Available online at www.elixirpublishers.com (Elixir International Journal)

Educational Technology

Elixir Edu. Tech. 100 (2016) 43517-43529

ISSN: 2229-712X

Initiatives to Promote Commercialization of Research Outputs by Kenyan Universities

John G Ayisi, Gideon M Kivengea and George A Ombakho

Directorate of Research Management and Development, State Department of University Education, Ministry of Education, Nairobi, Kenya.

ARTICLE INFO

Article history:

Received: 12 September 2016;

Received in revised form:

29 October 2016;

Accepted: 10 November 2016;

Keywords

University,

Commercialization,

Research Outputs,

IPRs,

Kenya.

ABSTRACT

In this emerging era of global, fast-paced knowledge-based economy, universities, as major centres of learning and research, are becoming increasingly important as sources of ideas, knowledge, skills, innovation and technological advances. These ideas can be turned into new products, processes and systems needed to drive their respective national economies, and thus placing universities at the centre of the national innovation systems. Consequently, commercialization of research outputs from universities to industry has become an area of strong policy interest in African countries. To assess initiatives to commercialize research outputs by Kenyan universities, a cross-sectional study was carried out in seventeen well established universities (15 public and 2 private), all accredited by the Commission for University Education, Kenya. Deans, Registrars, Directors or Deputy (Directors/Vice Chancellors) responsible for research and development were interviewed. All the surveyed universities had a strategic plan; though not all had innovation and commercialization as part of it. More than half of the seventeen surveyed universities indicated to have established designated offices for fostering commercialization. Majority had guidelines on Intellectual Property Rights (IPRs), which advocate for IP to be co-owned by researcher/university. University-industry linkages are weak. Most universities are taking precursory steps to incentivize and encourage entrepreneurial activities among their academic staff and students, even though the level of resources devoted to them is low. It is recommended that building capacity in entrepreneurship among staff and students and committing more resources to Research and Development (R&D) activities hold potential to increased commercialization of university research outputs in Kenya.

Views expressed here are of the authors and do not imply endorsement by the Kenyan Ministry of Education.

Introduction

Knowledge-based economy

Nowadays, knowledge, technology, innovation and human capital are generally understood as central and key drivers for generating sustainable economic growth and competitiveness. They represent key explanations for significant and persistent divergences in economic growth and development between countries and regions (Howells, 2005) - not natural resources or exports based on cheap labour. Knowledge-based economy is depended on high investment in education and training, research and development (R&D), the presence of high-quality scientific research institutions, extensive relationships between governments, academia, and industry and the protection of intellectual property (Lowe, 2005; World Economic Forum, 2010/2011). The university is thus a key element of the innovation system both as a human capital provider and a seed-bed of new firms (Etzkowitz *et al*., 2000; Laredo and Mustar, 2001). To realize the benefits of knowledge and to receive returns from these investments, the resulting innovations or inventions must be sold, or commercialized (Meyers, 2009).

For emerging countries, the creation of conditions conducive to innovation and successful technology transfer is no longer a choice, but an imperative (Rodriguez-Pose and Hardy, 2014). Research is thus, a vital component of the mission of universities, and indeed academic institutions conduct a substantial volume of research that is funded by government, industry and philanthropic agencies (Vanderford and Marcinkowski, 2015). Development or the commercialization of research should also be a key component of universities' research mission such that novel ideas, knowledge, skills, innovation, technological advances and products, particularly so in the enabling technologies such as information and communications technologies, biotechnology and nanotechnology that can enter the marketplace for the benefit of a variety of stakeholders including inventors, universities and society. Thus, the production, distribution and use of knowledge and information will increasingly be a distinguishing factor of strong economies and robust societies in the 21st century (Audretsch *et al*., 2006). Across the globe, universities are therefore being positioned as strategic assets in innovation and economic competitiveness, and as problem-solvers of socio-economic challenges affecting their countries,

Tele: +254 721 299 540

E-mail address: ayisijohn@yahoo.com

thus placing them at the centre of the national innovation systems (Nelson, 1993; OECD, 1997).

Traditionally, teaching and research have been the university's main roles. However, commercialization of research results or entrepreneurial science also referred to as, 'technology/knowledge transfer', 'third stream' 'third mission' or 'engagement', has emerged as an additional role for universities as stimulators and facilitators of knowledge transfer (Perkmann *et al*., 2012). The 'third stream' is about the interactions between universities, industry and the rest of society, and can be said to be "the stimulation and direct application and exploitation of knowledge for the benefit of the social, cultural and economic development of society" - *i.e*., community outreach (Molas-Gallart *et al*., 2002), making technology available to end-users (Tahvanainen and Nikulainen, 2010).

