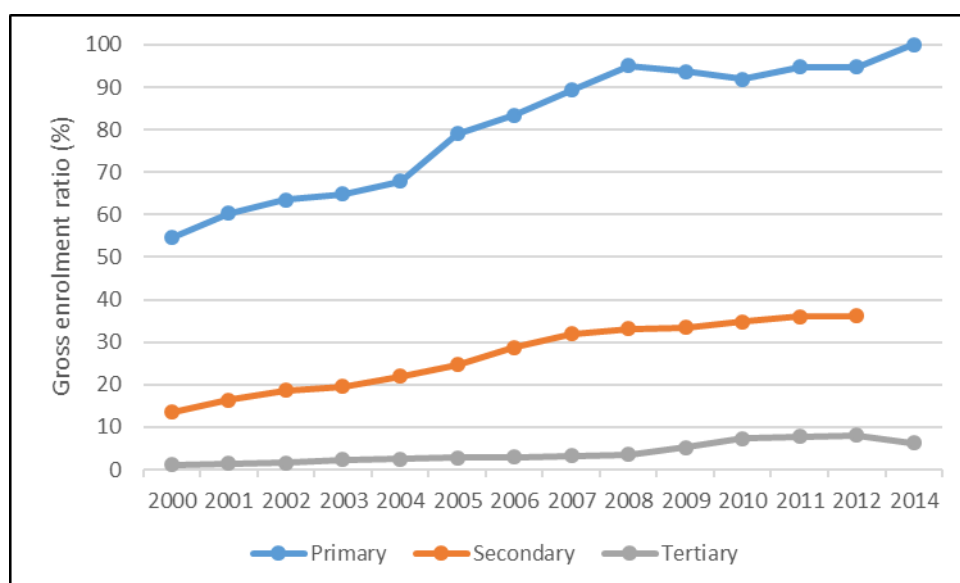
Source: World Bank (2016a)

Access to other critical forms of infrastructure, such as electricity, roads and water supply, is also lacking, as confirmed by the WBES 2015. For example, in Ethiopia firms reported that it takes on average 194 days to obtain an electrical connection, compared to averages of 33 days in SSA and 49 days in LICs (World Bank 2016b). On average, firms lost 4.6% of sales as a result of unreliable electricity supply and experienced 8.2 power outages – although these disruptions were slightly less costly and frequent than in SSA and LICs. Ethiopian manufacturing sector enterprises experienced an average of 2.7 water insufficiencies in a typical month, compared to 1.8 in SSA and 1.7 in LICs (World Bank 2016b). Such disruptions can have a significant negative impact on business operations.

4.1.3 Enrolment in education

Education, starting at primary levels and continuing through secondary to tertiary levels, lays the foundation for the acquisition and diffusion of knowledge in a society and economy; thus the enrolment rate is an important indicator of the basic capacity for innovation. Ethiopia has made great progress in gross primary enrolment, the ratio having increased from 55% in 2000 to 100% in 2014 (UNESCO Institute for Statistics 2016). The gross secondary enrolment ratio started from a much lower base of 14% in 2000, but has grown reasonably quickly, reaching 36% in 2012. The gross tertiary enrolment ratio has only begun to grow notably since 2009, but remains at very low levels and dipped in 2014 to 6.3% (UNESCO Institute for Statistics 2016), compared to averages of 11.1% in sub-Saharan Africa in 2013 and 8% in low-income countries (World Bank 2016a). Tertiary education is especially important for innovation, so these data show the severe limitations facing Ethiopia's NSI at this time. It will take a number of years – and considerable public investment in education – before the improvements in primary enrolments feed through into higher secondary and tertiary enrolment ratios.

Figure 6: Ethiopia's gross enrolment ratios in education, 2000-2014



Source: UNESCO Institute of Statistics (2016)

Note: Tertiary enrolment ratios for 2006 and 2007 were not available in the dataset, and have been linearly interpolated here. Data for 2013 were unavailable.

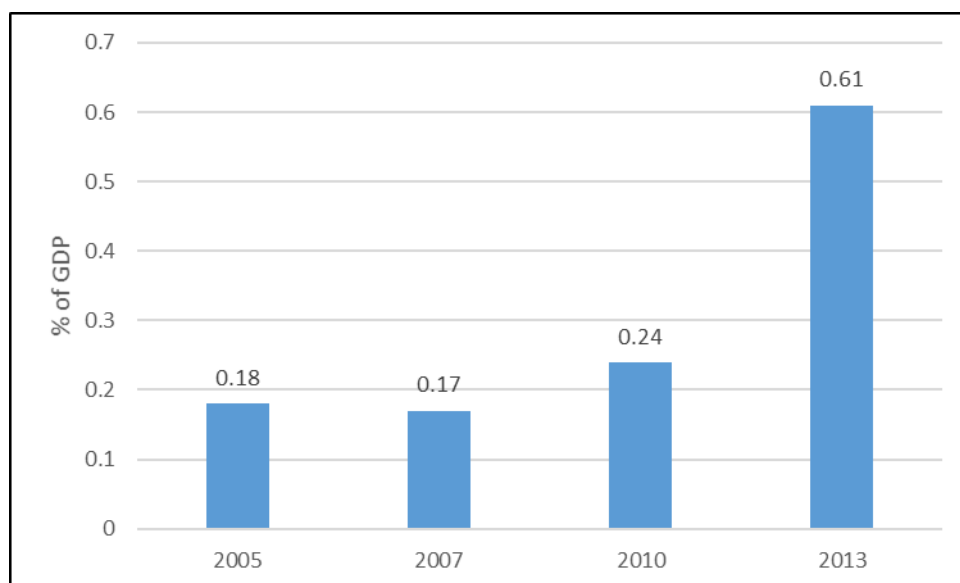
Government expenditure on education as a percentage of GDP rose from just under 4% in 2000 to 5.5% in 2007, but has since declined slightly to 4.5% of GDP in 2013 (UNESCO Institute for Statistics 2016). Still, the latter figure compares favourably with the averages of 4.1% among low-income countries (LICs) and 4.2% in Sub-Saharan Africa (SSA) in 2013.⁵ Education is a high priority for the Ethiopian government, as evidenced by the fact that 27% of total government spending was allocated to education in 2014, compared to averages of 17.1% among LICs and 16.6% in SSA in 2013. Government expenditure on tertiary education in Ethiopia amounted to 1.92% of GDP in 2013, and represented 11.5% of total government spending. Tertiary education spending accounted for 42.7% of all government education expenditure in Ethiopia, compared to 18.8% in SSA and 21.5% in LICs; Ethiopia's percentage allocation of expenditure to tertiary education was the largest in both country groupings. These figures show that while the resources available for education are limited due to the small absolute size of Ethiopia's GDP, the government is clearly prioritising investment in higher education. This will lay the platform for more dynamic innovation in the years to come.

4.1.4 Expenditure on research and development

Gross domestic expenditure on research and development (GERD) is an important indicator of the resources allocated for supporting broad innovation in a country. The share of GERD in GDP in Ethiopia has risen steadily in the past few years, more than tripling from 0.17% in 2007 to 0.61% in 2013 (Figure 7). This percentage is comparatively high for a low-income country, and compares favourably with the proportion recorded in several upper-middle-income African countries such as Egypt (0.68%) and Botswana (0.23%), as well as with fellow LICs Uganda (0.48%) and Tanzania (0.52%) (figures for 2010). The absolute amount of GERD reached \$679 million (at purchasing power parity rates and in 2005 prices) in 2013, up from \$202 million three years earlier and \$90 million in 2005. The recent increase in GERD reflects the new priority given to STI with the introduction of the STI Policy framework in 2012, but is largely due to a 41% increase in the headcount of R&D personnel between 2010 and 2013, the majority of whom were non-research personnel (Kuriakose et al. 2016).

⁵ Comparative figures for Sub-Saharan African countries and low-income countries are drawn from the World Bank (2016) *World Development Indicators*.

Figure 7: GERD as a percentage of GDP in Ethiopia

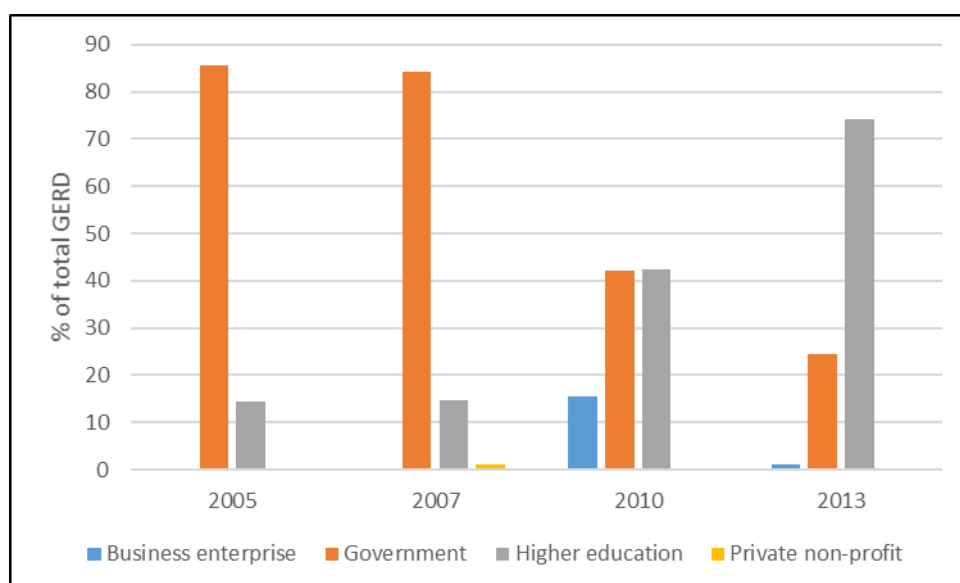


Source: UNESCO Institute of Statistics (2016)

The patterns of GERD across types of research, types of institutions performing R&D, and subject areas can influence the capacity of such spending to underpin innovation. Of the total GERD in 2013, 12.2% was allocated to basic research, 45.6% to applied research, and 42.2% to experimental development. This allocation augurs well for innovation, which should benefit from applied and experimental activities. Over the past ten years, the locus of spending on GERD has shifted dramatically from government (down from 86% in 2005 to 25% in 2013) to HEIs (up from 14% to 74%) – see Figure 8. According to the UNESCO Institute for Statistics (2016) figures, the share of GERD performed by business enterprises fell from 16% in 2010 to 1.2% in 2013, while that of non-profit organisations was a paltry 0.2% in the latter year.⁶ It would appear that the government has decided that HEIs are the best vehicle for R&D, which makes sense considering the importance of the research function in these institutions. The marked drop in business expenditure on R&D (BERD) from 144.6 million Ethiopian Birr (ETB) to 61.5 million ETB between 2010 and 2013 is a cause for much concern (Kuriakose et al. 2016).

⁶ The percentage shares of GERD by sector contained in the UNESCO Institute for Statistics (2016) database are the same as those reported in the Science and Technology Indicators Report by the Ethiopian Science and Technology Information Centre (STIC 2014).

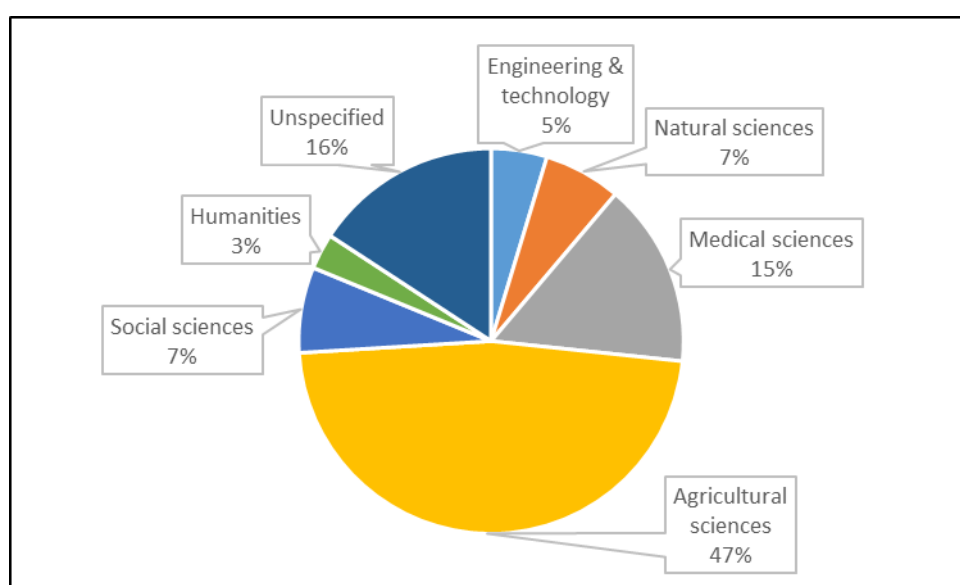
Figure 8: GERD by type of institution in Ethiopia



Source: UNESCO Institute of Statistics (2016)

The subject areas to which GERD is allocated can affect its role in facilitating innovation. In particular, engineering and technology subjects, along with natural sciences, are generally expected to be more supportive of product and process innovation than fields like the humanities and social sciences. Figure 9 shows the allocation of GERD by subject area in 2010. Agricultural sciences accounted for nearly half of GERD, and medical sciences a further 15%. By contrast, engineering and technology (5%) and natural sciences (7%) received small shares of GERD; social sciences and humanities together accounted for 10%. It can therefore be concluded that Ethiopia's GERD allocation was not very supportive of innovation in the manufacturing sector at that time. More recent data are not available to assess to what extent these allocations may have shifted.

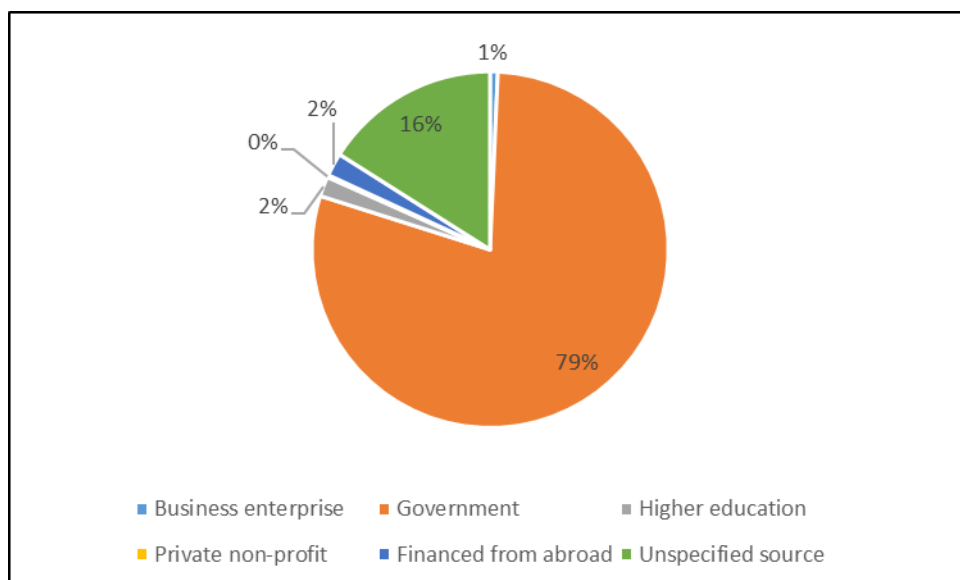
Figure 9: Shares of GERD by subject area, 2010



Source: UNESCO Institute of Statistics (2016)

As can be seen in Figure 10, the government directly provides the lion's share of GERD (79%), while 5% is sourced from business enterprises, HEIs, non-profit organisations and external sources combined; 16% had an unspecified source in 2013 (Figure 10).⁷ As the country develops further, it may be expected that non-governmental sources of funding for R&D might be more forthcoming, but considering Ethiopia's early stage of development it is not surprising that the government provides most of the funds.

Figure 10: Sources of financing for GERD, 2013



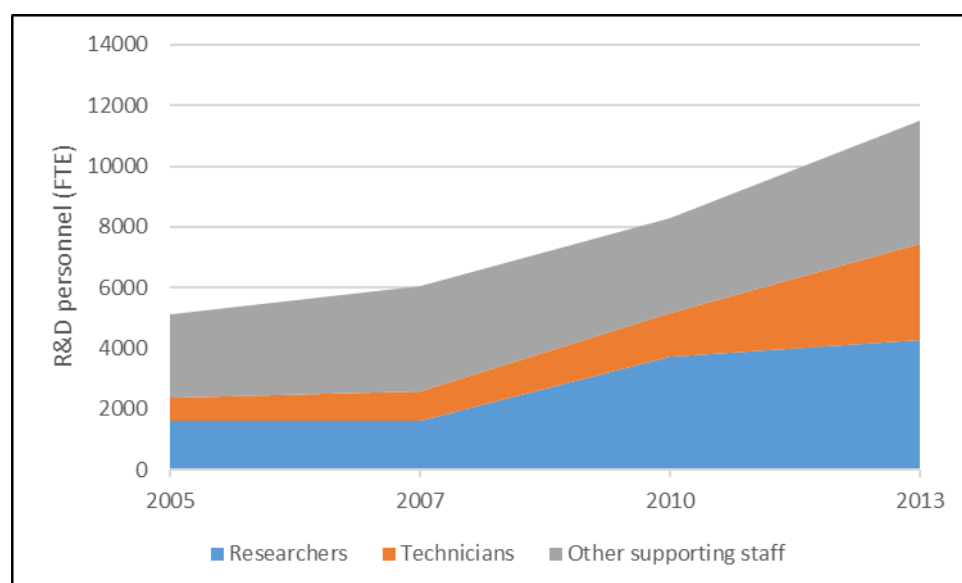
Source: UNESCO Institute of Statistics (2016)

4.1.5 Research and development personnel

The extent of innovation in an economy depends partly on the availability of skilled personnel who are engaged in R&D activities. Figure 11 shows that the total number of full-time equivalent (FTE) R&D personnel more than doubled from 5,112 in 2005 to 11,501 in 2013. In 2013, researchers comprised 37% of all personnel, technicians 27%, and other supporting staff 36%. The largest increase between 2010 and 2013 was in technicians, with a much more modest growth in the number of FTE researchers.

⁷ The Science and Technology Indicators Report produced by STIC (2014) has slightly different figures for source of financing for GERD: government (79.1%); organisations (18.8%) (the type of organization is not defined); businesses (0.1%), foreign sources (2.1%), and other national sources (0.4%).

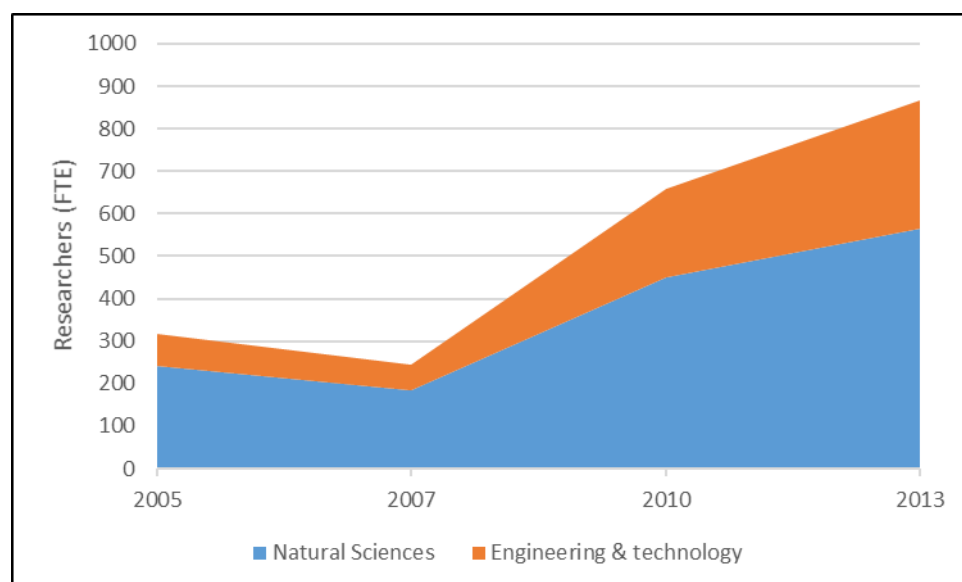
Figure 11: R&D personnel by type, 2005 to 2013



Source: UNESCO Institute of Statistics (2016)

The number of FTE researchers in the Natural Sciences and Engineering and Technology grew rapidly between 2007 and 2013, from 318 to 868 (Figure 12). This augurs well for innovation, provided there is sufficient interaction between researchers and enterprises.

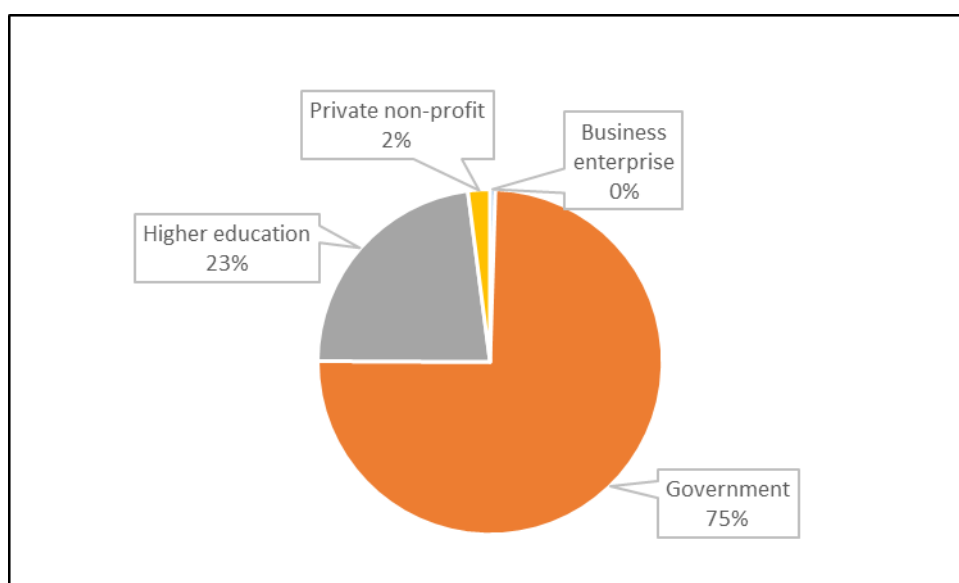
Figure 12: Researchers in science and engineering, 2005-2013



Source: UNESCO Institute of Statistics (2016)

In 2013, three-quarters of R&D personnel were in the government sector, 23% in HEIs, 2% in private non-profit organisations and just 0.5% in business enterprises (Figure 13). This pattern is typical of less developed countries, where the government has to step in to invest in R&D as the private sector is relatively underdeveloped, and lacks the capital and risk appetite to fund R&D activities.