Studies into the 'third mission' of academic institution highlight that universities have matured in their approach to technology transfer, in what appears to be a more iterative and cyclical process of innovation diffusion, such that the double-helix character of DNA has been metaphorically adapted to describe the university-industry-government relationship, this time as a *'triple-helix'* to encourage development (Leydesdorff and Etzkowitz, 1996; Etzkowitz and Leydesdorff 2000). The intertwined (overlapping) relationship of the triple-helix suggests that the movement of knowledge is not necessarily one way but rather cycles in and out (iterative) of each triple-helix partner depending on the nature of the technology and the sources of intellectual capital best suited to its movement (Powers and Campbell, 2011). In this sense universities (and independent research institutions) are not only a source of knowledge, but are also active participants in the organization, development and commercialization of innovation. More recently, there has been the inclusion of the 'the market/society' as a fourth strand to the helix, leading to a '*Quadruple helix*' model (Carayannis and Campbell 2009). This makes a perfect sense since the desired output of the triple helix activity is new and innovative products and services, which have to relate to the market and society in order to generate jobs and wealth and ultimately achieve greater competitiveness (Carayannis and Campbell 2010).

Thus, knowledge flows from universities (and research institutions) are much more diverse than they had been in the past, with publications and paper presentations at meetings being just two among a wide array of transfer mechanisms. Commercialization as a new form of technology transfer is becoming increasingly common which can be either directly, by nurturing academic entrepreneurship in incubation centres, or indirectly, by transferring knowledge and sharing expertise through consulting, joint research ventures, patenting, licensing of intellectual property, contract research or forming start-up companies (Cohen *et al*., 2002).

Commercialization is however, not a straightforward process; as many challenges must be overcome (Al Natsheh *et al*., 2015). It has been shown that new knowledge from universities must penetrate what is known as *''the knowledge filter''* in order to contribute to innovation, competitiveness and ultimately economic growth (Audretsch *et al*., 2006; Acs *et al*., 2010). The knowledge filter is defined as the barrier or gap between the investment in new knowledge and its commercialization (Al Natsheh *et al*., 2015); and has been associated with bureaucratic red tape and illogical government regulation (Audretsch, 2014).

Bayh-Dole Act and commercialization of university research

In order to penetrate a formidable knowledge filter and facilitate university entrepreneurship and technology transfer from the university, the U.S. Congress attempted to remove potential obstacles to university technology transfer and commercialization by passing the University and Small Business Patent Procedures Act of 1980, more commonly known as the Bayh-Dole Act, 1980 (Link *et al*., 2007; Kenney and Patton 2009). This Act established the legal framework for commercializing the research that is developed within university settings by transferring the ownership of intellectual property (IP) from the publicly funded granting agencies to the universities (Thursby and Thursby, 2003). The logic was to give the universities incentives to support and build an infrastructure for the commercialization of research, with licensing preferences going to small businesses and industries within the United States (Link *et al*., 2007; Kenney and Patton 2009).

This policy change stressed the expectations that the universities could contribute more directly to industrial development (Stevens, 2004). It played a critical role in rejuvenating the entire U.S. economic system, transforming it from a manufacturing base to an innovation base (Loise and Stevens, 2010). Prior to the Bayh-Dole Act, the United States government owned and managed intellectual property developed at academic institutions as the result of federal funds, hence, nobody could exploit the outputs of publicly funded research without tedious negotiations with a federal agency concerned (Kesselheim and Rajkumar, 2011). Because of this arrangement, patent protection and licensing of technology was rarely pursued (Kirschenbaum, 2002). Worse, companies found it nearly impossible to acquire exclusive rights to a government owned patent, and without that, few firms were willing to invest millions more of their own money to turn a basic research idea into a marketable product (Audretsch, 2014).

Bayh-Dole Act (1980), led to a massive increase in funding to universities by venture capitalists (Valentine and Claasen, 2002), resulting in a rapid rise in commercial knowledge transfer from university to industry (Jensen and Thursby, 2001), through mechanisms such as, partnerships, licensing agreement and university start-ups, also known as "spin-offs" or "Spin-outs" (Banal-Estañol and Macho-Stadler, 2010). For example, a commercialization survey by the Association of University Technology Managers (AUTM – the technology transfer profession's interest organization) among United States-based institutions showed that due to the Act, the number of patents granted to US universities increased from 589 in 1985 to more than 3200 in 2006 (AUTM, 2007). In addition, there were 16000 patent applications and 553 spin-off establishments in the same year. Start-ups are "new firms created to exploit commercially some knowledge, technology, or research results developed within a university" (Pirnay *et al*., 2003).

Research has pointed out that there are two essential determinants explaining the process of knowledge transfer from universities to industry namely: (1) the linkages between researchers and research users, such as private firms and government agencies; and (2) the focus of the research projects on users' needs *i.e*., research that is-fit-for purpose (Landry *et al*., 2007). As a result, the United States has become very advanced in technology transfer and commercialization (TT&C) because of this Act, which has been in effect for more than 30 years (Loise and Stevens,

2010). The subsequent success of Bayh-Dole Act as a catalyst in the US for bringing new research findings to the marketplace inspired legislative changes in many OECD and beyond countries such as Germany, Denmark, Japan, Canada, India, the United Kingdom and Singapore to enact similar laws to this Act (Slaughter and Leslie, 1997; OECD, 2003; Mowery and Sampat, 2005).