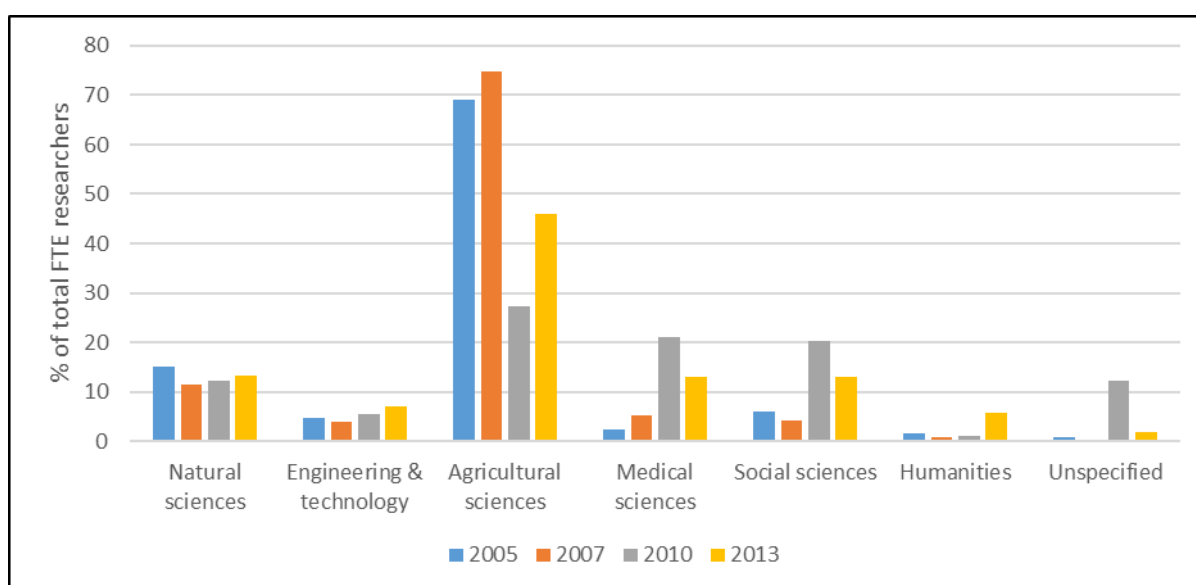
Figure 13: R&D personnel by type of institution, 2013



Source: UNESCO Institute of Statistics (2016)

Figure 14 shows the proportion of total full-time equivalent (FTE) researchers by field for several different years. Agricultural sciences dominate, with 46% of all researchers in 2013, although there appears to have been a shift towards other disciplines in recent years. Engineering and technology accounted for just 7% of FTE researchers, and natural sciences for 13%, in 2013. However, the data (provided by UNESCO 2016) are quite volatile from year to year and should therefore be interpreted with caution. The high share of researchers involved in agricultural sciences is explained by the predominance of agriculture in the Ethiopian economy, but innovation in industry and manufacturing will be better served by researchers in the fields of science, engineering and technology.

Figure 14: Share of researchers by field



Source: UNESCO Institute of Statistics (2016)

4.1.6 Laws and regulations

The business sector in Ethiopia is more intensively regulated than in many other Sub-Saharan African and low-income countries. For example, 96% of Ethiopian enterprises registered with the authorities when they first started operations, compared to averages of 83% in SSA and 86% in LICs (World Bank 2016b). Senior management reportedly spent on average 11.9 percent of their time dealing with regulatory compliance, significantly more than the averages for SSA (7.6%) and LICs (6.6%), as well as high-income countries (9.7%). However, the average number of tax meetings in a year was slightly lower in Ethiopia (1.6 compared to 2.2). The average number of days required to obtain an import license (13 days) and a construction permit (48 days) in Ethiopia is in line with its peer countries, although it takes considerably less time to acquire an operating license (5 days, compared to 19 days in SSA). Just over a quarter (27%) of Ethiopian enterprises reported that they experienced at least one bribe payment request, which is slightly higher than the SSA average (25%) but lower than the average in LICs, where 32% of firms reported at least one bribe payment request. Bribery and corruption place administrative and financial burdens on firms.

Environmental laws – and the effectiveness of law enforcement – are especially relevant for innovation in green technologies, whose uptake often depends on effective enforcement of regulations to reduce pollution or emissions. The Ethiopian Environmental Protection Authority (EPA) was established under the Ministry of Natural Resources Development and Environmental Protection (MNRD&EP) in 1994. In 2002 the EPA's status was elevated to an independent institution with the responsibility for environmental regulation and monitoring (Ethiopian Environmental Protection Authority 2011), and subsequently the EPA has been promoted to ministerial level as the Ministry of Environment, Forest and Climate Change. These institutional developments demonstrate the increasing commitment to environmental policy and protection within the Ethiopian government.

The Environmental Policy of Ethiopia (EPE) was promulgated in April 1997, with the overarching goal “to improve and enhance the health and quality of life of all Ethiopians and to promote sustainable social and economic development through the sound management and use of natural, human-made and cultural resources and the environment as a whole so as to meet the needs of the present generation without compromising the ability of future generations to meet their own needs” (EPA 1997:3). One of the key objectives of the EPE is to “prevent the pollution of land, air and water in the most cost-effective way so that the cost of effective preventive intervention would not exceed the benefits” (EPA 1997:4). One of the guiding principles is that “market failures with regard to the pricing of natural, human-made and cultural resources, and failures in regulatory measures shall be corrected through the assessment and establishment of user fees, taxes, tax reductions or incentives” (EPA 1997:5).

In their assessment of Ethiopia's environmental policy and environmental impact assessment (EIA) process, Ruffeis et al. (2010) argue that several factors undermine the enforcement and effectiveness of the EIA law: institutional-level inconsistencies; a lack of complementarities between institutions and between environmental and investment policies and proclamations; a dearth of multidisciplinary experts; non-existent environmental baseline data; and insufficient monitoring and evaluation. Another assessment of environmental policy found that “environmental stakeholders in government, in academia, and in the NGO community all appear to agree that formal environmental policies in Ethiopia are well-written and praiseworthy, but that on-the-ground implementation of policies remains incomplete” (Colby Environmental Policy Group 2011:1). The implication is that regulation-driven technology forcing is weaker than it could be if environmental laws and regulations were adequately implemented.

In 2015 the government commissioned a review of the 1997 Environmental Policy, in order to assess the gaps that had arisen as a result of structural, socio-economic and environmental changes in the global and national context. The assessment found gaps relating to technology and innovations, the

transport sector, wildlife protection and conservation, private sector involvement, and international partnerships, and also highlighted the need to align the environmental policy with the CRGE strategy (which was promulgated in 2011). A draft of the new Environmental Policy was completed in December 2015. The overall policy goal was unchanged, but an additional policy objective was included to reflect the CRGE, namely to “ensure the reduction of GHG emission to the threshold level, hereby promoting emission reduction technologies and practices” (MEFCC 2015). The implementation of the policy is to be guided by a number of principles, among which is the ‘polluter pays’ principle: “The polluter and users of environmental and natural resources shall bear the full environmental and social costs of their activities” (MEFCC 2015).

The original collection of sectoral policies contained in the 1997 Environmental Policy was revised, with the notable inclusion of a new subsection focusing on the Industry Sector. This section spells out many requirements for industry in general terms, including environmental management plans, environmental impact assessments, use of clean technologies, environmental audits for both new and existing industries including registers of hazardous and toxic wastes, and proper waste control procedures. A new addition to the cross-sectoral environmental policies that is of particular relevance to this report is a section on ‘technology and innovation’. This calls for policies that promote the transfer and deployment of technologies and innovations that are low-carbon, generate little or no waste, and reduce pollution. It also seeks “to encourage development of a system to incentivize and motivate green and clean technology innovations, intellectual property right and the importation and local production of green technologies”, to encourage the use of renewable energy by industry, and to promote the establishment of technology incubation centres (MEFCC 2015). Thus green innovation is explicitly promoted in the draft revised environmental policy.

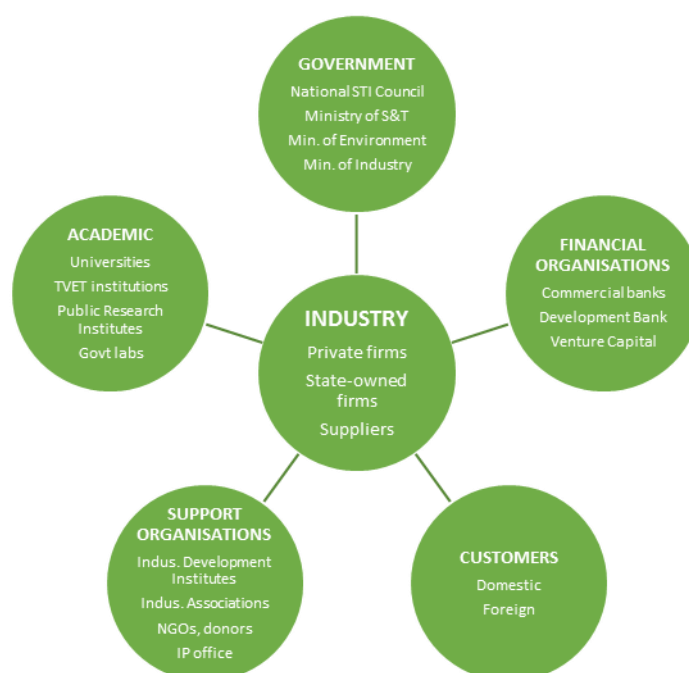
A separate subsection in the revised policy deals with hazardous chemicals and wastes, which falls within a section on Environmental Quality. The specific intentions are threefold: “To ensure proper management system of obsolete or banned toxic and hazardous chemicals; to promote establishment of appropriate hazardous waste management systems and treatment facilities; and to facilitate the development and enforcement of legal frameworks on the importation, production, transportation and use of toxic and hazardous chemicals” (MEFCC 2015). These provisions apply in particular to the leather and textile processing industries. The draft revised policy also promotes the use of standards, including for manufacturing, as a tool to minimize environmental pollution (MEFCC 2015).

4.2 Mapping the key elements of the NSI

As mentioned in section 2.2, analysing the structure of a national system of innovation involves identifying the actors that are involved (organisations, firms etc.) and the relationships among them. The analysis in this section is based on quantitative data drawn from international databases and domestic surveys, as well as qualitative information elicited from interviews with stakeholders. It begins with the role of government policies and agencies, and then considers HEIs, PRIs, financial organisations, industry associations and support organisations. The main actors in the NSI are represented in Figure 15.⁸

⁸ The figure does not attempt to capture all of the complex interactions among the various actors, but rather presents a simplified list of major actors that interact with firms in the innovation process.

Figure 15: Main actors in Ethiopia’s national system of innovation



4.2.1 Government policies and agencies⁹

The transitional government of Ethiopia adopted a national Science and Technology (S&T) policy in 1993 in order to boost innovation activities for economic development through the application of science and technology. However, this policy was not adequately implemented and “there was no strong and legitimate body that could coordinate the use of limited resources among key stakeholders” (Kuriakose et al. 2016:46). More recently, the Ethiopian government recognized that a coherent science, technology and innovation (STI) policy was a precondition for realizing its Growth and Transformation Plan for 2011–2015 (UNESCO 2016). To this end, the Federal Democratic Republic of Ethiopia (FDRE) promulgated a new National Science, Technology and Innovation (STI) Policy in February 2012. The national STI vision is “to see Ethiopia entrench the capabilities which enable rapid learning, adaptation and utilization of effective foreign technologies by the year 2022/23” (FDRE 2012). The mission specified in the STI policy is “to create a technology transfer framework that enables the building of national capabilities in technological learning, adaptation and utilization through searching, selecting and importing effective foreign technologies in manufacturing and service providing enterprises” (FDRE 2012). The seven major policy objectives are as follows (FDRE 2012:4):

1. Establish and implement a coordinated and integrated general governance framework for building STI capacity;
2. Establish and implement an appropriate national Technology Capability Accumulation and Transfer (TeCAT) system;
3. Promote research that is geared towards technology learning and adaptation;
4. Develop, promote and commercialize useful indigenous knowledge and technologies;
5. Define the national science and technology landscape and strengthen linkages among the different actors in the national innovation system;
6. Ensure implementation of STI activities in coordination with other economic and social development programs and plans;

⁹ This section draws on the Greening Industrialization in Ethiopia Scoping Report compiled by EDRI (2015).

7. Create [a] conducive environment to strengthen the role of the private sector in technology transfer activities sustainably.

Based on an analysis of current STI systems and international best practice, the STI policy identified eleven critical policy issues, along with a set of strategies to deal with each issue (for details see EDRI 2015). These 11 critical issues are: technology transfer; human resources development; manufacturing and service enterprises; research, financing and incentive schemes; universities, research institutes, TVET institutions and industry linkages; intellectual property system; national quality infrastructure development; science and technology information; environmental development and protection; and international cooperation. In the area of environmental protection, one of the strategies is to “create local capabilities to learn about, adapt and adopt green technologies” (FDRE 2012:18).

The STI Policy clearly mandates the government to take the lead in implementing the policy strategies and thereby strengthening the NSI. To this end, the policy spells out a governance structure comprising a National Science, Technology and Innovation Council (NSTIC); the Ministry of Science and Technology (MoST); other related Ministries such as the Ministries of Education, Industry, Agriculture, Health, Finance and Economic Development; and innovation support and research systems. The national innovation support and research system comprises universities, government research institutions, national laboratories, Technical and Vocational Education and Training (TVET) institutions, financial support service providers, science and technology parks, the intellectual property office, manufacturing and service-providing enterprises and the agencies of the national quality infrastructure.

The National Science, Technology and Innovation Council (NSTIC) comprises government officials, scientists and prominent individuals from the private sector. Chaired by the Deputy Prime Minister, the Council is the highest governing body for the STI policy and sets its long-term strategic direction. According to the STI policy document, the Council is responsible for (a) monitoring and evaluating technology adoption and utilization, (b) resource allocation for technology capacity-building, (c) recommending national priority areas, and (d) creating and promoting an environment that integrates and develops synergies between all the actors in the innovation system. The Ministry of Science and Technology and other government bodies (including the Ministries of Finance and Economic Development, Industry, Trade, Agriculture, Health, Education, Labor and Social Affairs, and Communication and Information Technology) are tasked with implementing the STI policy and recommendations from the NSTIC. The MoST serves as secretariat of the Council. The Ministry of Industry and affiliated actors have a special role in leading and promoting innovation systems in the industrial sector. The Science and Technology Information Centre (STIC), established in 2011, carries out the important function of data collection and dissemination.

The MoST is currently undertaking several activities to encourage institutional and individual innovative talent such as its award and funding scheme for innovative ideas and projects (MoST 2015). The Ministry provides awards for students and teachers, trainees and trainers, and researchers and innovators who have registered an outstanding innovation in science and mathematics, technical and vocational education, or research and innovation, on a competitive basis. For instance, more than 33.2 million ETB was spent in 2015 to finance 11 selected research projects to encourage research and innovation activities. The innovation awards have three major categories, namely an innovative institution award, an innovative individual award and a female innovator award (MoST, 2015). Furthermore, the Ministry formulated a directive by which innovative ideas, processes and productive systems can be patented.

The National STI Policy called for an annual government allocation for STI of at least 1.5% of GDP in all sectors (UNESCO 2016). Thus far, as detailed earlier, GERD has reached just 0.6% of GDP (in 2013).

4.2.2 Higher Education Institutes

Higher education institutes in Ethiopia include public and private universities, colleges and TVET institutions. Currently, Ethiopia has 35 public universities and 59 accredited non-government universities or colleges awarding degrees (Kuriakose et al. 2016). According to Mamo et al. (2014:13), “universities are given the freedom to choose their areas of research in accordance with the country’s development priorities and their own comparative competency and academic advantages.” As of 2010/11, there were 505 TVET institutions in Ethiopia providing training aimed at enhancing skills for 371,347 enrolled learners (Ministry of Education 2011). The Ethiopian government has recognized the need for establishing a large number of TVET institutions in order to promote economic and technological development in the country. Among others, TVET institutions are expected to serve as a source of innovation through generating new technologies, replicating foreign technologies and transferring those selected to the relevant industry, thus contributing to industrial productivity and competitiveness.

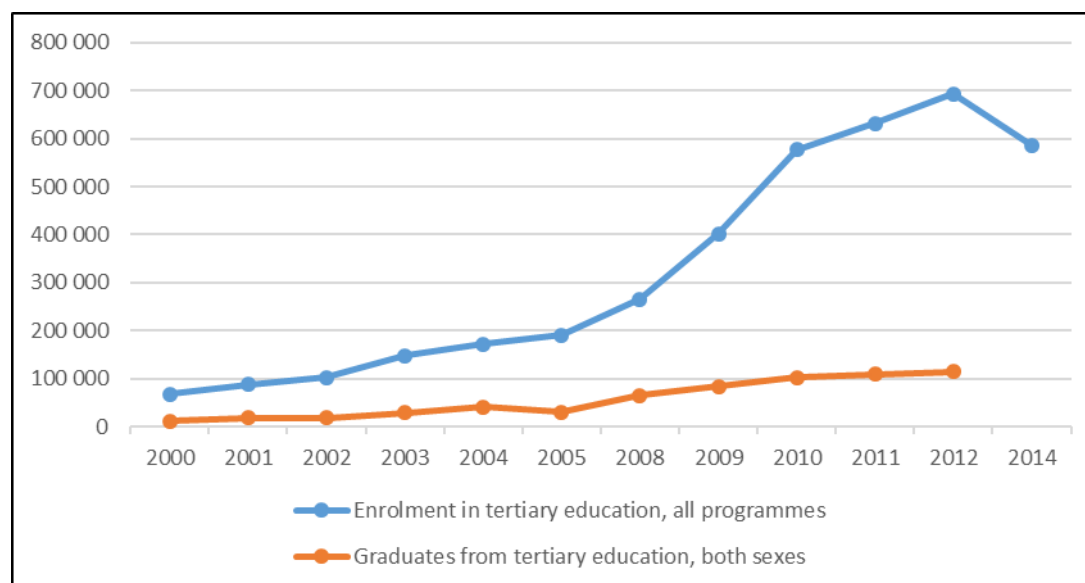
Higher education institutes were the source of just 2% of GERD in 2013. However, HEIs performed 74% of the R&D, amounting to \$502,829 in 2005 PPP (UNESCO Institute for Statistics 2016). Thus HEIs rely mostly on government funding for R&D, rather than their own internal resources.

Total enrolment in tertiary education stood at 587,015 students in 2014, having risen rapidly from 264,822 in 2008 (Figure 16). On a proportional basis, the enrolment rate for tertiary education was 605 per 100,000 people in 2014 (UNESCO 2016). Of the total number of tertiary enrolments of 693,287 in 2012, 173,517 (25%) were post-secondary non-degree students, 517,921 (74.7%) were Bachelor’s and Master’s students, and 1 849 (0.3%) were enrolled in PhD or equivalent programmes (UNESCO 2015). In 2011 there were 114,895 graduates from tertiary education, a very large increase from the 65,373 graduates in 2008 (UNESCO Institute of Statistics 2016). In the latter year, 6.4% of graduates were from science programmes, and a further 4.8% graduated from engineering, manufacturing and construction programmes (proportions for more recent years are not available). Recognizing that these proportions need to be increased in order to further develop capacity in science, innovation and technology generation and transfer, the FDRE government’s 70/30 strategy framework decrees that 70% of students joining higher education have to be placed in engineering and technology courses (Ministry of Education, 2012).

Under the University Capacity Building Program, the government has supported the establishment of Institutes of Technology (IoTs), either as new bodies or by converting existing Engineering and Technology Faculties to IoTs (Kuriakose et al. 2016). These IoTs function as relatively autonomous units within university structures, having flexibility in their budgets and programmes. Technology Transfer Offices (TTOs) have been formed within IoTs in order to lead direct connections with industry role-players. At Bahir Dar University there is an Institute of Textile and Fashion Technology, which educates specialized professionals in the area of textile, garment and fashion design (Kuriakose et al. 2016). Other than this, there are no universities offering programmes that particularly target the textile, leather or cement industries. Most of the higher education institutions in Ethiopia provide a general education, rather than sector-specific training. Moreover, the agenda of greening industry in particular and the green economy strategy in general has not been mainstreamed into education and training in Ethiopia as yet.

Two new initiatives have been introduced to strengthen the direct linkages and flow of knowledge and technology between universities and industry (Kuriakose et al. 2016). The first is a technology business incubation centre at Addis Ababa University, which was launched in 2012. The second is the planned establishment of a Research Park by Adama Science and Technology University, with assistance from German partners, namely University of Leipzig and Conoscope GmbH.

Figure 16: Tertiary education enrolments and graduates

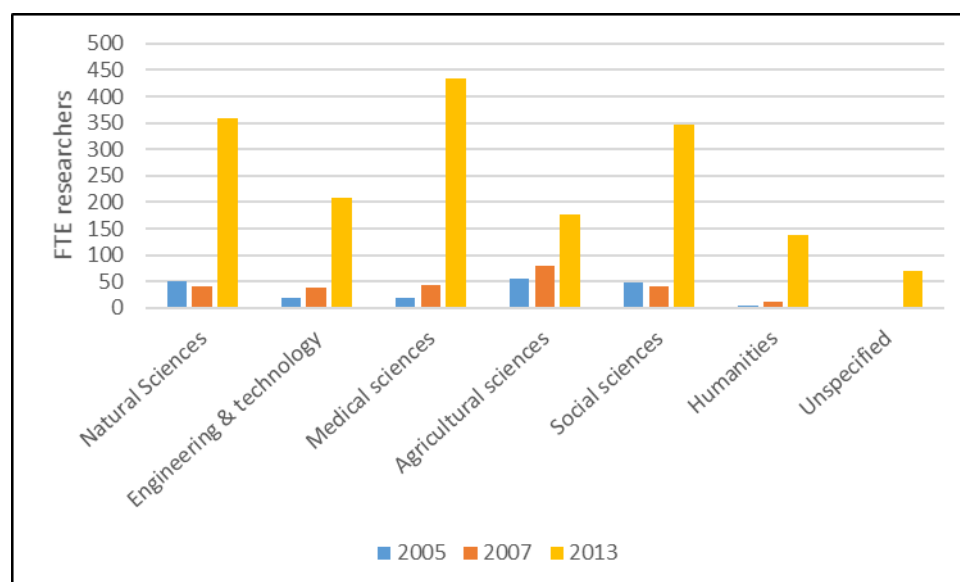


Source: UNESCO Institute of Statistics (2016)

Note: The number of tertiary graduates was missing for 2009, and therefore a linear interpolation was performed. Data were not available for either series for 2006 and 2007.

In 2013 there were 2,800 R&D personnel (FTE) in HEIs, up from 224 in 2005 (UNESCO Institute of Statistics 2016). Of these, 1 731 were researchers. Figure 17 shows the breakdown of these researchers by field. In 2013, there were 360 researchers (21% of the total) in the natural sciences and 208 (12%) in engineering and technology.

Figure 17: Higher education researchers (FTE) by field



Source: UNESCO Institute of Statistics (2016)

With the very rapid expansion of the HEI sector, several challenges have emerged (Kuriakose et al. 2016). University and research infrastructure, including buildings, classrooms and laboratories, has not grown quickly enough to accommodate the rapid response student enrolments. In addition,

there is a severe lack of suitably qualified and experienced academic staff, especially at new public universities. This is compounded by weak incentives (e.g. low salaries) for qualified persons to enter academia. There is also a lack of incentives for academics to cooperate with industry and focus their research on the needs of industry (Kuriakose et al. 2016).

4.2.3 Public Research Institutions

According to a survey conducted by STIC (2014), Ethiopia had 47 federal and regional agricultural research institutions, 20 governmental agencies and 8 health research institutions in 2013. Among these are some well-established, large PRIs. The Ethiopian Institute of Agricultural Research (EIAR) is one of the largest PRIs in Ethiopia, and includes 16 Research Centres and over 40 research laboratories distributed across the country (Mamo et al. 2014; Kuriakose et al. 2016). The Ethiopian Public Health Institute (EPHI) is a governmental research establishment involved in research activities in health, indigenous medicinal plants and nutrition (Mamo et al. 2014).

The Ethiopian Development Research Institute (EDRI) is a semi-autonomous research think tank involved in economic research and policy analysis, bridging research and policy, capacity-building, knowledge dissemination and consultancy. Environment related research has been a tradition at EDRI, since it started to host the Environment for Development initiative (EfD) Ethiopia chapter around 2005/06. The Ethiopian hub of EfD was transformed into the Environment and Climate Research Centre (ECRC) in 2015. ECRC/EDRU aims to support green and climate-resilient development in Ethiopia as a knowledge hub. ECRC's core functions include undertaking policy oriented research on the economics of climate and environment in Ethiopia, conducting real time impact evaluation of CRGE's implementation process, and serve as an interaction hub for research and policy.¹⁰ The Centre has identified six thematic areas of research that include agriculture, water, energy, forestry, urban and industry.

The Ethiopian Environment and Forest Research Institute (EEFRI) was established under the ME FCC in December 2014, with a mandate to undertake research into agroforestry, plantations, forest product utilisation and protection, climate science and environmental pollution management.¹¹ EEFRI has its own laboratory for assessing water quality and to enforce effluent standards.

Unfortunately, the UNESCO Institute for Statistics database does not have PRIs as a separate category for its data on researchers and GERD. Nor are there data available on the number of publications and citations per PRI or the number of patent applications and patents granted (also field/category if available).

4.2.4 Non-government organisations

As noted earlier, the private non-profit sector accounted for only 0.2% of GERD in 2013 (STIC 2014), and this sector is therefore of limited importance within Ethiopia's NSI. However, one prominent organisation is the Horn of Africa Regional Environment Centre and Network (HoAREC), a non-government research institution and network that is financed entirely by external donor funding.¹² It has more than 40 members in six East African countries, including universities from the major cities in the region (including Addis Ababa, Nairobi, Juba and Khartoum). HoAREC deals primarily with issues of sustainability, resilience and governance. The principal aims are to support government initiatives, including green growth, and to support private sector actors on how to green their operations. The main focus is on land use planning, especially in the areas of agriculture, tourism and conservation.

¹⁰ Source: <http://www.efdinitiative.org/ethiopia/about> accessed 30 Sep., 2016

¹¹ See www.eefri.org.

¹² The information about HoAREC in this section is based on an interview with a senior executive within the organisation.

HoAREC has contributed in various ways to national and regional systems of innovation in Ethiopia, especially with regard to green innovation, although not specifically within the cement, leather and textiles industries. First, HoAREC provided support for the development of the CRGE strategy, working with the former Environmental Protection Agency (EPA). Second, HoAREC has been facilitating networking and knowledge transfers among institutions, including national government ministries, city-level local government, universities and private sector firms. Third, HoAREC has been working extensively at the city level to promote greening and sound environmental management, e.g. in the design and implementation of waste management strategies and especially a new landfill in Addis Ababa. In collaboration with government and university partners, HoAREC also assisted in the development of a Centre of Excellence on sustainable landfill management, which serves the African continent. Fourth, HoAREC has been active in building institutional capacity that contributes to the green economy agenda. Specifically, it has participated in three projects funded by the UK Department for International Development (DFID) to establish the following institutions: the National Academy of Science; the Centre for Certification and Monitoring (based at the University of Addis Ababa); and the Climate Innovation Centre (CIC). Fifth, HoAREC has engaged proactively with certain private sector firms in order to assist them in implementing green technologies and processes. For example, the Centre worked with the largest firm in the local Ethiopian flower industry (which has approximately 80% market share) to implement a system of biological waste management through the creation of artificial wetlands, and to eliminate the use of pesticides by switching to biological control mechanisms. As a result, the firm was able to obtain environmental certification that helped it secure markets in Europe.

The Ethiopian Academy of Sciences (EAS), which was established in 2010, is another non-governmental organization that promotes science and technology in Ethiopia. According to the EAS brochure, the aim of the Academy is to advance the development of all the sciences, including the natural sciences, mathematics, the health sciences, agricultural sciences, engineering, social sciences and humanities, fine arts and letters. Its engagements are mainly concerned with organizing conferences and workshops on significant national issues, awarding prizes in recognition of excellence and publishing reports in its own journal as well as other periodicals and books.

4.2.5 Financial organisations

Ethiopia's financial system comprises 19 banks, 16 of which are privately owned (Zerihun et al. 2015). "Access to financial services has been improving and the total number of bank branches reached 2,208 in 2014 (about 34% of which are located in Addis Ababa), bringing the ratio of bank branches to population from 49,675 to 39,834" (Zerihun et al. 2015:9). Private banks account for 54% of the banking sector's total capital of 25.6 billion ETB (USD1.28 billion), while the largest state-owned bank, the Commercial Bank of Ethiopia, accounts for 34.2%. Although Ethiopia's banking sector is stable and on solid footing, "the financial sector remains shallow with a limited range of services" (Zerihun et al. 2015:9). Ethiopia ranked 120th out of 144 countries in financial market development in the 2014/15 *Global Competitiveness Report*, scoring 3.3 out of 10. Ethiopia also performed poorly in terms of access to credit, ranking 165th out of 189 countries in the *Doing Business 2015* survey (World Bank 2014).

4.2.6 Industry

The innovation actors in the industry sector obviously include small, medium and large scale enterprises. GERD performed by the business sector (or business expenditure on R&D, BERD) amounted to a paltry \$7 957 (2005 PPP dollars) in 2013, down from \$31 439 in 2010 (UNESCO Institute for Statistics 2016).¹³ This represented 1.2% of total GERD in 2013 (15.5% in 2010). The

¹³ Neither UNESCO Institute for Statistics (2016) nor STIC (2014) specifies whether the business sector expenditure on R&D (BERD) is limited to privately owned businesses only, or includes state-owned companies.

Ethiopian Innovation Survey and the Technology Capabilities Survey both found that innovation cooperation arrangements between firms and other actors within the NSI are inadequate (STIC 2015a, 2015b).

4.2.7 Support organisations

The main support organisations are various sector development institutes. For the purposes of this study, the most relevant support organisations are those pertaining to the three focus sectors, namely the Chemical and Construction Inputs Industry Development Institute (CCIIDI), the Leather Industry Development Institute (LIDI) and the Textile Industry Development Institute (TIDI). There are also Development Institutes for the Food, Beverage and Pharmaceutical Industry, the Metal Industry, and the Meat and Dairy Industry. All of the institutes report to the Ministry of Industry.

TIDI's stated mission is "enabling the Ethiopian textile industry competency in the global market by providing sustained investment promotion, consultancy, training study and research, laboratory and marketing support and services" (TIDI 2012). The institute's objective is "to facilitate the development and transfer of textile and apparel industries' technologies and enable the industries to become competitive and beget rapid development" (TIDI 2012). The responsibilities include: strategy formulation for industry development; provision of training on technology, marketing and management; data collection and dissemination; project and investment advice, including feasibility studies; consultancy services concerning production process; cooperation with government and private institutions; undertaking benchmarking studies; cooperation with universities on product and human resource development, and conduct joint research.

The objectives of the LIDI are "to facilitate the development and transfer of leather and leather product industries' technologies as well as enable the industries become competitive and beget rapid development" (LIDI 2013). LIDI's responsibilities mirror those of TIDI.

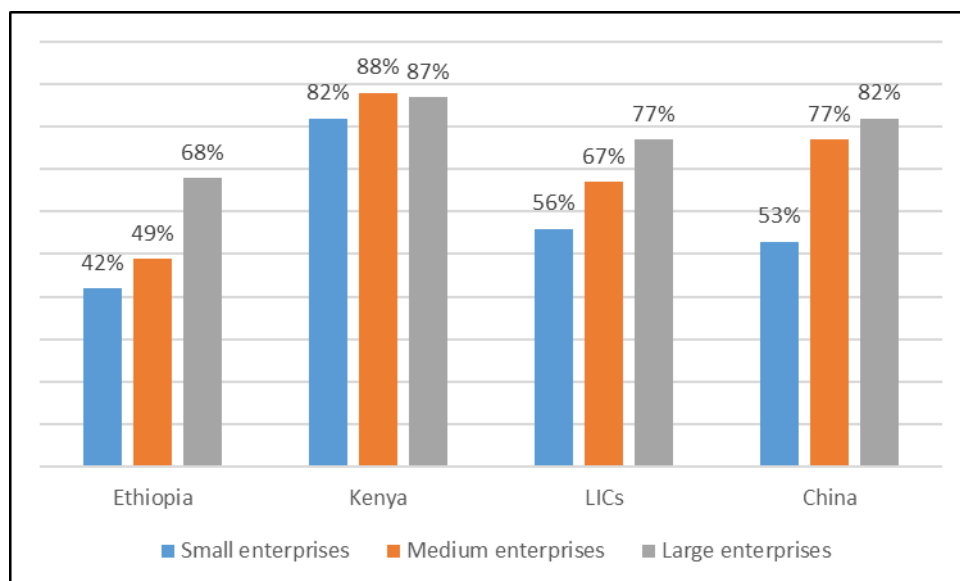
4.3 Performance of the NSI

The overall performance of Ethiopia's NSI can be assessed empirically on the basis of a recent national innovation survey and international comparative measures. In 2015 the Science and Technology Information Centre (STIC) based in Addis Ababa conducted a national innovation survey based on a sample of 1,200 small, medium and large-scale firms across various economic sectors (STIC 2015a). The main findings are as follows. Overall, 60% of firms reported that they had undertaken innovations in the three-year period 2012-2014. Non-technological innovation (56.4%) was more widespread than technological innovation. Of the four types of innovation, marketing innovation was the most commonly implemented innovation (49.5%), while product innovation, undertaken by 19.5% of firms, was the least common. Some 34.9% of enterprises undertook organizational innovation, and 24.6% of enterprises reportedly engaged in process innovation. Innovation was influenced by firm size, with 77% of large enterprises innovating, compared to 66% of medium and 57% of small enterprises. The highest sectoral rate of innovation took place within manufacturing (68%). The major driver of innovation was the desire to enhance product quality, and the most common mechanism used by firms was the acquisition of machinery and software, as opposed to performing R&D.

Compared to other countries, Ethiopia's innovation performance is poor. According to data from the World Bank Enterprise Surveys, 68% of large firms in Ethiopia reported product or process innovation, compared to 87% in Kenya, 77% on average in LICs, and 82% in China (Figure 18). The

proportion of innovative medium and small enterprises is also lower in Ethiopia compared to the other countries.

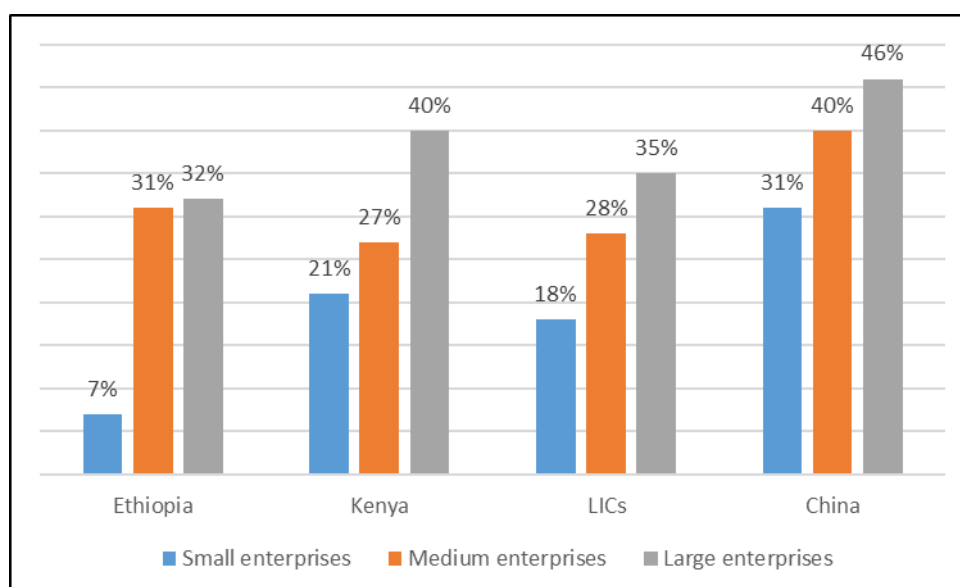
Figure 18: Percentage of firms engaging in product or process innovation in selected countries



Source: Adapted from Kuriakose et al. (2015), Figure A1.

Similarly, the percentage of Ethiopian enterprises spending money on R&D is generally lower than that in comparator countries (Figure 19). An exception is medium sized enterprises, a greater share of which spend money on R&D than in Kenya and LICs. However, given the extremely low levels of R&D spending recorded for private enterprises, these comparisons should not be overstated.

Figure 19: Percentage of firms spending money on research and development in selected countries



Source: Adapted from Kuriakose et al. (2015), Figure A1.

Ethiopia's low level of innovation performance hinders its economy's competitiveness. Ethiopia ranked 109th out of 140 countries on the World Economic Forum's Global Competitiveness Index (GCI) in 2015-16, with a score of 3.7 out of 7.0 (WEF 2015). On the innovation pillar, Ethiopia was

ranked 81st out of 140 nations. Although the composite score of innovation indicators rose by 0.5 points over the past six years (from 2.7 in 2009-10 to 3.2 in 2015-16), Ethiopia has much scope for improvement in its innovation performance. The best areas of comparative innovation performance were in ‘company spending on R&D’ (49th) and ‘government procurement of advanced technology products (49th)’ (Table 4). Ethiopia ranked low on ‘capacity for innovation’ (112th) and the number of patent applications per inhabitant (117th).

Table 4: Innovation indicators from the Global Competitiveness Index 2015-16

Indicator	Score (ex 7)	Rank (ex 140)
Capacity for innovation	3.5	112
Quality of scientific research institutions	3.6	79
Company spending on R&D	3.5	49
University-industry collaboration in R&D	3.5	78
Gov’t procurement of advanced tech products	3.6	49
Availability of scientists and engineers	3.8	81
PCT patents, applications per million population*	0.0	117

Source: WEF (2015) Global Competitiveness Report

*Units as described.

4.4 Functioning of the NSI

As mentioned earlier, how well an innovation system functions depends to a significant extent on its structure, i.e. which elements exist and how sound their capacity is. This section builds on the foregoing structural analysis and examines the functioning of Ethiopia’s NSI according to the dimensions described in section 2.2.3. Considering that the focus in this section is on the NSI rather than TSIs,¹⁴ as well as the limited availability of quantitative and qualitative data in the Ethiopian context, the set of functions is adapted slightly for present purposes. In particular, the data do not support an analysis of the entrepreneurial activity/experimentation function, and only limited discussion of ‘influence on the direction of search’ and ‘legitimation’. In addition, following Botta et al. (2015), we split the ‘resource mobilisation’ function into (i) access to finance and (ii) skill development, both of which are particularly relevant in the case of an early-stage developing country such as Ethiopia.

4.4.1 Knowledge development and diffusion

One measure of a country’s general performance in knowledge creation is the number of scientific publications produced. In this respect, Ethiopia has shown dramatic improvement in recent years, trebling its output from 281 publications in 2005 to 865 in 2014 (UNESCO 2015). In absolute terms, Ethiopia is performing well relative to other East and Central Africa (ECA) countries, taking second place in the publication rankings behind Kenya in 2014. On a per capita basis, however, Ethiopia’s publication ratio of just nine publications per million inhabitants (compared to 30 in Kenya and 80 in Gabon) indicates that the growth in Ethiopia is coming off a very low base. The share of foreign co-authors in Ethiopia’s publications between 2008-2014 was 71%, the lowest ratio amongst the top seven most prolific ECA countries (UNESCO 2015). The most external collaborators were in the USA, UK, Germany, India and Belgium, respectively. According to the SCImago Journal & Country Rank (2016) database, which measures research output and citations, Ethiopia ranks 78th out of 239

¹⁴ As mentioned earlier, Hekkert et al. (2007) and Bergek et al. (2008) developed their frameworks for analysis of innovation functions in TSIs rather than NSIs.

countries; Kenya ranks 67th, Tanzania 82nd, Uganda 84th, and Cameroon 85th. However, merely producing publications is not enough to guarantee a positive impact on innovation; evidence suggests that “a critical misalignment exists between the research outputs from academic institutions and the technology needs of industry” (Kuriakose et al. 2016:52).

Another measure of knowledge creation is the number of patents generated. In the period 2010-2015, Ethiopia did not register any design, plant or reissue patents with the United States Patent and Trademark Office (USPTO), which serves as a proxy register for global patents (UNESCO 2015). To put this in perspective, the only two countries in the East and Central Africa region obtained patents from the USPTO during this period, namely Cameroon (which registered 11 utility patents) and Kenya (with seven utility patents) (UNESCO 2015). Clearly, the capacity of Ethiopia’s NSI to generate new inventions of international importance is very limited. However, it must be re-emphasized that innovation does not require new inventions; rather, it most often involves the adoption of innovations and new technologies that have been developed in other countries. Given Ethiopia’s early stage of industrial development, it is not surprising that the country is far away from the technological frontier.

However, the results of the national innovation survey reveal a certain level of IPR activity in Ethiopia. Specifically, during the survey period (2012-2014), 17% of enterprises reported registering a trademark, 3.1% registered an industrial design, and 4.1% secured a patent within Ethiopia; only 0.6% of enterprises applied for a patent outside Ethiopia (STIC 2015a). Table 5 shows the number of IP applications filed and granted by the Intellectual Property Office between 2010 and 2014. The general trend has been in increase in the number of applications annually (including the total), although not in every case (e.g. the number of patent applications has fluctuated).

Table 5: Intellectual property applications filed and granted by the IP office, 2010-2014

IP activity	2010/11		2011/12		2012/13		2013/14		Total	
	Applications	Grants	Applications	Grants	Applications	Grants	Applications	Grants	Applications	Grants
Patent	29	0	34	16	20	6	22	4	105	26
Utility Model	163	30	172	95	206	56	183	57	724	238
Patent of introduction	75	11	83	2	93	13	114	9	365	35
Industrial design	160	35	231	51	231	39	165	30	787	155
Trademark	1166	795	1325	871	1435	935	1608	738	5534	3339
Total	1593	871	1845	1035	1985	1049	2092	838	7515	3793

Source: STIC (2014), Table 5.4, p.162.

The sharing of knowledge and information among the various actors is a vital aspect of the innovation system. Notably, the Ethiopian Innovation Survey found that “linkage mechanisms in terms of information exchange and collaboration for innovation was (sic) minimal”, and in particular, “collaboration among firms, universities and government research institutes was very weak” (STIC 2015a:xx). The most common source of information for innovative enterprises was within the enterprise or enterprise group (65%), followed by information from clients or customers (55%). Only 6.6% of firms reported receiving information from government and public research institutes, 5% from universities and colleges, and 4% from professional and industry associations. About 30% of enterprises reported collaborative partnerships for innovation activities, the most common partner

being competitors (62%), whereas only 15% of firms reported partnerships with government and public research institutes. These statistics clearly show that the functioning of Ethiopia's NSI in terms of the interactions between key actors has severe limitations that need to be addressed.

A survey of R&D capabilities among firms in four manufacturing sectors (cement, metals, textiles and leather) conducted in 2015 by the Science Technology and Innovation Centre (STIC 2015b) found that with the exception of the cement industry, firms demonstrated weak R&D capacity. The underlying reasons included a lack of skilled labour, inadequate infrastructure and insufficient cooperation with external partners such as research institutions.

4.4.2 Influence on the direction of search

A detailed examination of this function is not possible at the level of the NSI. However, in general terms one can identify several broad factors that are encouraging firms and other organisations to join Ethiopia's NSI and explore new technologies. Firstly, the rapid economic growth over the past decade, together with the government's commitment to continuing growth and industrialisation, create a general belief that the country has substantial growth potential. Factor prices have been somewhat volatile in recent years, but the expectation of cheap electricity generated from hydropower resources becoming available in the near future is a definite incentive. The search by firms for greener technologies is expected to be positively influenced by the government's commitment to implementing the CRGE.¹⁵ Demand incentives are being boosted by, for example, increasing international trade and the state-driven infrastructure building programme.

4.4.3 Market formation and access

The national innovation survey of 2015 revealed that regional markets within the country were the most common type of market for both innovative and non-innovative enterprises; "63.6% of innovative and 63.5% of non-innovative enterprises sold their goods and services only in some provinces of Ethiopia (STIC 2015a:18). By contrast, 36.4 % of innovative enterprises and 36.5 % of non-innovative enterprises had access to national markets for their products and services. Innovative firms were found to have better access to international markets than non-innovative firms, but the percentages of all firms with access to international markets were very low: rest of Africa (2.4%); Europe (2%); USA (1.5%); Asia (1.9%) and other countries (1.2%) (STIC 2015a).

The higher rates of access to local and national markets in Ethiopia does not necessarily imply that these markets are well developed and free of market failures and barriers. One barrier is excessive industry concentration, which makes it difficult for small firms to compete and to afford innovation activities. This is illustrated in the cement industry, with four of the 11 firms initially identified for the survey having either shut down operations or being in the process of changing ownership (e.g. being bought out by a larger competitor) as of April 2016. More broadly, in response to the national innovation survey questions about factors hindering innovation, 21% of firms stated that their market was dominated by established enterprises (STIC 2015a). A further 12% of firms reported that they faced uncertain demand for innovative goods and services (implying a lack of developed markets) and 13% of enterprises said that innovation is easy to imitate – implying a lack of secure intellectual property rights. On the other hand, a much smaller percentage (23%) of firms in Ethiopia's formal sector report facing competition from informal sector firms than is the case in SSA (66%) and LICs (59%) (World Bank 2016b).

¹⁵ Evidence for this is discussed in section 5 in the case study sectors.

Another market failure is information asymmetries: in the Ethiopian Innovation Survey, 19% of enterprises cited lack of information on technology as a factor hindering innovation (STIC 2015a). The public good nature of innovation and R&D is another market failure, and this is being addressed to some extent through government-financed expenditure on R&D. Finally, the lack of pricing of environmental 'bads' (pollution, emissions and waste) constitutes a market failure that deters the adoption of 'green' innovations.

4.4.4 Access to finance

As mentioned in section 4.1, the GERD/GDP ratio has risen to 0.61, and as a result of the rapid GDP growth in recent years the absolute amount of expenditure on R&D has therefore risen dramatically, from \$90 million in 2005 to \$679 million in 2013 (2005 PPP dollars). The sources of funding for GERD were shown in Figure 10 above. As mentioned earlier, the National Science, Technology and Innovation Policy called for an annual government allocation for STI of at least 1.5% of GDP in all sectors (UNESCO 2016). It also advocated the formation of a centralized innovation fund for R&D, which was to be financed through a contribution of 1% of the yearly profits generated in all productive and service sectors. However, there have been delays in the implementation of these two funding initiatives. In the 2015 National Innovation Survey, about one-fifth of innovation active enterprises reported receiving financial support for innovation (STIC 2015a). Of these, 66% received funding from regional, zonal or local administrators, 27% from national funding agencies, 19% from national government, 14% from monitoring government institutions, and 3.4% from foreign government or public sources. According to the World Bank's recent report, "existing [government] programs serve only a fraction of the enormous demand from innovative enterprises for access to financial services" (Kuriakose et al. 2016:66).

The greatest inhibitors of innovation identified by firms that participated in the national innovation survey were a lack of funds available within the enterprise or group (reported by 35% of firms) and high costs of innovation (34% of firms) (STIC 2015a). These factors were especially acute in the case of manufacturing sector firms that were active innovators. In the year 2014, innovation active enterprises allocated 8.8% of their turnover to innovation activities (STIC 2015a).

The WBES 2015 also highlights the difficulties that Ethiopian firms experience in accessing finance. For example, firms relied on internal financing for 83% of purchases of fixed capital, compared to 8% financed by banks, 1% financed by equity, and a negligible percentage financed by supplier credit (8% was derived from other sources) (World Bank 2016b). The reliance on internal financing was higher than on average in SSA (76%) and LICs (78%). While the vast majority of firms reported having checking/savings accounts at banks (91% of small firms, 95% of medium firms and 98% of large firms), access to credit (i.e. firms with bank loans) was much more limited, especially amongst small (30%) and medium firms (28%); 68% of large firms had bank loans (World Bank 2016b). The prime lending rate in Ethiopia was reported as 11.5% in December 2015 (CIA 2016), which is moderate compared to rates in many other LICs. Tellingly, lack of access to finance emerged as by far the most common business environment obstacle identified by managers in the WBES; 40% ranked this as the top obstacle amongst 15 obstacles (World Bank 2016b). Access to finance was identified as the major obstacle by small, medium and large firms alike, although was especially problematic in smaller firms.

Business incubation is a recent phenomenon and in its infancy in Ethiopia. According to some studies, there have been five Business Incubation Centres (BIS) owned by the Information Technology and Government owned Universities (MCIT) located in various regions.¹⁶ However, the only operational

¹⁶ Source: <http://etd.aau.edu.et/bitstream/123456789/9872/1/Konjit%20Desalegn.pdf>

BIC currently is the one in Bahir Dar, in the region of Amhara. Some universities such as Addis Ababa University, Hawassa University and Bahir Dar University have also established their own BIC, while other universities are in the process of doing so. There are also a few privately owned incubation centres such as X-Hub and ICE Addis.

The Climate Innovation Centre (ECIC) is another BIC relevant to the theme of green innovation, which is supported by the World Bank's infoDev programme and a multi donor trust fund (Kuriakose et al. 2016). ECIC offers various kinds of support to entrepreneurial small and medium enterprises operating in the clean tech sector. This includes the provision of start-up grants of up to US\$50,000 and investment facilitation for more established enterprises.

4.4.5 Skill development

The recent rapid growth of educational enrolments documented above, especially in tertiary education, indicates that the Ethiopian NSI is accelerating the production of skills that are needed in the economy. However, the types of qualifications and skills that are produced ideally need to be aligned with the demand for skills from enterprises. To this end, the Ethiopian government has recently been prioritising science, engineering and technology-related higher education programmes. One example is "the National Priority Technology Capability Programmes launched in 2010 in the areas of agricultural productivity improvement, industrial productivity and quality programmes, biotechnology, energy, construction and material technologies, electronics and microelectronics, ICTs, telecommunications and water technology" (UNESCO 2015:521). In addition, the government decided in 2014 to locate universities specializing in science and technology and which have connections with industry under the purview of the Ministry of Science and Technology, the aim being to bolster innovation in academia and catalyse technology-driven firms (UNESCO 2015). In cooperation with its German counterparts, the Ethiopian government initiated an Engineering Capacity-Building Programme in 2005, which is jointly financed and implemented by the two countries (UNESCO 2015). Several sectors have been singled out for special attention, including textiles, construction (and by implication, cement), leather and agro-processing.

The national innovation survey of 2015 found that one quarter of enterprises reported that none of their employees held either a diploma or a university degree (STIC 2015a). Just over half (54%) of firms reported that up between 1-24% of employees had tertiary qualifications, and 14% had between 25-49% of employees with degrees or diplomas. Only 7% of enterprises reported having more than half of their employees with tertiary qualifications. Nearly a quarter of firms (24%) reported that a lack of qualified personnel was a significant hindrance to innovation.

The WBES 2015 found that 21% of Ethiopian firms offer formal training to their employees, compared with an averages of 31% for Sub-Saharan Africa and 33% for low income countries (World Bank 2016b). Within manufacturing sector firms that offered training, 27% of workers received training, compared to 45% on average in Sub-Saharan Africa and 46% in low income countries (World Bank 2016b).

4.4.6 Creation of legitimacy

Analysis of the process of legitimation relating to particular technologies is not tractable within an assessment of the national system of innovation. However, the key aspect of legitimation with respect to Ethiopia's NSI is the government's commitment to and support of innovation in general, and green innovation in particular. The earlier analysis (section 4.2.1) shows that the Federal Government has a high level of commitment both to the national STI policy and to the CRGE. However, what appears to be lacking is an equally strong commitment to green innovation

specifically, which would link the STI Policy more strongly with the CRGE. Indeed, innovation has been recognised at a high level of government as a critical gap in the implementation of the CRGE.¹⁷ While innovation is under consideration, it is acknowledged within the government that it has not yet been adequately addressed and that there is a need to build confidence and capacity, which will take time.

5 Analysis of Innovation in Selected Ethiopian Manufacturing Sectors

This section provides details about the sectoral systems of innovation based on interviews with key actors, and investigates the extent, nature and drivers of innovation activities within the cement, leather and textiles sectors based on a survey of firms in these manufacturing sectors (see section 3 for details on the data collection process).¹⁸

5.1 Sectoral Systems of Innovation and the Greening Agenda¹⁹

Several national ministries and agencies are important actors in the sectoral innovation systems, including the Ministry of Environment, Forestry and Climate Change (MEFCC), Ministry of Industry (Mol), Ministry of Science and Technology (MoST), the Ministry of Finance and Economic Cooperation (MoFEC), the Ethiopian Investment Agency (EIA), the Ethiopian Quality and Standards Agency (EQSA), and finance institutions.

The MEFCC plays a critical role in the implementation of environmental policy in general and the CRGE in particular. The MEFCC is therefore an important actor in both the national and sectoral systems of innovation, especially with regard to providing information and stimulus (by way of regulatory enforcement) for green innovation. For example, the MEFCC has introduced several national proclamations and regulations to control pollution emanating from various industrial sources, including an EIA proclamation, a solid waste control proclamation, a pollution control proclamation, and industrial pollution control regulations. The MEFCC provides technical support both to strengthen regional agencies that enforce environmental regulations and to assist other stakeholders (particularly enterprises) to comply with environmental standards and regulations.

Although the Mol is active in the national and sectoral systems of innovation, its involvement in supporting green innovation specifically appears to be somewhat limited. While the Mol has regular communications with MEFCC and MoFEC, for example in quarterly forum meetings involving the six main line ministries involved in implementing the CRGE, innovation is not a particular focus within these forums. The Mol also holds irregular meetings with other ministries, such as Education. There are some communications between the Mol and the MoST, but these are not very regular. The Mol gives support and direction to the various Industry Development Institutes, but responsibility for implementation of the CRGE strategy and for liaising with universities is delegated to the institutes. All of the industry development institutes are part of the national STI programme, which includes guidelines on how the institutes must collaborate with universities and firms. The institutes have facilitated some memorandums of agreement between universities and firms, but the institutes have limited direct interaction with the MoST.

¹⁷ Source: confidential interview with a high-ranking government official.

¹⁸ This survey, and the author's calculations based on the data, are the source for all tables and figures in this section, unless otherwise stated.

¹⁹ The analysis in this section is based on interviews with senior officials in the relevant ministry, institutes or associations. Names of interviewees are withheld due to confidentiality agreements.

The MoI apparently 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, as this is seen as falling under the wider remit of the MECC. The main route that the MoI uses to promote innovation is to gather information on best practices and forward recommendations to the CRGE Facility, which then dispenses funding to firms to help them to meet the targets of the CRGE strategy (especially with regard to clean energy and energy efficiency). So far, the MoI has submitted eight projects to the Facility, only three of which have been approved.

The MoI is still working to develop a sectoral policy for implementation of the CRGE strategy. The MoI's main priority is building and expanding industry, rather than protecting the environment. This could explain its limited role in fostering green innovation.

The environmental impact and performance of new entrants into the manufacturing industry in Ethiopia comes under considerable scrutiny. Investors wanting to build new manufacturing facilities have to apply for an investment licence at the Ethiopian Investment Commission (EIC). If the licence is granted, the firm approaches the regional authorities in the region in which it intends to set up operations. It then has to undertake an Environmental Impact Assessment, and submit this to the regional authority. 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.

Many new industrial investments, particularly in the leather and textile sectors and especially by foreign companies, are being channelled into industrial parks, where centralised facilities are provided to clusters of similar firms to optimise environmental performance (e.g. through the provision of clean energy and wastewater treatment plants). See Box 1 below for a description of the recently inaugurated Hawassa Eco-Park. 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 alone. In fact, it appears as if the government's primary strategy for achieving greening in the textiles and leather sectors is to direct its attention and resources towards the establishment of the industrial parks, rather than supporting (green) innovation at the individual firm level. Firms located in the industrial parks are forced to comply with environmental regulations, including Environmental Impact Assessments and implementation of effluent treatment, whereas established firms are not subject to the same level of environmental scrutiny and thus have less incentive to adopt greener processes and products. Thus at the economy-wide and sectoral level, green innovation is occurring mainly through new firms that build factories with modern equipment and technologies, and through industrial parks with centralised effluent treatment facilities.

Box 1: Hawassa Eco-Industrial Park

In Hawassa, located 275 kilometres south of Addis Ababa, Ethiopia has built an eco-industrial park, which was inaugurated in August 2016. The construction of the first phase of the Hawassa Industrial Park (130 hectares out of 300 hectares) cost USD 247 million. Recently, 38 sheds have been completed, of which five are reserved for domestic investors. The remaining 33 sheds are rented by well-known international textile and apparel companies, including PVH, Vanity Fair from the US, Arvin and Remount from India, and other big players from Sri Lanka, Indonesia, Hong Kong and China. The park is expected to generate about USD 1 billion from the exports per year and to create 60,000 productive jobs.

As an Eco-Park, Hawassa will mostly utilize renewable electricity sources (hydro-electricity) and fully implement energy and water conservation strategies including maximization of natural lightning and ventilation, fitting of energy-efficient lightbulbs, recycling of water, and solar powered LED street lights. Hawassa Industrial Park also has a world-class common effluent treatment plant (CETP) equipped with 'Zero Liquid Discharge' technology. The treatment plant has capacity to treat 11,000 cubic metres of liquid wastes per day. In addition, 30% of the delineated park area is being covered by greenery infrastructure including trees and grasses. To ensure sustainable and reliable electricity and water supply, a separate power station capable of carrying of 50 MW electricity supply from hydropower in its initial phase and growing to 200 MW in due course, as well as deep underground water wells, are being built. This will solve the electricity and water shortages reported by existing industries in Ethiopia as major challenges. In addition to power from grid, the park will produce energy from waste. For instance, Africa Bamboo, one of the companies renting sheds in the park, will produce its own electricity from bamboo biomass.

Moreover, Hawassa Park is specialized to produce high quality textile and apparel eco-products that are competitive in the world market. Therefore, the construction of the park is fitted to comply with the standards of *C-TPAT: Customs – Trade Partnership Against Terrorism* act to export manufactured products to America. In addition, the industrial sheds constructed for the textile and apparel factories are made to comply to Europe's Accord and Alliance Agreements.

At the firm level, green innovation is also necessary amongst incumbent firms that typically use older processes and equipment. Existing manufacturing facilities tend to be spread out geographically, which makes it more difficult and costly for them to deal with wastes and effluents. In some cases, existing firms (e.g. tanneries) have been encouraged to relocate to industrial parks. However, many domestic firms face a cost barrier to enter these industrial parks, as they cannot afford the rentals. Hence many such firms cannot take advantage of the opportunities for process innovations that industrial parks and their facilities make possible. 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. There is a proposal for EIAs to be required for the expansion of existing manufacturing facilities, but this has not yet been approved. Therefore, from the environmental regulatory perspective, the incentives for green innovation amongst existing firms are limited.

A key challenge of the sectoral innovation systems, highlighted in the previous section at the national level, is the lack of established links between the relevant manufacturing sector development institutes and research institutions in order to foster innovation and the diffusion of new technologies. The FDRE (2012) STI policy document recognized this challenge and proposed strategies to create effective linkages amongst relevant actors. The proposed strategies include establishing a system to integrate and synergize technology transfer issues between universities, research institutes and industry, creating a conducive environment for university academics and

students to engage in technology transfer activities in industries, creating strong links among universities, research institutes and industry addressing technology adaptation, and enabling universities to take on an advisory role for industry with regards to technology transfer. As the following subsections show, some progress has been made in strengthening institutional linkages and cooperation.

5.1.1 Cement sector innovation system

Though there is no association or union of cement producers in Ethiopia, the Chemical and Construction Inputs Industry Development Institute (CCIIDI), the Ministry of Mining, the Ethiopian Geological Survey and other stakeholders involved in cement production and the value chain are the major actors in the cement industry.

Enforcement of environmental requirements is ultimately the responsibility of the MEFCC. However, the Mol has responsibility for implementing the CRGE within industrial sectors, including cement manufacturing. The Mol oversees the activities of the CCIIDI, which is responsible for assisting the cement industry to meet the CO₂ emission reduction targets contained in the CRGE. Every new entrant into industry must meet various environmental criteria, but especially with regard to CO₂ emissions in the case of cement. An Environmental and Social Impact Analysis (E&SIA) must be undertaken before a firm can obtain a manufacturing licence.

Conforming to the STI Policy, the CCIIDI is part of a tripartite relationship with academia and industry. The CCIIDI links universities with firms within specific geographical areas, organising regular meetings or workshops involving all partners are held every three months. The CCIIDI generates research agendas, along with the firms in its constituency, and engages professors and other experts who contribute to the institute's emissions reduction programme and identify critical problems, which the universities can address by developing solutions. Research is therefore (partly) demand-led, according to the industry's problems and needs. The CCIIDI 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. This requires diversified knowledge from experts in a wide range of fields, including economists, sociologists and natural scientists (e.g. on the plant issues and chemical processes). The CCIIDI, along with other Development Institutes, therefore engages with academics from diverse fields.

The cement industry is acknowledged as having a significant impact on CO₂ emissions as the result of the calcination of raw materials and the energy used to make cement. The key mitigation effort within the cement industry involves reducing emissions from energy use, because the industry cannot at this point take action to reduce calcium carbonate inputs. There are two key process innovations for reducing energy-related emissions: improving efficiency and fuel switching. According to the CCIIDI, each firm must analyse its energy efficiency potential. For example, some firms are using hot gas emissions to capture heat for use in the industrial processes. A two-stage programme of fuel switching has been undertaken by the cement industry, with assistance from the CCIIDI. Planning began in 2010 to switch from the use of heavy fuel oil to coal, imported from South Africa; implementation took place largely in 2014/5. 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 in turn allowed firms to exploit efficiency gains by investing in new equipment. Use of heavy fuel oil was highly inefficient, so it was bad for emissions. All cement firms are now using coal.

The second stage of fuel switching will involve the partial substitution of biomass energy for coal. In Afar state, an invasive plant (*Prosopis juliflora*) is a significant problem for farmers, having invaded 1.2 million hectares by 2013, and subsequently spreading to other areas. Research conducted with the Global Climate Fund (GCF) has shown that *Prosopis* has a relatively high calorific value for biomass (estimated at approximately 4200 to 5200 calories per kilogramme (cal/kg), 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. It has been estimated that biomass energy can replace up to 40% of coal consumption without modifying the main burners in cement plants. The use of biomass is planned for six major cement producers that are located in different areas. The biomass source is centrally located within Ethiopia, and after baling is transported to cement plants up to a maximum of about 400km away. Under a Joint Implementation Mechanism programme, involving the CCIIDI, government and private industries, and supported by the government of Japan, six of the main cement producers will be converted to a biomass model. Japan will fund 50% of the conversions and will allocate 50% of the reduced GHG emissions towards its Kyoto Protocol obligations. Although the biomass programme has not yet been officially approved (MoFEC has the final say), it has been verbally confirmed. The plan is to migrate all cement firms to use biomass for 40% of their energy (with the balance being coal) over the next few years, starting in 2016/17. By 2020, CCIIDI expects most cement firms to have adopted this measure. It is estimated that this project can meet the whole CO₂ reduction commitment for the cement industry within the CRGE. In the Ethiopian context, cement producers are possibly less likely to pioneer product innovations, and as the country does not produce any coal-fired electricity, it lacks fly ash for use in alumino-silicate cement.

5.1.2 Leather sector innovation system²⁰

The main actors in the leather sector innovation system are firms operating along the leather product supply chain (including livestock producers, slaughterhouses, suppliers of hides and skins, leather processing enterprises and leather product manufacturers), along with the Leather Industry Development Institute (LIDI) and the Ethiopian Leather Industries Association (ELIA).

LIDI is responsible 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, LIDI collaborates with relevant government ministries, domestic and foreign universities and research institutes, and local firms in the leather sector. LIDI holds regular meetings with MEFCC and the Ministry of Industry. LIDI is collaborating with universities to build capacity in the leather sector, based on the requirements of tanneries. In collaboration with Addis Ababa University (AAU), LIDI established both first and second degree programmes in leather processing technology and is striving to ensure 100 percent work placement for the graduates. Moreover, LIDI provides incentives for students to enrol in the department and rewards those who attain good grade point averages. LIDI also collaborates with the Addis Ababa Science and Technology University (AASTU) in delivering a course in Footwear Engineering. Bahir Dar University also offers a teaching and research programme in leather and garment technologies. LIDI has a partnership with a university in India, under which several students are sent to India to undertake Master's and PhD studies. LIDI also has links with universities and research organizations in the UK. However, LIDI is mindful of avoiding saturation of the industry with graduates.

The Ethiopian Leather Industries Association (ELIA) represents tanneries as well as enterprises manufacturing leather products such as footwear and gloves. ELIA provides services such as market

²⁰ The main sources of the information in this section are interviews with key officials in LIDI and ELIA.

information, promotion of products in international markets, and policy advocacy concerning the challenges and interests facing its members. For example, ELIA distributes marketing information to its members from an international marketing information office based in Geneva, organises stalls at international trade fairs, and organises the All Africa Leather Fair in Addis Ababa (which has its 8th round in 2016). Thus ELIA assists in the exchange of information relevant to innovation. ELIA recognizes that one of its significant challenges is to help improve the environmental performance of constituent firms, especially tanneries. The Association states that as yet green certification for leather products has not yet been secured, and that this will require concerted efforts from other stakeholders including government ministries and export promotion agencies. While FDI has been attracted from seven countries into the leather sector, technology transfers are somewhat limited because such ventures remain fully-owned by foreign interests.

Impetus to undertake green innovations emanates from both external and internal sources. There is pressure to innovate from certain international buyers, which require compliance with environmental standards and social issues including child labour 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.

Recognising the importance of clustering and the construction of common effluent treatment facilities for greening the leather sector, especially tanneries, the government is encouraging and supporting the private sector to build their own industrial parks. In response to this, some private industrial groups are building facilities, such as the George Shoe Industry Zone in Mojo (which aims to employ 250,000 workers) and the Huajan Industry Zone. One of the main greening initiatives being promoted by the government and LIDI is a plan to establish a 'leather city' in Modjo with a common effluent treatment plant so as to reduce pollution from tanneries. 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, although precise roles and contributions have yet to be determined. At this stage, according to ELIA, tanneries will have to relocate to Modjo at their own cost, but they have the alternative of building their own waste treatment plants. However, LIDI reports that promising negotiations on funding are underway with the European Investment Bank.

Green innovation in the leather industry faces a number of challenges. One is the mindset of private sector businesses, which need to understand that they are responsible for their environment and the sustainability of their operations. Owners sometimes fail to comply with environmental standards and focus only on generating profits. Most private businesses consider cleaner production innovations as an expense and ignore future benefits pertaining to green industrialization. Another challenge is the lack of strong market incentives for environmental protection, particularly for the establishment of effluent treatment facilities. There are no separate incentives for companies that develop their own effluent treatment plants. Established enterprises can be especially reluctant to engage in innovation to comply with environmental regulations and require more capital to implement environmental innovations. According to ELIA, enterprises face financial constraints as banks are reluctant to lend money for greening activities, forcing firms to use their own resources. However, some firms are benefitting from the Ethiopian Competitive Facility (ECF), a fund

administered by the UK Department for International Development to support activities such as ISO standardization and improved environmental performance.

Newer firms, particularly those resulting from FDI, are taking the lead in terms of environmental compliance (see earlier discussion about the Ethiopian Investment Commission). LIDI is working closely with foreign investors to implement environmental standards in new investments. Several specific process innovations are being promoted by LIDI in order to implement cleaner production technologies, especially at tanneries. These include methods to decrease salt formation (e.g. 100% waterless chrome effluent), decrease Total Dissolved Solids (TDS), remove pickling and salt processes, and reduce Chemical Oxygen Demand and Biochemical Oxygen Demand from liming. LIDI's environmental technology department is providing training to industries on effluent treatment, handling and recovery (recycling). LIDI plays a pivotal role in the implementation of innovations designed to achieve the CRGE emission reduction goals in the leather industry. For example, LIDI supports firms to use less emission intensive technologies and helps firms to monitor their activities. The institute has an accredited environmental laboratory for testing and a model treatment facility.

5.1.3 Textiles sector innovation system

In the textiles industry, the main actors include the suppliers of inputs for cotton production, cotton plantation farms, various industries involved in the processing and production of textile products, the Textile Industry Development Institute (TIDI), the Association of Textile and Textile Products Industries, the Ethiopian Textile and Garment Manufacturers Association (ETGAMA), and actors involved in cotton and other raw materials supply and value chains.

ETGAMA has 85 member firms and represents their interests in capacity building, creating market linkages, investment promotion and policy advocacy. ETGAMA works closely with the Ethiopian Textile Industry Development Institute (TIDI), which was established under the Ministry of Industry to support the sector's development. For example, the association collaborates with TIDI in the provision of training in order to build technical capacity in the sector. Another area of collaboration is the formation of market linkages and development through organising trips abroad for members to participate in international trade fairs. Two international conferences on sustainability helped raise awareness and created opportunities for links to be made with other stakeholders so as to improve competitiveness of member firms in the international market.

The association also holds quarterly meetings with the MEFCC to discuss issues of environmental compliance. Consumers, through the market mechanism and via global retailers who monitor compliance, are exerting pressure on factories to comply with environmental standards. ETGAMA monitors the activities of its members and supports them to comply with the international standards pertaining to environmental sustainability and social issues.

In pursuit of capacity building, ETGAMA also collaborates with various development partners like the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the Embassy of the Kingdom of Netherlands. ETGAMA initiated a three-year project, funded by the Dutch government, which has engaged a consultant ('Solidar Dag') 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.

5.2 Extent and types of innovation

This section reports the results of the survey of innovation activities among firms in the cement, leather and textile sectors (see description of the methodology in section 3). The survey questionnaires asked firms about the extent of product and process innovations undertaken in the preceding three years, i.e. 2013 to 2015. Table 6 displays the headline results.

Table 6: 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 innovating firms for which at least one product innovation was new to the industry in Ethiopia	100%	50%	57%	53%
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
Percentage of innovating firms for which at least one process innovation was new to the industry in Ethiopia	50%	45%	64%	54%

Of the 15 cement firms, only one (7%) reported that it had undertaken product innovation, and in that case it was a single innovation that was claimed to be new to the industry in Ethiopia. Two other cement firms reported process innovations; a single instance for one firm, and two new or significantly improved production processes in the second firm. One of the firms claimed that its process innovation was new to the industry in Ethiopia.

Of the 40 leather sector firms, 26 (65%) engaged in product innovation. The reported number of product innovations varied from as few as 2 to as many as 90. Unfortunately, what constitutes a product innovation is hard to define, and respondents' answers were inevitably somewhat subjective. If we discount the outlier, which seems unrealistic for true innovations, the average number of product innovations per innovating firm was 15. Of the innovating firms, 50% said that at least one of their innovations were new to the industry in Ethiopia. Process innovation was conducted by 11 leather firms (28% of the sample), ranging between 1 and 5 innovations per firm and averaging 2.4. Five innovating firms (45%) claimed that at least one of their process innovations were new to the industry in Ethiopia.

Just 7 of the 62 textile sector firms (11%) reported product innovations, with the number of individual innovations per firm varying between 1 and 28, averaging 10 per firm, and totalling 71. Of the innovating firms, 57% said that at least one of their innovations were new to the industry in Ethiopia. Eleven textile firms engaged in process innovation, with the number of such innovations varying between 1 and 5, except for one firm which claimed to have introduced 28 process innovations. Seven firms (64%) claimed that at least one of their process innovations were new to the industry in Ethiopia.

Aggregating all firms across the three sectors, 29% reportedly engaged in product innovation, with an average of 15 innovations per innovating firm. Fifty-three percent of all innovating firms said that at

least one of their product innovations were new to the industry in Ethiopia. Of the 117 firms surveyed, 21% reportedly engaged in process innovation, with an average of 4 innovations per innovating firm. Fifty-four percent of all innovating firms said that at least one of their process innovations were new to the industry in Ethiopia.

Given that the cement industry by and large produces a single homogeneous product (Portland cement), it is not surprising to find a low rate of product innovation. By contrast, textile and garment manufacturers deal with a much larger range of products (various types of fabrics and numerous different garment types and styles), which also tend to change more frequently. One would expect the leather industry to be somewhere in between these extremes. The extensive product innovation reported in the leather sector is somewhat surprising. This could be because of how leather and shoe producers interpreted the meaning of product innovation, e.g. new shoe designs. One tannery reported 30 product innovations, while one shoe factory claimed 90. Given the difficulty in precisely specifying what constitutes a product/process innovation, and the further difficulty of communicating this to the enterprise representatives, the data should be interpreted with discretion.

Enterprises were asked about the origin of their product innovations (Table 7). The majority of product innovating firms in all three sectors said their enterprise developed the innovations by themselves, while none said that they relied entirely on other companies or organisations. In the case of textile firms, 29% reported that their enterprise adapted or changed products originally developed by other companies.

Table 7: Origin of product innovations

Who mainly developed the product innovations	Cement	Leather	Textiles	All firms
Your enterprise by itself	100%	73%	57%	71%
Your enterprise with other companies or organisations	0%	23%	14%	21%
Your enterprise by adapting or changing products originally developed by other companies	0%	4%	29%	9%
Other companies or organisations	0%	0%	0%	0%
<i>Number of firms reporting production innovation</i>	<i>1</i>	<i>26</i>	<i>7</i>	<i>34</i>

The majority of enterprises reported that they developed their process innovations by themselves (63% of all firms), with the exception of the two cement firms, both of which collaborated with other companies or organisations (Table 8). No firms relied completely on product innovations developed by other companies or organisations.

Table 8: Origin of process innovations

Who mainly developed the product innovations	Cement	Leather	Textiles	All firms
Your enterprise by itself	0%	64%	73%	63%
Your enterprise with other companies or organisations	100%	27%	9%	25%
Your enterprise by adapting or changing manufacturing processes originally developed by other companies	0%	9%	18%	13%
Other companies or organisations	0%	0%	0%	0%
<i>Number of firms reporting process innovation</i>	<i>2</i>	<i>11</i>	<i>11</i>	<i>24</i>

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 9, which shows both the percentage of all firms in each sector that reported at least one product innovation to reduce each type of input or waste product, and the average number of green product innovations per innovating firm. The single 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 9 reports no green product innovations in the cement sector. In the leather sector, just one enterprise (3% of firms) 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, indicating a lack of diffusion. In aggregate, less than 5% of firms introduced product innovations to reduce most categories of inputs and wastes, with the exception of material inputs (for which the proportion was 12%). Overall, 21% of all firms reported at least one green product innovation.

Table 9: Product innovations adopted in the last three years to reduce inputs or wastes

Innovations to reduce:	Cement		Leather		Textiles		All firms	
	Percentage of firms	Av. number of innovations per firm	Percentage of firms	Av. number of innovations per firm	Percentage of firms	Av. number of innovations per firm	Percentage of firms	Av. number of innovations per firm
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 10 shows the reported extent of ‘green process innovations’ per sector, i.e. the percentage of all firms that reported at least one process innovation to reduce each category of input or waste product, and the average number of green product innovations per innovating firm. In the cement sector, a single firm reported that it introduced 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 much more numerous (averaging between 2.7 and 4.9) and somewhat more common (adopted by between 10% and 15% of firms).²¹ Overall, 15% of all firms reported at least one green process innovation.

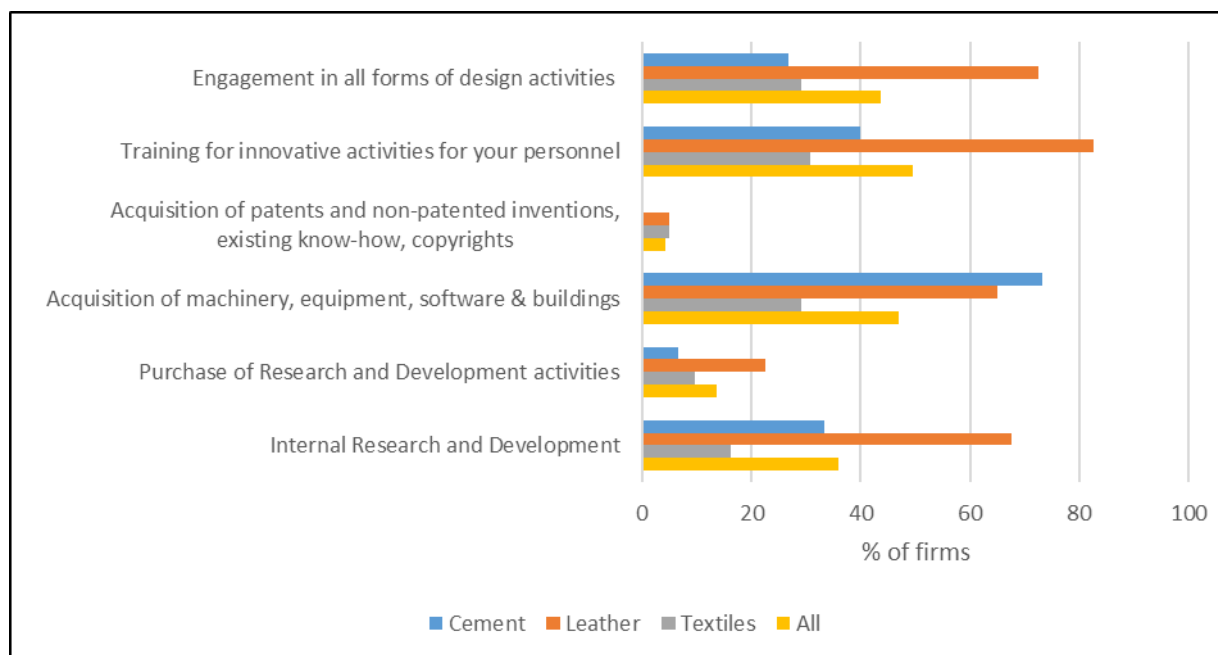
Table 10: Process innovations adopted in the last three years to reduce inputs or wastes

Innovations to reduce:	Cement		Leather		Textiles		All firms	
	Percentage of firms	Av. number of innovations	Percentage of firms	Av. number of innovations	Percentage of firms	Av. number of innovations	Percentage of firms	Av. number of innovations
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

²¹ A caveat is necessary, as on close inspection some of the responses seemed unrealistic. For example, a textile firm that reported having introduced 5 process innovations in total, also said that 5 process innovations were adopted to reduce every one of the input and waste categories listed in the table. This would mean that every innovation served to reduce every type of input and waste, which seems very unlikely. The same occurred with two other textile firms, which reported 3 and 2 product innovations, respectively. Therefore, the data should be interpreted with caution.

Figure 20 displays the percentage of firms that reported investing in various types of activity to support product and process innovation. In the cement sector, acquisition of machinery, equipment, software and buildings was the most common activity (73% of firms), followed by training of personnel (40%). In the leather sector, the most-cited investment activities were in training (83%) and design activities (73%). Among textile firms, the percentage engaging in investments for innovation was generally much lower, reaching just 31% in the case of training. The proportion of firms reporting investment in all categories except acquisition of machinery etc. was highest among leather sector enterprises.

Figure 20: Percentage of firms investing in activities to support product and process innovations



5.2.1 Benchmarking against other countries

It is instructive to place the main innovation results for Ethiopia in the context of rates of innovation occurring in other developing countries. Table 11 (Table 12) displays the percentage of firms undertaking product (process) innovation in the textiles, apparel, leather and manufacturing sectors in a selection of developing countries for which data were available on the UNESCO Institute for Statistics (2016) database. The data for Ethiopia are drawn from the firm survey conducted for this project (for the textiles and leather sectors) and from the Ethiopian National Innovation Survey (STIC 2015a) for the manufacturing sector as a whole. As can be seen, the reported rates of both product and process innovation among firms vary greatly, which may partly be due to the lack of consistent, objective definitions of what constitutes different types of innovation in these sectors (firms typically respond to surveys by subjectively reporting on the number of innovations).

As shown in Table 11, 11% of surveyed Ethiopian textile firms reportedly engaged in product innovation, which is in line with the percentages in other developing countries (with the exception of Ecuador, which is an outlier). In the leather sector, Ethiopia's 65% rate of product innovation is similar to the rate reported for Ecuador, but is far higher than any of the other countries. The average percentage of product innovation among all (cement, leather and textile) firms in the survey was 29%, which is somewhat below the 43% of manufacturing firms found to be product innovators

in Ethiopia (STIC 2015a). The latter figure is similar to Ethiopia's neighbour Kenya (40%), and somewhat below the 61% recorded for both Tanzania and Uganda.

Table 11: Percentage of firms reporting product innovation in selected countries

Country	Year	Textiles	Apparel	Leather	Manufacturing
Brazil	2011	9	10	14	17
Bulgaria	2012	9	10	8	15
Ecuador	2011	52	48	66	46
Egypt	2010	5	2	4	6
India	2009	13	14	20	12
Poland	2012	10	2	6	12
Romania	2010	11	5	12	12
Uruguay	2009	16	13	27	17
Kenya	2011	--	--	--	40
Malaysia	2011	--	--	--	44
Tanzania	2010	--	--	--	61
Uganda	2010	--	--	--	61
Ethiopia	2014	11²	--	65²	43³

Source: UNESCO Institute of Statistics 2016 (2) Firm survey conducted for this project (3) STIC (2015a)

The corresponding benchmarking results for process innovation, shown in Table 12, are broadly similar. Among surveyed textile firms in Ethiopia, 18% reported process innovation, which is consistent with the percentages in the other countries (aside from Ecuador, which again is an outlier). In the leather sector, the Ethiopian result (28%) within the range of other countries. However, the overall rate of product innovation found in the firm survey (21%) was considerably lower than that for the manufacturing sector (54%) found in the Ethiopian National Innovation Survey (STIC 2015a). The latter percentage was much higher than the 33% found for Kenya and 27% for Tanzania, but less than Uganda's reported 63%.

Table 12: Percentage of firms reporting process innovation in selected countries

Country	Year	Textiles	Apparel	Leather	Manufacturing
Brazil	2011	26	30	27	32
Bulgaria	2012	10	7	6	11
Ecuador	2011	52	46	65	47
Egypt	2010	12	5	7	8
India	2009	16	15	13	12
Poland	2012	10	2	6	12
Romania	2010	11	1	10	13
Uruguay	2009	24	20	30	24
Kenya	2011	--	--	--	33
Malaysia	2011	--	--	--	44
Tanzania	2010	--	--	--	27
Uganda	2010	--	--	--	63
Ethiopia	2014	18²	--	28²	54³

Source: UNESCO Institute of Statistics 2016 (2) Firm survey conducted for this project (3) STIC (2015a)

The African Development Bank (2014) conducted a ‘strengths, weaknesses, opportunities and threats’ (SWOT) analysis on the competitiveness of several manufacturing sectors in East African countries, and identified the level of innovation as a weakness for both leather and textile sectors. For the textile and clothing sector in East Africa, one of the weaknesses in competitiveness resulted from under-developed linkages with technical institutes for research and innovation support. In the leather and leather products sector, a significant weakness resulted from “under-developed linkages with technical institutes for research and innovation support to improve livestock on the input side and design and technical skills on the processing and product developing side” (AfDB 2014:55).

5.3 Characteristics of innovating firms

In order to analyse the possible determinants of innovation, such as certain characteristics of firms that may make them more or less likely to innovate, linear regression models were estimated using the combined sample of data on 117 firms in the cement, leather and textile industries. The dependent variable of each model is binary, i.e. it takes on a value of 0 if the firm did not innovate and 1 if it did innovate. Models were estimated for each of the four dependent variables indicated in Table 13. “Green” innovation is defined in this instance as innovations that aimed to reduce various types of inputs (energy, water, chemicals and materials) or reduce various wastes (solid, liquid and gaseous).

Table 13: List of variables included in probit regression models

Dependent Variables		
Variable Name	Description	Type
product_inn	Firm engaged in product innovation between 2013-2015	categorical
green_proinn	Firm engaged in green product innovation between 2013-2015	categorical
process_inn	Firm engaged in process innovation between 2013-2015	categorical
green_procinn	Firm engaged in green process innovation between 2013-2015	categorical
Explanatory Variables		
Variable Name	Description	Type
age	Age of firm in years	continuous
log_turnover	Turnover in 2014/2015 (Birr) (logged)	continuous
log_empt	Number of full-time equivalent employees in 2014/15 (logged)	continuous
cement	Firm is a cement producer	categorical
leather	Firm is in the leather and leather products sector	categorical
textile	Firm is in the textile and garment sector	categorical
ind_park	Firm is located in an industrial park	categorical
domestic	Firm has domestic ownership	categorical
foreign	Firm has foreign ownership	categorical
joint_df	Firm has joint domestic-foreign ownership	categorical
private	Firm is privately owned	categorical
state_owned	Firm is a state-owned enterprise	categorical
pub_priv	Firm has joint public-private ownership	categorical
exporter	Firm is an exporter	categorical
inv_ownrnd	Firm invested in internal R&D in 2014/15	categorical

A “probit” model specification was selected for the estimations, based on the assumption that the random (dependent) variables follow a normal probability distribution. The model effectively estimates the probability that any particular firm engaged in product/process innovation, conditional on a number of independent variables. The continuous independent variables (see Table 13) include the age of the firm, the annual turnover in 2014/15 (logged so as to reduce heteroscedasticity), and the size of the firm using the number of full time employees as a proxy for firm size (also logged). In addition, several binary (dummy) explanatory variables are included in order to assess whether the following factors are statistically significant determinants of the propensity of firms to innovate:

- industrial sector (dummies for cement and leather, with textiles selected as the base case);
- whether or not the firm was situated in an industrial park;
- whether or not the firm was an exporter;
- whether the ownership of the firm was domestic (base case), foreign or a joint venture;
- whether the firm was privately owned, state-owned or a joint public-private operation; and
- whether the firm invested in its own R&D to support innovation.

The standard errors of coefficients were calculated using the Huber/White adjustment for heteroscedasticity to ensure greater robustness. In some instances, one or more of the dummy variables had to be excluded because the lack of variation in the variables meant that coefficients could not be calculated by the algorithms in the EViews econometric software package. The number of observations is less than the total number of firms surveyed (117) because not all firms provided answers to all of the questions, i.e. there are missing observations (especially for variables such as turnover and number of employees). The following subsections discuss the main results obtained for models of product and process innovation, respectively. The full output for each model specification is provided in Appendix A.

5.3.1 Product innovation model results

Table 14 shows the main results for full model specifications (including all explanatory variables) and reduced forms (including only statistically significant independent variables) for product innovation and green product innovation. In the case of product innovation, the statistically significant explanatory variables were turnover, leather sector, location in an industrial park, exporter, state ownership and investment in own R&D. The age of the firm, number of employees, cement industry dummy and foreign ownership were all statistically insignificant even at the 10% level. The negative sign on the coefficient of `log_turnover` suggests that smaller firms are more likely to innovate – perhaps because they face greater competitive pressures. Interestingly, firms in the leather sector are more likely to engage in product innovation than their counterparts in the cement and textile sectors. The negative sign on `industrial_park`, which indicates that this status reduces the probability of product innovation, could possibly be explained by the fact that such firms are generally new entrants to the industry in Ethiopia arising from FDI, and they are therefore likely to have more up-to-date product lines than established domestic firms. Firms that produce goods for exports are more likely to engage in product innovation, which conforms to the literature suggesting that such firms innovate in response to international competition. Only three firms in the sample are state-owned, but it is somewhat surprising that the coefficient on this variable is positive, as private sector firms are generally thought to be more innovative. The probability of a firm engaging in product innovation is positively associated with firms investing in their own R&D, as expected. The overall goodness of fit (McFadden R-squared of 0.48) is reasonably good for a small cross-section sample. In the reduced form model, the coefficients change slightly (partly because the sample size has increased by four observations), but the level of significance remains the same in each case, as does

the goodness of fit. In both the full and reduced forms, applying the logit estimation technique (which assumes an underlying logistic distribution function) did not materially change the results in terms of the significance of variables, although the coefficients are generally slightly larger.

Table 14: Summary of probit model results for product innovation

Explanatory variable	Dependent Variable			
	product_inn		green_prodiinn	
	full	reduced	full	reduced
constant	1.96	1.17	-1.65	-1.74**
age	0.001		-0.02	
log_turnover	-0.29**	-0.18*	-0.09	
log_empty	0.20		0.27	
cement	-0.39	-0.49	-0.41	
leather	1.20**	1.07**	0.27	
ind_park	-1.68**	-1.49**	-0.41	
exporter	0.95**	1.05**		
foreign	0.15		-0.50	
state_owned	1.94**	1.95**		
inv_ownrnd	1.23**	1.29**	1.76**	1.13**
No. of observations	93	97	92	115
Obs with Dep = 1	66	68	82	101
Obs with Dep = 0	27	29	10	14
McFadden R ²	0.48	0.48	0.29	0.15

* Statistically significant at the 10% level. ** Significant at the 5% level.

Green product innovation was modelled in a similar way, but in this case only one explanatory variable was statistically significant at even the 10% level, namely inv_ownrnd. The goodness of fit (0.29) is clearly poor as a result. This is likely due in part to the fact that only 18 out of the 117 firms engaged in green product innovation, and only 10 of the 92 firms included in the full regression after missing observations were excluded. The reduced form model, which is estimated over a somewhat larger sample, has an even poorer fit (0.15) with only the single significant explanatory variable included.

5.3.2 Process innovation model results

Table 15 displays the main output for models of process innovation and green process innovation. In the case of process innovation, the explanatory variables that are statistically significant (at the 5% level) are age, ind_park, exporter and inv_ownrnd. Turnover, number of employees, cement and leather industry dummies, and foreign ownership were all insignificant at the 10% level. The negative sign on the coefficient of age suggests that younger firms are more likely to innovate, which is a common finding in the literature. The negative sign for ind_park and the positive sign on 'exporter' may be explained as above. The goodness of fit is not very good (0.39), but it must be borne in mind that only a small number of firms reported engaging in process innovation (24 out of 117 in the full sample, and 16 of the 93 included in the estimation). When the insignificant variables are excluded and the model re-estimate, the results are broadly similar although the ind_park variable becomes insignificant and the McFadden R² falls to 0.27, indicating a poor fit.

Table 15: Summary of probit model results for process innovation

Explanatory variable	Dependent Variable			
	process_inn		green_procinn	
	full	reduced	full	reduced
constant	-6.04**	-5.43**	-8.45	-7.35**
age	-0.3**	-0.02**	-0.03**	-0.02**
log_turnover	0.22	0.21**	0.35**	0.29**
log_empty	0.15		0.02	
cement	-1.00		-0.50	-0.66
leather	-0.89		-1.36**	-1.40**
ind_park	-1.10**	-0.75	-0.95*	-0.91*
exporter	1.11**	0.96*	1.89**	1.53**
foreign	0.01		-0.54	
inv_ownrnd	1.54**	1.04**	2.00**	1.87**
No. of observations	93	95	93	95
Obs with Dep = 1	77	79	81	83
Obs with Dep = 0	16	16	12	12
McFadden R ²	0.39	0.27	0.47	0.43

* Statistically significant at the 10% level. ** Significant at the 5% level.

The model results are more robust in the case of green process innovation. Age of the firm, turnover, leather sector, exporter and inv_ownrnd are all significant at the 5% level, and ind_park at the 10% level. The sign of the coefficient on 'age' is negative as before. However, log_turnover has a positive sign, indicating that larger firms (in terms of revenue) are more likely to undertake process innovations – perhaps because they have the resources to invest in new equipment. In contrast to product innovation, firms in the leather sector are less likely than textile firms to engage in process innovation. The probability of process innovation is higher amongst exporting firms and those that invested in R&D. The goodness of fit (0.43) is rather weak in the reduced form model, suggesting that there are other factors (not captured in the survey) that determine whether or not firms engage in green product innovation. Application of the logit estimation technique does not materially change the sign or significance of the variables in either of the process or green process innovation models, except that the leather dummy is somewhat less significant in the latter case.

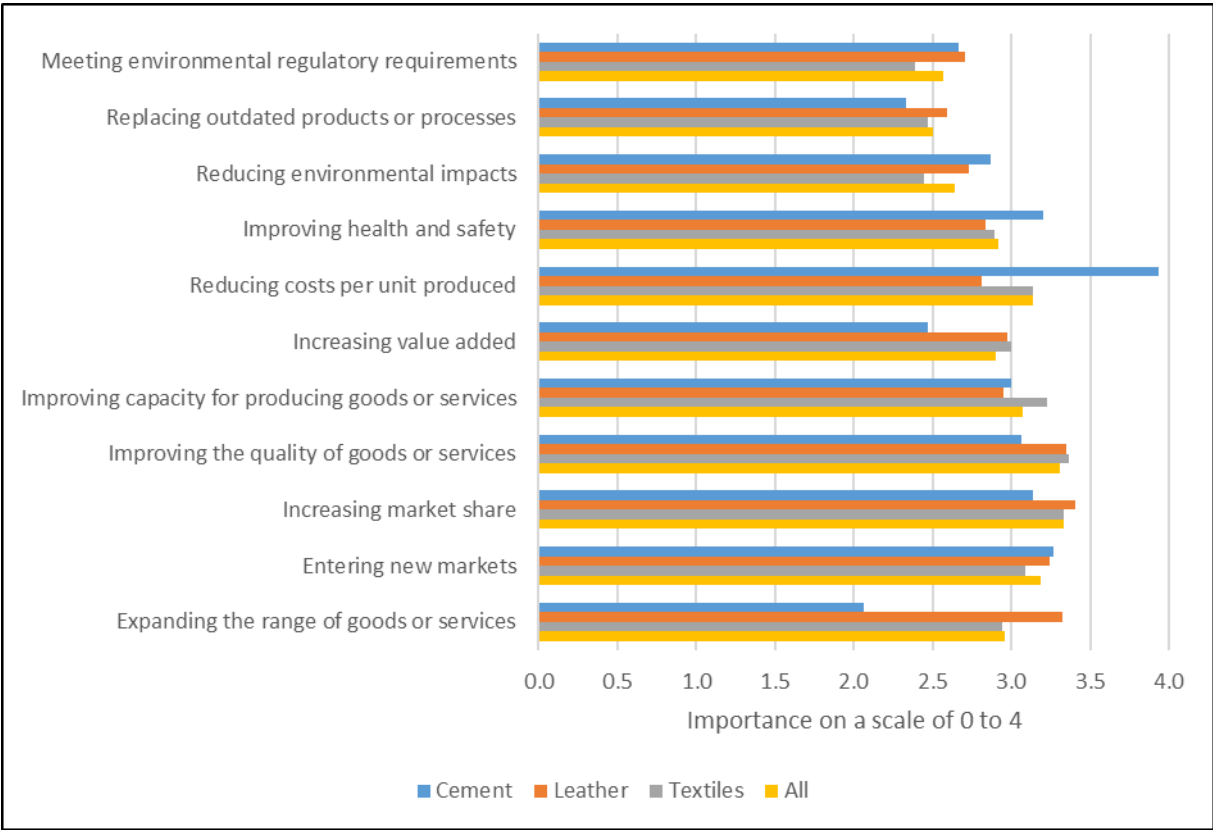
5.4 Drivers and inhibitors of innovation

In order to assess the relative importance or strength of a number of different potential drivers and inhibitors of innovation, firms were asked to score each factor on a scale of 0 (not significant) to 4 (a very strong factor). Figure 21 reports average scores across firms in each sector and in aggregate for 11 drivers of innovation. The most striking feature of the results is that 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 textiles (3.1) firms. However, “increasing value added” is a markedly lower concern for cement producers (2.5) than leather and textiles firms (both 3.0). As could be expected, “expanding the range of goods or services” is not of great importance to cement manufacturers, as they produce a homogeneous product. By contrast, this factor is of considerable importance for leather producers (3.3). For both leather and textile producers, the most important drivers of innovation are

“increasing market share” and “improving the value of goods and services”. Of course, the averages conceal greater variation in the scores across individual firms within each sector.

Of special relevance for this report, 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. For cement firms, the two environment factors were the fourth and fifth weakest out of 11 drivers. For all firms, only “replacing outdated products or processes” (2.5) received a lower score than the two environmental drivers (both of which scored 2.6 on average). This is a clear indication that improved environmental policies are needed to stimulate green innovations.

Figure 21: Relative strength of factors encouraging innovation

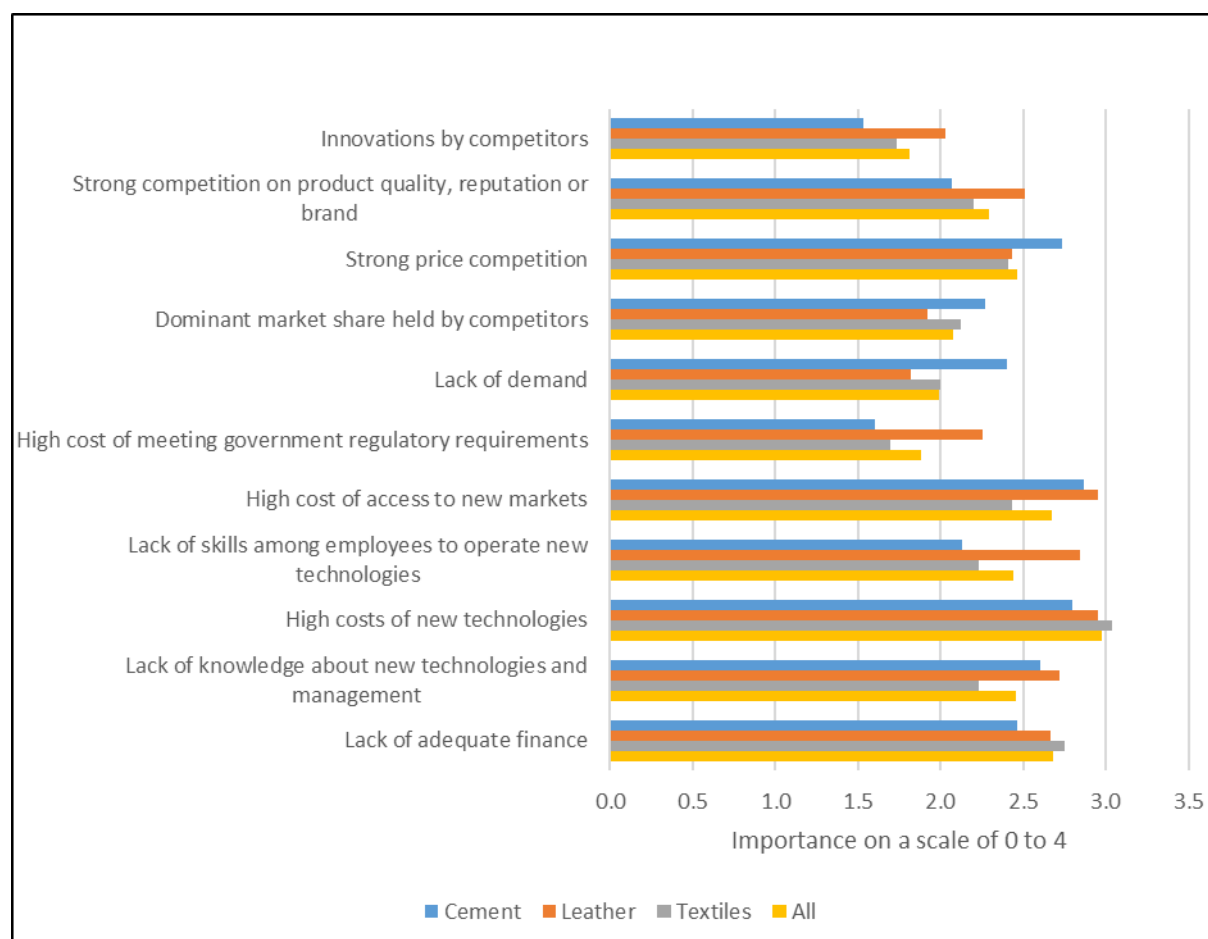


Notes: Firms were asked to score each factor on a scale of 0 (not significant) to 4 (very strong factor). The figure reports averages across firms in each sector and in aggregate. Three leather industry firms responded “do not know” or “not applicable”. Twenty-four textile firms returned null values, while another responded “not applicable”.

Figure 22 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 biggest inhibitor for leather and textile firms and the second biggest for cement firms. “High cost of access to new markets” was also the top obstacle for cement and leather firms. The relatively high average score (2.7) 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 concerning inhibitors were “lack of demand” and “dominant market share held by competitors”. The cost of meeting government regulatory requirements does not appear to be an important obstacle to innovation, especially in the cement and textiles sectors. This

might indicate a lack of regulations or enforcement thereof. Lack of adequate finance was the second ranked inhibitor for textile firms and of medium importance for leather firms. “Lack of skills among employees to operate new technologies” was considered a relatively major obstacle for leather firms, but of limited importance in the other two sectors. 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.

Figure 22: Relative strength of factors inhibiting innovation

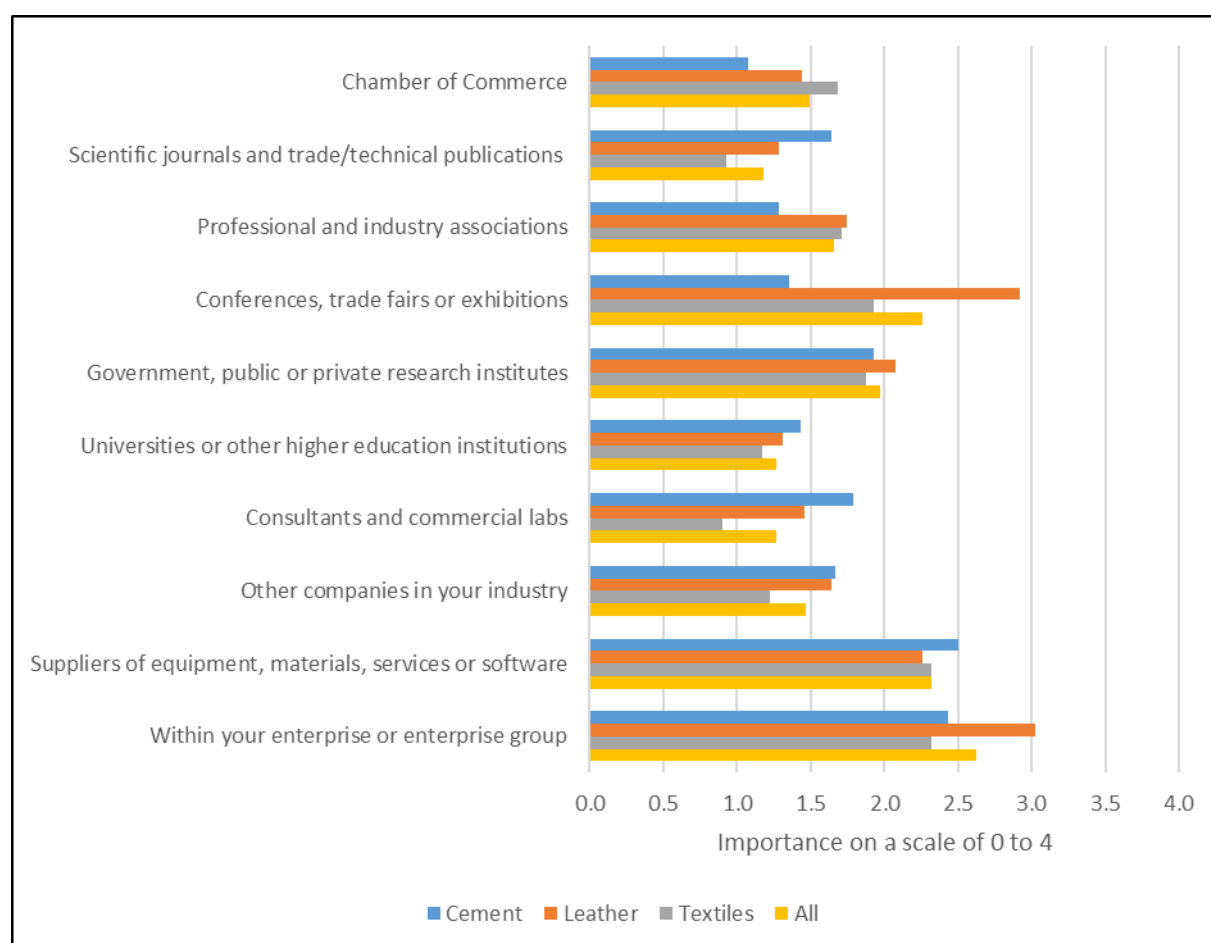


Note: Firms were asked to score each factor on a scale of 0 (not significant) to 4 (very strong factor). The figure reports averages across firms in each sector and in aggregate. One leather industry firm responded “do not know”, and six textile firms returned null values.

5.5 Sources of information and partnerships for innovation

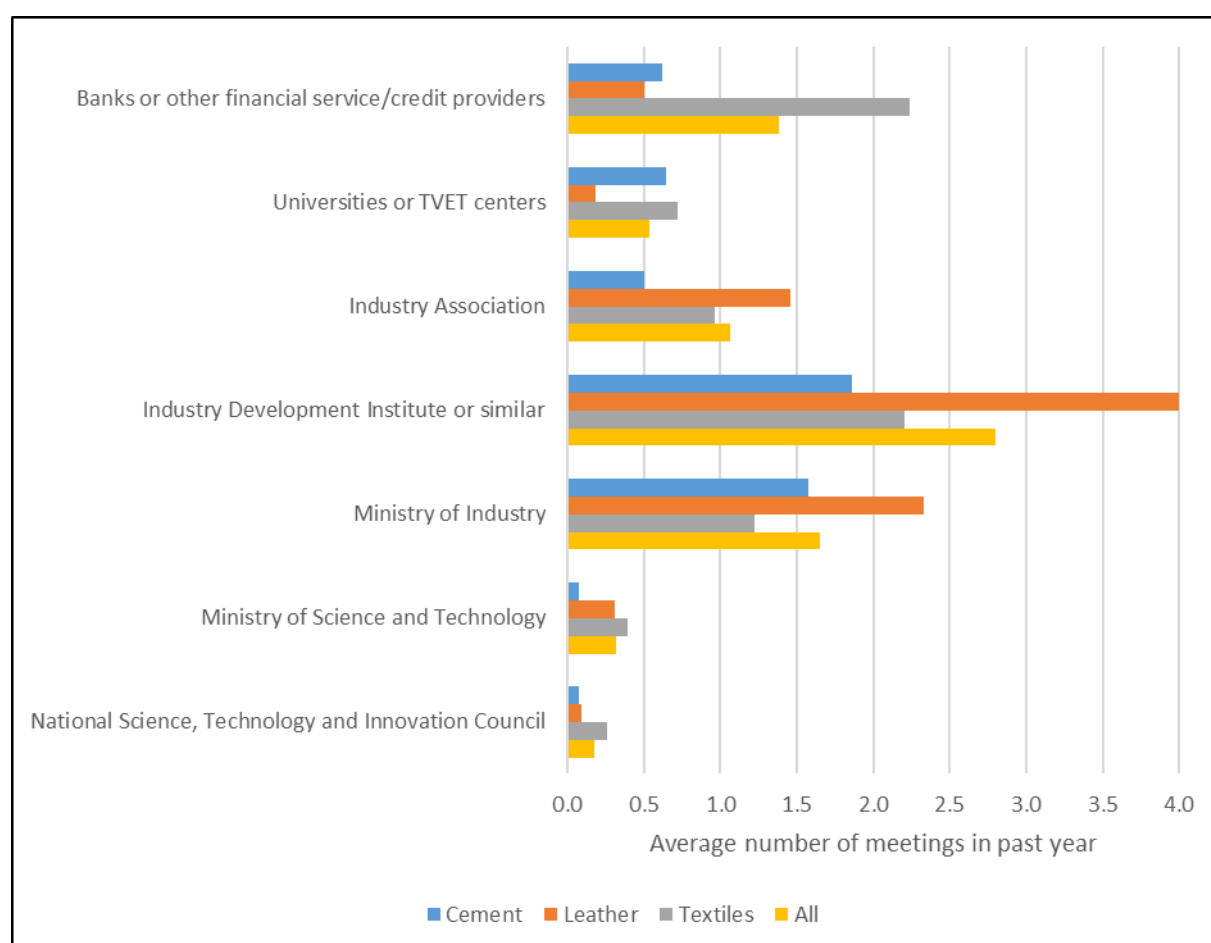
The firms were asked several questions relating to the sources of information and types of partners they cooperated with in the innovation process, with a view to establishing how strong the innovation networks are and where the gaps lie. Figure 23 shows the relative importance of 10 sources of information for innovation that firms rated. Information from within the enterprise or group was considered most important of all 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), which was also relatively important for textile firms. For leather sector firms, an important source of information was conferences, trade fairs and exhibitions (2.9), whereas this was one of the least productive sources for cement firms. Government, public or private research institutes constituted a mediocre source of information for innovation, which clearly indicates scope for more effective implementation of innovation policies. Even more concerning are the very low scores given by firms in all sectors to higher education institutions, which has the second lowest average (1.3) across all firms. This confirms the findings of the Ethiopia National Innovation Survey (STIC 2015a), and implies that much more needs to be done to strengthen linkages between HEIs and firms to foster knowledge and technology transfers.

Figure 23: Sources of information for innovation



To further assess the strength of innovation system linkages, firms were asked how many meetings they had with key innovation actors in the past year. To some degree, the results conform to the governance structure that has been adopted by the government for the implementation of the CRGE in these industrial sectors, as described in section 5.1 (namely that the MoI has the primary responsibility for implementing the CRGE, but uses the industry development institutes for this purpose). For firms in all three sectors, the most meetings occurred with the respective industry development institute. Leather sector firms reported more meetings on average with the LIDI and MoI, which is consistent with the higher rates of product and process innovation in this sector. Meetings with financial service providers were much more common among textile firms than among cement or leather firms. At least some meetings took place with the Ministry of Industry, although there is clearly scope for more interaction. Perhaps the most significant result is the generally low number of meetings with all of the innovation partners. The very low number of meetings with universities and TVET institutions (0.5 on average across all firms) again highlights the need for more regular contact between HEIs and firms.

Figure 24: Average number of meetings held with innovation partners in the past year



Note: One of the cement firms reported that it had 365 meetings with banks or other financial service providers in the past year; among the textiles firms, three firms reported 300 or more such meetings. Given that these responses were extreme outliers and were deemed unrealistic, it seems likely that the respondents misinterpreted the question. Hence, these four outliers were excluded.

Table 16: Percentage of firms reporting at least one meeting with innovation partners in the past year

Innovation partner	Cement	Leather	Textiles	All firms
National Science, Technology and Innovation Council	7%	8%	15%	11%
Ministry of Science and Technology	7%	20%	21%	19%
Ministry of Industry	40%	65%	39%	48%
Industry Development Institute or similar	40%	73%	53%	58%
Industry Association	20%	35%	34%	32%
Universities or TVET centers	27%	10%	27%	21%
Banks or other financial service/credit providers	27%	20%	35%	29%

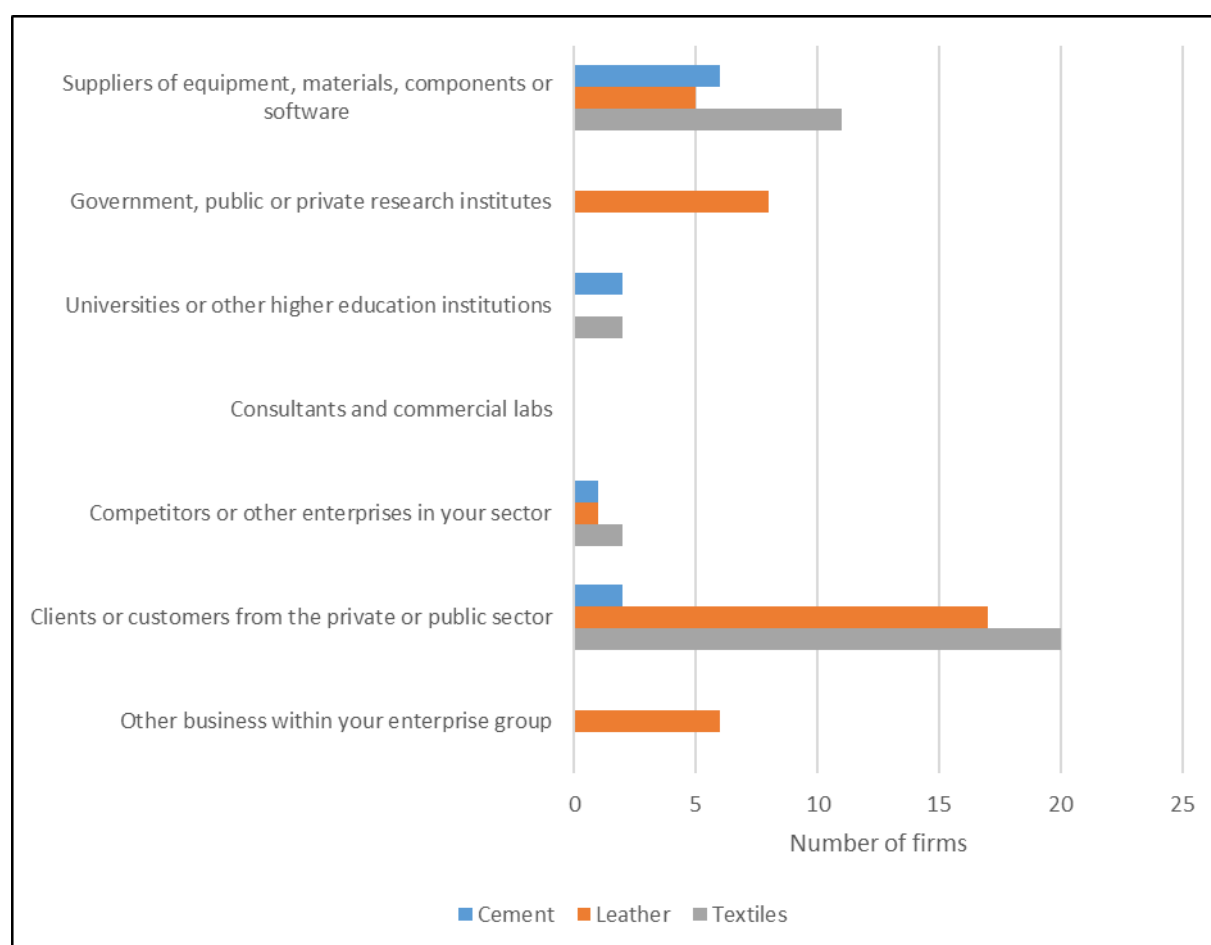
displays the percentage of firms in each sector that reported having at least one meeting in the preceding year with the various key innovation partners. In the case of cement firms, 40% said they had met with the Ministry of Industry, and the same percentage reported having met with the Industry Development Institute. Only about a quarter met with HEIs and financial service providers, while just 7% (one firm) met with either the NSTIC or MoST. The pattern was broadly similar in the other sectors, with 73% of leather firms and 53% of textile firms having met with the LIDI and TIDI, respectively. Probably the most notable result is the low percentage of firms that reported meetings with HEIs.

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Industry Development Institute or similar	40%	73%	53%	58%
Industry Association	20%	35%	34%	32%
Universities or TVET centers	27%	10%	27%	21%
Banks or other financial service/credit providers	27%	20%	35%	29%

Finally, firms were asked about their most important cooperation partners for innovation. Figure 25 shows that for the leather and textile sectors, clients or customers from the private or public sector were cited by the largest number of firms. Among cement firms, suppliers of equipment, materials, components or software were the most common innovation partners. Government, public or private research institutes were ranked top by eight leather firms, but no cement or textile firms. Universities or other HEIs were the most important partner for just two cement firms and two textile firms. Once again, these results confirm that there is much scope for building institutional linkages between HEIs, government agencies, research institutes and firms in order to foster the transmission of knowledge and technologies for innovation.

Figure 25: Most important cooperation partners for innovation



6 Conclusions and Recommendations

The Federal Government of Ethiopia has over the past few years embarked on an ambitious economic modernisation and industrialisation strategy, as encapsulated in its first and second Growth and Transformation Plans. At the same time, the FDRE has committed the country to a low-carbon development trajectory by adopting a Climate Resilient Green Economy Strategy. Questions remain, however, as to how compatible these two policy visions are in practice and implementation. Such questions provided the motivation for the research project funded by CDKN, which seeks to enhance the understanding of the interaction between the emerging industrial policies and green economy strategies in Ethiopia.

The international development literature makes it clear that innovation – that is, the adoption and diffusion of new knowledge and technologies within an economy – is a critical driver and enabler of economic transformation and industrialisation. Furthermore, the literature on green growth and sustainable development also places a large emphasis on the role of ‘sustainability-oriented’ or ‘green’ innovations as a key mechanism for achieving improvements in resource productivity and reductions in wastes and emissions, including greenhouse gases.

In light of these findings from the research literature, this report aimed to assess the strengths and weaknesses of the emerging national system of innovation in Ethiopia, and to conduct an analysis of sectoral innovation systems in key industrial sectors, with a view to establishing the extent to which they are geared toward supporting green innovation and hence green industrialisation. The report drew on extensive secondary data to assess the framework conditions and functioning of the NSI. It also analysed primary innovation data collected from a survey of 117 firms in the cement, leather and textiles sectors. Thirdly, the report drew on interviews with key actors in the national and sectoral innovation systems. The major findings are summarised below, following which recommendations are made for policies to strengthen green innovation systems in Ethiopia.

6.1 Summary of main findings

6.1.1 The national system of innovation

The Federal Government has undertaken concerted efforts to bolster the national system of innovation in recent years, especially following the adoption of the national STI Policy in 2012. The STI policy has spelled out the governance structure of the national innovation systems leading to the establishment of the NSTIC, which is chaired by the Deputy Prime Minister and the Ministry of Science and Technology act as a secretariat. Several line ministries are members of the Council but also have responsibilities in leading and promoting innovation in their respective ministries. The STI policy identified eleven key policy issues along with a set of strategies to deal with each of these issues. Environmental protection is one of these key policy and strategy issues.

The Ethiopian government has long recognized the importance of human resource development in order to promote the technological and economic transformation of the country. Education is a high priority for the government of Ethiopia as evidenced by the fact that 27% of total government spending is allocated to education, which is far larger than the average for LICs and SSA countries. The country has seen a rapid expansion in education particularly in primary and secondary enrolments. Tertiary enrolment has also seen strong growth. This has been accompanied by a rapid increase in state expenditure on research and development, and a substantial rise in the number of R&D personnel.

Despite these positive developments, the NSI is still emerging and will require further commitment and resources to become fully fledged. For example, despite rapid growth, tertiary education enrolments remain below the average in LIC and SSA countries. Ethiopia's indicators of research activity, such as publications and patents, are growing, but off an extremely low base. The bulk of government-sponsored research occurs in the agricultural sciences, accounting for nearly half of the GERD. By contrast, engineering, technology and the natural sciences garnered small shares of funding, implying that the GRED allocation was not very supportive of innovation in the manufacturing sector. Over the past ten years, the spending on GRED has shifted from government to HEIs, which may be a reflection of the perception that the HEIs are the best vehicles for R&D.

In contrast, the recent years has seen a marked drop in business expenditure on R&D. Business enterprises are spending very little on R&D, and report that access to finance for innovation and for access to new markets is highly constrained, while costs are high. Many firms cite a lack of appropriately skilled labour as a hindrance to innovation. Furthermore, there are weaknesses in the interactions among innovation system actors. For example, there appears to be insufficient engagement between the main ministries, particularly the MoST with the MoI and MEFCC, regarding green innovation. Moreover, the links between universities and research institutes on the one hand, and private enterprises on the other, are generally quite weak. The focus on HEIs could, therefore, be a cause of concern in the presence of weak linkages between academia and industry. The national research infrastructure is yet in its infancy stage. Despite high spending, the universities' research labs have not grown quickly enough to accommodate the increasing enrolment. Moreover, there is a lack of suitably qualified academic staff, particularly in the new universities, and incentives (e.g. salaries) are too low to sufficiently motivate the research staff.

Innovation has been recognised at a high level of government as a critical gap in the implementation of the CRGE. While innovation is under consideration, it is acknowledged that it has not yet been adequately addressed. The greening agenda has not yet been mainstreamed into the education and training system. Moreover, despite institutional upgrading, enforcement of the EIA law remains weak. The implication is that regulation-driven technology forcing is weaker than it could be if environmental laws and regulations were adequately implemented. Our firm survey in the selected sectors have shown that greening requirements are among the weakest drivers of innovation.

The macroeconomic environment, as well as the rapid expansion of transport and energy infrastructure, have been broadly supportive of business activity and innovation – although rising public debt is a possible cause for concern if the rate of economic growth should falter in the coming years. However, high trading costs emanating from inefficient customs clearance and poor infrastructure such as road and electricity is still hampering the country's competitiveness. ICT infrastructure is still severely limited, which inhibits firms' ability to tap into global knowledge banks and to effectively network with innovation actors.

6.1.2 The greening agenda and innovation in the manufacturing sector

The MEFCC and MoFEC are the two ministries that coordinate the implementation of the CRGE and associated innovations. While the MoI has regular communications with these two ministries, for example in quarterly forum meetings involving the six main line ministries involved in implementing the CRGE, innovation is not a particular focus within these forums.

Although the MoI is one active actor in the national and sectoral systems of innovation, its involvement in supporting green innovation specifically appears to be somewhat limited. The MoI's

main priority has been on building and expanding industry, rather than protecting the environment. This could explain its limited role in fostering green innovation. The MoI made some attempts to streamline the environmental issues into the industry development agenda by way of incorporating those issues into the second GTP. There are, however, no specific industrial sector policies and laws aimed at encouraging eco-innovations as yet. The ministry is still working to develop sectoral parameters for implementation of the CRGE strategy.

It appears that the government's main strategy for addressing the green agenda is through the development of industrial parks. Many new industrial investments, particularly in the leather and textile sectors and especially by foreign companies, are being channelled into industrial parks, where centralised facilities are provided to clusters of similar firms to optimise environmental performance (e.g. through the provision of clean energy and wastewater treatment plants). Geographically dispersed firms, for example tanneries, are also encouraged to move into industrial parks. In contrast, many established firms are not subjected to environmental scrutiny, and thus have less incentive to adopt greener production techniques. They are also discouraged from entering the industrial parks by high entry costs. There are no additional incentives that encourage innovation in compliance with environmental standards. Therefore, from the environmental regulatory perspective, the incentives for green innovation amongst existing firms are limited. There also seems to be a problem in the mindset of the private sector businesses. Most businesses ignore the fact that they are responsible for the environment and fail to comply with standards.

6.1.3 Sectoral innovation in cement, leather and textile industries

The survey of innovation activities among enterprises in the cement, leather and textiles industries provided useful information about the extent of innovation (and specifically green innovation), the main drivers and inhibitors of innovation, and the linkages that firms have with other innovation system actors. The rate of product and process innovation was found to be low amongst cement and textile enterprises (less than 20% in each case). A large percentage of leather sector firms reported product innovation (65%), but only a moderate proportion (28%) engaged in process innovation. The extent of green innovation, defined as innovations that aimed to reduce energy, water and material inputs or solid, liquid and gaseous wastes, was substantially lower. Only 12% of firms reported green product innovations, and 15% engaged in green process innovation. However, according to the responses nearly half (46%) of all process innovations were undertaken to reduce inputs or wastes. The majority of product and process innovating firms in all three sectors said their enterprise developed the innovations by themselves, with relatively small percentages of firms collaborating with or relying entirely on other companies or organisations. The percentage of firms that reported investing in various types of activity to support product and process innovation was quite low in the case of cement and textile firms, but reasonably high (above 60% for four of the six investment categories) in the case of leather firms. This sectoral pattern of investment activity levels is consistent with the different rates of innovation reported across sectors. The survey results on the extent of innovation in the leather and textile sectors are broadly in line with statistics from other developing countries, although product innovation in Ethiopia's leather sector was particularly high, which might cast some doubt on the reliability of the responses.

Results from probit regression models shed some light on the characteristics of firms that make them more or less likely to innovate. The following firms were more likely to engage in product innovation: those with smaller turnover; firms in the leather sector (relative to cement and textile sector firms); enterprises not located in an industrial park; firms that produce for export; state-owned firms; and enterprises that invest in internal R&D. In the case of green product innovation, the only significant explanatory variable was investment in internal R&D. The probability of (general) process innovation

falls with increasing age of the firm, rises with turnover, is lower for leather sector firms, and is higher for exporting firms and those that invest in internal R&D. The same results were obtained for green process innovation, although in this case location in an industrial park was also significant, and reduced the probability of innovation.

For both leather and textiles producers, the most important drivers of innovation are increasing market share and improving the value of goods and services, while for cement firms it is reducing unit costs. Of concern is that “reducing environmental impacts” and “meeting environmental regulatory requirements” ranked amongst the least important motivators of innovation for firms in all three sectors. This is a clear indication that improved environmental policies and/or enforcement is needed to stimulate green innovations. 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. The cost of meeting government regulatory requirements did not feature as an important obstacle to innovation, which might indicate a lack of regulations or enforcement thereof. 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 in order to drive innovation.

When it comes to sources of information for innovation, firms generally relied more heavily on their own resources (within the enterprise or group), as well as on suppliers of equipment, materials, services or software, rather than on external sources such as universities, research institutes and government agencies. This implies that much more needs to be done to strengthen the linkages between public and academic innovation actors and firms to foster knowledge and technology transfers. This is further reinforced by the finding in the survey that the number of meetings between firms and most innovation system partners – especially universities – was very low.

On the positive side, the sectoral Industry Development Institutes appear to play some role in facilitating interactions and knowledge transfer. But the lack of established links between the relevant manufacturing sector development institutes and research institutions remains a key challenge of the sectoral innovation systems.

6.2 Policy recommendations

A number of recommendations emerge from the preceding analysis for policies that could help to stimulate green innovation in support of the country’s green industrialisation ambitions. Three key strategies are outlined below: (1) mainstreaming greening within the STI policy framework and promoting (green) innovation as a core part of the CRGE strategy; (2) enhancing the framework conditions for the national system of innovation so as to promote innovation in general; and (3) implementing policies designed to improve the functioning of the national and sectoral innovation systems. A critical aspect of the latter is implementing a combination of economic incentives and environmental regulations designed specifically to promote green innovation at the enterprise level.

Before proceeding to specific policy recommendations, a caveat is necessary. Schumpeterian theories of innovation-based economic development emphasize the process of ‘creative destruction’, whereby innovation and growth in dynamic sectors and firms causes disruptions to other sectors and enterprises, possibly putting some of them out of business. This disruptive influence of innovation inherently creates a tension between the national process of growth and economic transformation, and the development of specific incumbent subsectors (including cement, leather and textiles). Thus the process of innovation can have different outcomes at a national versus a sectoral level. At a

national level, innovation may result in growth overall but in some sectors being side-lined while others thrive, i.e. there will be sectoral winners and losers. Policy-makers must therefore be aware that by promoting the national innovation system, they could potentially create conditions that make the realisation of sector-specific industrial strategies (such as promotion of leather and textiles) more complicated or risky.

6.2.1 Mainstreaming green innovation and enhancing policy coordination

Effective governance requires proactive leadership, policy coherence, institutional capacity building and strong implementation of policies. Interviews with several high-level government officials confirmed that the former Prime Minister Meles provided strong leadership for the formulation of the CRGE strategy around 2009-2010 and its subsequent devolution through numerous government ministries. There has been similar high-level endorsement and support for national innovation policy from the top leadership; as indicated earlier, Ethiopia has promulgated an innovation policy and constituted an innovation council, which is led by the Deputy Prime Minister. However, judging from the results of the Ethiopian national innovation survey conducted by STIC (2015a) and the survey of cement, leather and textile firms conducted for this report, there is still much to be done to fully implement the national STI policy in order to stimulate a greater extent of innovation. Moreover, greater leadership and commitment to support *green* innovation specifically is required to support the implementation of the CRGE. Such commitment to green innovation also needs to filter down to relevant ministries (in particular the Ministry of Industry). This mainstreaming will help to foster the legitimization of green innovation and technologies, which is one of the important functions that the innovation system needs to perform.

Although the STI Policy does include some elements that are related to environmental policy, the need for green innovation needs to be raised in profile in order to align the policy with the desire for green industrialisation as motivated for in the CRGE. Conversely, green innovation also needs to be mainstreamed within the CRGE implementation process. However, as of today innovation has not been the particular focus, for example, in quarterly forum meetings involving the six main line ministries involved in implementing the CRGE. Moreover, the greening agenda has not been mainstreamed to the education system. All government departments that are involved in implementing the CRGE need to understand the importance of innovation as the key enabler of improving environmental performance. Mechanisms that have been created to facilitate inter-ministerial cooperation on the implementation of the CRGE should also be used to promote green innovation more explicitly. Ideally, there should be an inter-ministerial coordinating body to lead the innovation/greening industry agenda at the national level. Encouragingly, the revised Environmental Policy (a draft of which was published in December 2015) gives explicit attention to the need for policies to encourage green innovation.

At all levels, capacity building needs to occur to strengthen the ability of government departments to contribute to the green innovation agenda. Vertical policy coordination is required to ensure that different levels of government (federal, regional and local) are pulling in the same direction. In addition, horizontal policy coordination is necessary; for example, innovation policies also need to be dovetailed with other relevant policies, such as macroeconomic, trade, industrial and competition policies.

6.2.2 Enhancing the enabling environment for innovation

Although it is typically firms that bring innovations into the economy, government has a critical role to play by establishing conducive framework conditions, including the macroeconomic and business environment, large-scale infrastructure, and the broad educational and public knowledge creation

systems. These structural underpinnings are important for innovation in general as well as green innovation in particular.

Improving the macroeconomic and business environment

Ethiopia's strong and consistent economic growth record, and mostly stable price inflation (aside from exogenous price shocks), attest to the government's successful macroeconomic management through prudent fiscal and monetary policies. Such stable policies need to be maintained in order to maintain economic growth and thereby contribute to an overall economic environment that is conducive to innovation. One area of potential concern is the accumulation of large amounts of debt to finance infrastructure expansion, especially the construction of large dams with hydroelectric power supplies; the MoFEC needs to be wary of over-reach and ensure prudent debt management.

Compared to many other countries Ethiopia's innovation performance is low, thereby hampering the competitiveness of the economy. Trade policies should continue to promote international trade to facilitate inflows of technology and to incentivise both export and import competing firms to meet international product standards, including environmental standards, through product and process innovations. Ethiopia's industrial policies are encouraging foreign direct investments, and it appears that efforts are being made to ensure that new entrants stemming from FDI are – at least in principle – forced to comply with environmental regulations. However, many established firms are not subjected to environmental scrutiny. The government needs to devise proper instruments, which reward firms that comply and punish the violators. This way it can encourage innovation and also change the mindset of private businesses to internalize their negative environmental externalities. The lack of monitoring capacity and coordination among the regulatory bodies have been identified as major reasons for the lax enforcement of environmental regulations. Hence, monitoring and compliance need to be bolstered through the enhancement of capacity and coordination.

The UN (2011:131) states that “widespread adaptation and diffusion of green technologies require effective government industrial policies to “crowd in” private investment.” These could include subsidies and access to credit. Since one of the barriers to innovation identified by Ethiopian firms is the dominance of large incumbents, the promotion of competition could help to enhance the incentives to innovate.

Building quality infrastructure

Infrastructure can lay a supportive foundation for an innovative economy, but it can also reinforce incumbent regimes, so the type of infrastructure is important. The Ethiopian government has been investing heavily in infrastructure in recent years, especially for transport (roads and railways) and energy (mainly renewable hydropower and electricity transmission). A particular need of Ethiopia's innovation system is an accelerated rollout of communication infrastructure, especially to facilitate Internet connections. This will allow firms to more easily access information and to communicate more effectively with suppliers, consumers and other actors in the innovation system.

As mentioned in section 5.1, the Ethiopian government is focusing much of its resources in the area of industrial policy into the creation of industrial parks and export zones. These are supplied with grid electricity (increasingly from renewable energy sources) and centralised water treatment facilities where relevant. This is generally an efficient use of resources, and should help enterprises to exploit agglomeration economies and technological learning benefits. Since, as reported in an interview with a key stakeholder, many existing domestic firms find the cost of relocating to industrial parks

prohibitive, policy-makers could consider introducing tax breaks or rental subsidies to enable firms to take advantage of the opportunities for greening their activities and learning from other firms.

Expanding quality education and R&D

Public investment in education and science is essential to create the human capital that is required to generate, adopt and adapt new knowledge and technologies in the Ethiopian economy. As shown in section 4.1, Ethiopia's education system has expanded rapidly in recent years. Government policy should continue to expand and strengthen the basic educational system of primary and secondary education, which forms the foundation layer of human capital formation and fosters creativity and critical thinking skills. Furthermore, in the light of concerns about quality standards within sections of the rapidly expanding tertiary education system, the Ministry of Education should arguably aim to consolidate and enhance the quality of tertiary education before expanding it further. Quality education cannot be envisaged without due consideration to improve the skills and incentives of the academic staff. It will take time to grow cohorts of adequately qualified academics to staff the university sector, but sufficient incentives need to be put in place as soon as possible in order to attract and retain qualified staff.

The emphasis placed in the STI Policy on scientific, technical and engineering education is warranted, but in order to support green innovation, attention and resources need to be focused on the creation of environmental programmes at all levels of education. However, green innovation tends to be multidisciplinary in nature, drawing not just on environmental science, but also on a wide range of related fields, such as material science, chemistry, physics, engineering, energy studies, environmental science, Earth and planetary sciences, biochemistry, genetics and molecular biology, immunology and microbiology, and agricultural and biological sciences (OECD 2010: 36). Therefore, all of these disciplines should ideally be supported with appropriate levels of funding. Moreover, as shown above the bulk of government R&D funding is currently allocated for agriculture. This is not supportive for innovation in the manufacturing sector, and thus more funds should be allocated for engineering and technology.

As discussed earlier, the public good nature of basic and long-term research means that private sector actors typically underinvest in this critical element of innovation systems. This is especially the case in the low-income countries. Therefore, the Ethiopian government needs to continue playing the lead role in investing in research capacity to generate new knowledge and skills. While the recent increase in public spending on R&D in Ethiopia is commendable, it is important for a sufficient amount of funding to be allocated specifically for research programmes that generate knowledge and skills required for creating, adopting and diffusing *green* innovations. In addition, targets could be set for the training of increased numbers of R&D personnel who are skilled in environmental management, who can then ensure proper monitoring and control of private sector enterprises' environmental performance and regulatory compliance. The World Bank (2010:14) notes that "public research laboratories play a fundamental role in developing countries and should be equipped to respond efficiently to the need for technical research, technical assistance, certification, and quality control—functions that the business sector, which has low R&D capabilities in developing countries, is unable to perform." As the industry sector matures, another policy tool that can be used is the creation of special incentives (such as grants or tax breaks) to induce private sector firms to undertake green R&D activities.

6.2.3 Improving the functioning of the innovation system

In addition to bolstering the framework conditions, policies are required to support and enhance the functioning of the national and sectoral systems of innovation. As outlined in section 2.2.3 and

analysed in section 4.4, there are several aspects of innovation system functioning. At the national level, the ‘creation of legitimacy’ function is closely related to the mainstreaming of green innovation, which was discussed earlier. The following paragraphs discuss policies to address the other main dimensions.

Facilitating knowledge creation and exchange

Policies that lay the foundation for knowledge creation by stimulating education, science, research and development, have already been discussed in the previous section. A critical function of an innovation system, however, is to ensure that the knowledge that is generated in education and research institutions is effectively transmitted to businesses. This requires active mechanisms to strengthen the linkages between the various actors in the national and sectoral innovation systems, including government departments and agencies, HEIs (universities and TVET institutions), public research institutes, industry development institutes and associations, and enterprises. This is particularly relevant in Ethiopia given that the lack of – or weakness of – such linkages has been identified as a key limitation in both the Ethiopia Innovation Survey (STIC 2015a) and the firm survey conducted for this study. While the various industry development institutes (CCIIDI, LIDI and TIDI) are playing a leading role in facilitating linkages, they need adequate resources to ensure they have sufficient human and institutional capacity to fulfil their mandate. Greater resources could be provided for conferences, workshops and websites, which are all useful tools for sharing information. It is important to provide resources which allow small and medium-sized enterprises to partake in knowledge networks, not just larger firms. The industry development institutes should also be directed to prioritise support for innovation – and especially green innovation – among their enterprise constituencies. So far, the development institutes’ main engagement has been in facilitation activities for investors, which are mainly non-technical. They should become proactively involved in information gathering and dissemination regarding new and relevant technologies, including more environmentally sustainable products and production methods. The information dissemination can be further enhanced by establishing Science and Technology Information Centres under each of the sectoral development institutes. In 2011, Ethiopia established a national Science and Technology Information Centre (STIC) under the MoST. However, the STIC’s engagement is at a national level and too general to be helpful for innovation in the specific industries.

Another major policy opportunity is the formation of a programme to incentivise commercialisation of research activities at universities and to support collaboration with private sector firms. However, the OECD (2011e:12) cautions that support for commercialisation “should not be provided before technologies reach a sufficiently mature state of development.”

Improving market formation and access

As mentioned earlier, the demand side is also important as a stimulus for green innovation. There is a role for policy to help create markets for greener products and to assist firms to access such markets that may already exist, including international markets. Trade policies can help to expand access to foreign markets, and can encourage Ethiopian manufacturers to innovate in order to meet environmental standards set by other countries or regions, such as the European Union. In this regard, Ethiopia can brand the green manufacturing concept to enter export markets and enhance exports. In the case of domestic markets, public procurement can be an effective policy tool to encourage green innovations. For example, state-sponsored infrastructure projects could procure cement that is produced using process innovations that reduce CO₂ emissions. According to the World Bank (2010:13), “the experience of OECD countries offers a few valuable principles: define performance standards rather than set technical requirements; maintain fair competition in

tendering procedures; and offer small and medium firms a share of contracts (perhaps 10 percent).” Another way to boost markets for greener products is to raise consumer awareness, for example with eco-labelling. However, this is of less relevance at this early stage of Ethiopia’s development, since the domestic consumer base is very limited.

As mentioned in section 2.7.1, a carbon tax can provide strong incentives for firms to innovate in ways that reduce their carbon emissions (e.g. by adopting more energy efficient equipment), and at the same time the revenues generated by the tax could be directed towards greening efforts (such as subsidies for firms that innovate to reduce other environmental impacts such as pollution, or by subsidising clean energy). In the Ethiopian context, it must be borne in mind that utilisation of fossil fuels is currently limited; oil and coal together accounted for just 5.7% of the country’s primary energy supply in 2013 (IEA 2015). However, the cement industry is a notable user of coal, and so a carbon tax would incentivise energy efficiency and energy switching to low-carbon sources.

Mobilising finance for innovation

The high costs of innovation, together with lack of access to finance, were cited by many firms as significant barriers to innovation. Access to finance is often a key barrier to young entrepreneurial firms, which “play an important role in delivering more radical green innovations that challenge existing firms and business models” (OECD 2011e:12). This is particularly true in Ethiopia given the high level of collateral requirements in bank lending. As Kuriakose et al. (2016:66) note, “considering the major limitations of the financial sector in Ethiopia in lending to small and young entrepreneurs, there remains much need for targeted support to improve access to finance for innovative firms.” Several sources of financing exist in theory, including debt financing, equity financing, government funding of R&D, co-funding by government and firms, and subsidies. Given the shallow nature of the banking sector in Ethiopia, the Ethiopian Development Bank could play a major role in providing finance for innovation. This would entail a re-prioritisation of development objectives to give greater emphasis on supporting entrepreneurs and economic transformation.

The Ethiopian Climate Innovation Centre is playing a useful role in providing advisory services and matchmaking innovative firms with financiers and donors. The FRDE could contribute financially to support the work of the ECIC, and also to broaden its ambit into industrial sectors like leather and textiles (whereas the current focus is largely on energy efficiency and renewable energy). Similarly, the government could attempt to leverage international climate finance to fund green innovation. The Green Climate Fund administered by MoFEC, which is currently underutilized, can provide additional resources to motivate the private sector towards greening. The MoI needs to come up with sensible strategy to improve access of the private sector to this fund.

In addition to financing, various fiscal incentives can be used to stimulate R&D and innovation among firms. These can be either direct measures, such as contracts, grants and awards, or indirect incentives like R&D tax rebates, accelerated depreciation for R&D equipment, and duty exemption for imported inputs for R&D (OECD 2015b; World Bank 2010). Each instrument has advantages and disadvantages which need to be carefully weighed. In the case of young firms, the OECD (2015b:11) encourages governments to use more competitive and transparent grants and fewer tax incentives, since grants can be targeted towards high-impact areas and because “young firms often have not yet generated taxable income, which may prevent them from using (non-refundable) R&D tax incentives.” The Ethiopian government should carefully assess R&D tax incentive policies to ensure they provide value for money, and it is important that such incentives are stable and relatively predictable for firms.

Fostering skill development

Skill development is clearly an intended outcome of the investments in broad educational and research capacity that was discussed earlier in the context of framework conditions. However, the promotion of green innovation requires the identification of specific skills that are required to adopt and adapt green technologies. This reinforces the need for education and training programmes at HEIs that are aligned with the greening agenda. More broadly, a healthy innovation system requires a wide range of skills. There is a need for ‘hard’ skills in engineering, design, and business, but also ‘soft’ skills like teamwork, communication, problem solving, and a sound work ethic (World Bank 2010:15). The conditions that firms face in terms of acquiring highly-skilled human capital are important for their ability to innovate and adopt new knowledge (TIPP 2013). This in turn depends on policies that influence the availability of skilled labour, the cost of hiring/firing, and migration of skilled workers into and out of the country. To the extent that the appropriate skills are in limited supply domestically, it may be necessary to attract such skilled personnel from abroad. In this regard, the primary target should be on the highly qualified Ethiopian diaspora (brain gain).

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Appendix: Probit regression model results

The following tables provide the complete regression output generated by the EViews econometric software for probit models of product innovation, green product innovation, process innovation and green process innovation, respectively. In each case, the output for both full specifications and reduced forms is given.

Table 17: Full probit model output for product innovation

Dependent Variable: PRODUCT_INN

Method: ML - Binary Probit (Quadratic hill climbing)

Sample (adjusted): 2 117

Included observations: 93 after adjustments

Convergence achieved after 6 iterations

QML (Huber/White) standard errors & covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	1.962022	1.716092	1.143308	0.2529
AGE	0.001224	0.009525	0.128481	0.8978
LOG_TURNOVER	-0.289599	0.135817	-2.132273	0.0330
LOG_EMPT	0.197947	0.178541	1.108695	0.2676
CEMENT	-0.391818	0.557203	-0.703186	0.4819
LEATHER	1.195166	0.512984	2.329832	0.0198
IND_PARK	-1.683550	0.575641	-2.924654	0.0034
EXPORTER	0.951786	0.445470	2.136588	0.0326
FOREIGN	0.145177	0.537592	0.270051	0.7871
STATE_OWNED	1.943662	0.917425	2.118606	0.0341
INV_OWNRND	1.233280	0.472239	2.611560	0.0090
McFadden R-squared	0.483062	Mean dependent var		0.290323
S.D. dependent var	0.456371	S.E. of regression		0.340206
Akaike info criterion	0.859407	Sum squared resid		9.490668
Schwarz criterion	1.158962	Log likelihood		-28.96244
Hannan-Quinn criter.	0.980359	Deviance		57.92489
Restr. deviance	112.0539	Restr. log likelihood		-56.02694
LR statistic	54.12900	Avg. log likelihood		-0.311424
Prob(LR statistic)	0.000000			
Obs with Dep=0	66	Total obs		93
Obs with Dep=1	27			

Table 18: Reduced form probit model output for product innovation

Dependent Variable: PRODUCT_INN
Method: ML - Binary Probit (Quadratic hill climbing)
Sample: 1 117
Included observations: 97
Convergence achieved after 5 iterations
QML (Huber/White) standard errors & covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	1.170901	1.686469	0.694292	0.4875
LOG_TURNOVER	-0.182761	0.108720	-1.681019	0.0928
CEMENT	-0.491178	0.503798	-0.974951	0.3296
LEATHER	1.070098	0.465333	2.299637	0.0215
IND_PARK	-1.494342	0.505753	-2.954686	0.0031
EXPORTER	1.045081	0.451000	2.317256	0.0205
STATE_OWNED	1.951978	0.889207	2.195191	0.0281
INV_OWNRND	1.289546	0.480014	2.686475	0.0072
McFadden R-squared	0.480812	Mean dependent var		0.298969
S.D. dependent var	0.460184	S.E. of regression		0.338121
Akaike info criterion	0.798346	Sum squared resid		10.17501
Schwarz criterion	1.010693	Log likelihood		-30.71977
Hannan-Quinn criter.	0.884209	Deviance		61.43954
Restr. deviance	118.3377	Restr. log likelihood		-59.16886
LR statistic	56.89818	Avg. log likelihood		-0.316699
Prob(LR statistic)	0.000000			
Obs with Dep=0	68	Total obs		97
Obs with Dep=1	29			

Table 19: Full probit model output for green product innovation

Dependent Variable: GREEN_PRODINN
Method: ML - Binary Probit (Quadratic hill climbing)
Date: 08/03/16 Time: 10:13
Sample (adjusted): 2 117
Included observations: 92 after adjustments
Convergence achieved after 5 iterations
QML (Huber/White) standard errors & covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-1.645682	1.665178	-0.988292	0.3230
AGE	-0.020165	0.014451	-1.395413	0.1629
LOG_TURNOVER	-0.094750	0.137890	-0.687142	0.4920
LOG_EMPT	0.267997	0.222166	1.206293	0.2277
LEATHER	0.271606	0.568709	0.477583	0.6329
IND_PARK	-0.407568	0.466437	-0.873790	0.3822
FOREIGN	-0.501413	0.559401	-0.896338	0.3701
INV_OWNRRND	1.756778	0.565120	3.108681	0.0019
McFadden R-squared	0.288845	Mean dependent var		0.108696
S.D. dependent var	0.312963	S.E. of regression		0.292021
Akaike info criterion	0.662874	Sum squared resid		7.163213
Schwarz criterion	0.882160	Log likelihood		-22.49221
Hannan-Quinn criter.	0.751380	Deviance		44.98442
Restr. deviance	63.25544	Restr. log likelihood		-31.62772
LR statistic	18.27102	Avg. log likelihood		-0.244481
Prob(LR statistic)	0.010805			
Obs with Dep=0	82	Total obs		92
Obs with Dep=1	10			

Table 20: Reduced form probit model output for green product innovation

Dependent Variable: GREEN_PRODINN
Method: ML - Binary Probit (Quadratic hill climbing)
Date: 08/03/16 Time: 10:35
Sample: 1 117
Included observations: 115
Convergence achieved after 5 iterations
QML (Huber/White) standard errors & covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-1.744448	0.263168	-6.628658	0.0000
INV_OWNRRND	1.126463	0.336650	3.346097	0.0008
McFadden R-squared	0.145442	Mean dependent var		0.121739
S.D. dependent var	0.328415	S.E. of regression		0.310967
Akaike info criterion	0.667798	Sum squared resid		10.92716
Schwarz criterion	0.715536	Log likelihood		-36.39839
Hannan-Quinn criter.	0.687175	Deviance		72.79679
Restr. deviance	85.18644	Restr. log likelihood		-42.59322
LR statistic	12.38965	Avg. log likelihood		-0.316508
Prob(LR statistic)	0.000432			
Obs with Dep=0	101	Total obs		115
Obs with Dep=1	14			

Table 21: Full probit model output for process innovation

Dependent Variable: PROCESS_INN

Method: ML - Binary Probit (Quadratic hill climbing)

Sample (adjusted): 2 117

Included observations: 93 after adjustments

Convergence achieved after 6 iterations

QML (Huber/White) standard errors & covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-6.036761	1.905005	-3.168895	0.0015
AGE	-0.026215	0.012764	-2.053874	0.0400
LOG_TURNOVER	0.222733	0.150416	1.480778	0.1387
LOG_EMPT	0.149331	0.201379	0.741538	0.4584
CEMENT	-0.997391	0.737201	-1.352943	0.1761
LEATHER	-0.890224	0.569933	-1.561982	0.1183
IND_PARK	-1.099354	0.470722	-2.335462	0.0195
EXPORTER	1.110901	0.539052	2.060843	0.0393
FOREIGN	0.008798	0.517898	0.016988	0.9864
INV_OWNRRND	1.539762	0.547863	2.810489	0.0049
McFadden R-squared	0.390949	Mean dependent var	0.172043	
S.D. dependent var	0.379463	S.E. of regression	0.310909	
Akaike info criterion	0.774298	Sum squared resid	8.023163	
Schwarz criterion	1.046620	Log likelihood	-26.00485	
Hannan-Quinn criter.	0.884254	Deviance	52.00970	
Restr. deviance	85.39463	Restr. log likelihood	-42.69732	
LR statistic	33.38493	Avg. log likelihood	-0.279622	
Prob(LR statistic)	0.000114			
Obs with Dep=0	77	Total obs	93	
Obs with Dep=1	16			

Table 22: Reduced form probit model output for process innovation

Dependent Variable: PROCESS_INN
Method: ML - Binary Probit (Quadratic hill climbing)
Sample: 1 117
Included observations: 95
Convergence achieved after 5 iterations
QML (Huber/White) standard errors & covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-5.427542	1.634358	-3.320902	0.0009
AGE	-0.017543	0.008811	-1.991035	0.0465
LOG_TURNOVER	0.212486	0.092505	2.297019	0.0216
IND_PARK	-0.753332	0.465241	-1.619229	0.1054
EXPORTER	0.959679	0.500611	1.917015	0.0552
INV_OWNRRND	1.043173	0.371200	2.810268	0.0050
McFadden R-squared	0.286904	Mean dependent var		0.168421
S.D. dependent var	0.376225	S.E. of regression		0.325473
Akaike info criterion	0.772914	Sum squared resid		9.428027
Schwarz criterion	0.934211	Log likelihood		-30.71341
Hannan-Quinn criter.	0.838090	Deviance		61.42682
Restr. deviance	86.14101	Restr. log likelihood		-43.07050
LR statistic	24.71419	Avg. log likelihood		-0.323299
Prob(LR statistic)	0.000158			
Obs with Dep=0	79	Total obs		95
Obs with Dep=1	16			

Table 23: Full probit model output for green process innovation

Dependent Variable: GREEN_PROGINN
Method: ML - Binary Probit (Quadratic hill climbing)
Date: 08/03/16 Time: 10:27
Sample (adjusted): 2 117
Included observations: 93 after adjustments
Convergence achieved after 6 iterations
QML (Huber/White) standard errors & covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-8.452647	2.268821	-3.725569	0.0002
AGE	-0.031827	0.011793	-2.698818	0.0070
LOG_TURNOVER	0.348947	0.175218	1.991506	0.0464
LOG_EMPT	0.016940	0.228020	0.074293	0.9408
CEMENT	-0.495361	0.580850	-0.852821	0.3938
LEATHER	-1.362790	0.629344	-2.165415	0.0304
IND_PARK	-0.947401	0.508398	-1.863505	0.0624
EXPORTER	1.886393	0.554851	3.399822	0.0007
FOREIGN	-0.540511	0.565964	-0.955027	0.3396
INV_OWNRRND	2.000598	0.644515	3.104036	0.0019
McFadden R-squared	0.470632	Mean dependent var		0.129032
S.D. dependent var	0.337053	S.E. of regression		0.259054
Akaike info criterion	0.622183	Sum squared resid		5.570058
Schwarz criterion	0.894506	Log likelihood		-18.93153
Hannan-Quinn criter.	0.732139	Deviance		37.86305
Restr. deviance	71.52498	Restr. log likelihood		-35.76249
LR statistic	33.66193	Avg. log likelihood		-0.203565
Prob(LR statistic)	0.000102			
Obs with Dep=0	81	Total obs		93
Obs with Dep=1	12			

Table 24: Reduced form probit model output for green process innovation

Dependent Variable: GREEN_PROCINN
Method: ML - Binary Probit (Quadratic hill climbing)
Sample: 1 117
Included observations: 95
Convergence achieved after 6 iterations
QML (Huber/White) standard errors & covariance

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-7.353827	1.941155	-3.788378	0.0002
AGE	-0.020856	0.009884	-2.109939	0.0349
LOG_TURNOVER	0.293272	0.118499	2.474886	0.0133
CEMENT	-0.662133	0.551666	-1.200243	0.2300
LEATHER	-1.399455	0.571147	-2.450256	0.0143
IND_PARK	-0.914261	0.476301	-1.919501	0.0549
EXPORTER	1.526535	0.593425	2.572414	0.0101
INV_OWNRRND	1.871816	0.607476	3.081302	0.0021
McFadden R-squared	0.434010	Mean dependent var	0.126316	
S.D. dependent var	0.333967	S.E. of regression	0.262218	
Akaike info criterion	0.597807	Sum squared resid	5.981956	
Schwarz criterion	0.812870	Log likelihood	-20.39583	
Hannan-Quinn criter.	0.684709	Deviance	40.79165	
Restr. deviance	72.07131	Restr. log likelihood	-36.03565	
LR statistic	31.27966	Avg. log likelihood	-0.214693	
Prob(LR statistic)	0.000055			
Obs with Dep=0	83	Total obs	95	
Obs with Dep=1	12			