The Role of University in knowledge-based economy

Since policymakers increasingly view universities as engines of economic progress via the commercialization of intellectual property through technology transfer (Siegel and Phan, 2005), many governments around the world are supporting the establishment of more universities and taking action to foster an enabling environment for strengthened university-industry linkages (Leydesdorff and Etzkowitz, 1996; Laredo and Mustar, 2001). In Africa for instance, the relative importance of university research commercialization as a driver of the national economy has also increasingly come to the fore in higher education policy dialogue (African Higher Education Summit, 2013, Bolo *et al*., 2015a).

In Kenya, Universities have increased from 1 in 1983 to 70 in 2015 (www.cue.or.ke), enabling an increasing share of the population to have access to knowledge and thus benefiting communities through increased range of higher education institution's teaching and learning resources and research. The investments made are in expectation of benefits that can be reaped by the researchers as well as enriching the growth of the country's economy. Within the National Innovation System framework, innovation is viewed as a collective process in which firms do not innovate in isolation but within a larger system involving other firms, universities, research centres, government agencies and other actors (Freeman, 1987). Early network between universities with industry gives a greater chance that the invention will be exploited (Colyvas *et al*., 2002).

Kenya Vision 2030 and knowledge-based economy

Consistent with the above contexts, and in its economic development blue print Kenya Vision 2030, the country aspires to transform into "a globally competitive and newly industrialized middle income country, providing a high quality standard of life to all its citizens" by the year 2030 (GoK, 2007). This Vision is anchored on three pillars – economic (building a globally competitive and prosperous economy), social (a just and cohesive society with social equity in a clean and secure environment) and political (a democratic political system that protects rights and freedoms of every individual) – with science, technology and innovation as the foundation upon which the three pillars are erected. Based on the Vision, the Government of Kenya views technological innovation as an important component of the national economy and its intention is to move from a "*factor-driven*" model of economic development to one that is technology- and knowledge-based, "*innovation-driven*", with both "competitiveness" and "industrialization" as core drivers of the Vision being knowledge dependent.

Kenya Science, Technology and Innovation policy and Framework for knowledge-based economy

The Second Medium Term Plan of Vision 2030, (MTP2, 2013-2017), whose focus is on a transformative country; the Science, Technology and Innovation sector has an overarching theme, *"Harnessing Science, Technology and Innovation for Regional and Global Competitiveness"* (GoK, 2013a). MTP2 recommends for intensifying the coordination of technology, innovation, research, development and commercialization as a flagship programme for sustained productivity growth. Customized to the Vision, the country formulated ST&I Policy framework, consisting of the ST&I policy and strategy (2008) and enacted the Science, Technology and Innovation Act in 2013, (ST&I Act, 2013) that emphasize the need for a functional innovation system in which universities (and public research institutes) play a leading role in knowledge and technology generation through research and development (Bolo *et* al., 2015a; GoK, 2013b).

The ST&I Act, (2013) was mainly to address deficiencies in the development of ST&I in the country through creation of infrastructure, institutions, capacity for R&D, technology transfer and diffusion, establishing funding policies and mechanisms for research and technological innovation, reviewing, evaluating and enhancing the performance of science and technology system and promoting the mainstreaming of science and technology within all sectors of the economy and ensuring they are taking hold. The Act created three strategic institutions to promote research, development and innovation in Kenya through improved steering and financing mechanisms. These institutions are the:

– National Commission for Science, Technology and Innovation (NACOSTI) – with enhanced mandate to regulate, plan, coordinate, develop, monitor and evaluate, assure quality, and advise the Government on all matters of ST&I related activities

– Kenya National Innovation Agency (KENIA) - to develop and manage the National Innovation System, investing in research infrastructure and support mechanisms to facilitate the commercialization of research discoveries and other enabling technologies needed to conduct world-class research, as well as to attract and retain highly qualified researchers and;

– National Research Fund (NRF), to mobilize and manage financial resources at 2% of the country's GDP for R&D. The Fund is to be used to create knowledge, innovation and development in all fields of science and technology, including indigenous knowledge

Thus, the ST&I framework emphasizes the development of an efficient R&D infrastructure; strengthening networks between higher education, academic entrepreneurs, technological institutions, and local industries in support of R&D projects, technology transfer, the provision of risk capital for new innovative companies, university infrastructure, micro-financing for start-ups, seed coaching and stipends for academic entrepreneurs. These institutions are to bridge the "innovation chasm," which describes the gap between knowledge generators (universities and research institutions) and the market.

Against this background, commercialization of university research outputs, amongst other things, requires the universities to possess appropriate policies and management systems to support research commercialization (Slaughter and Leslie, 1997). Many of the initiatives by universities to commercialize their research in Kenya are rather new and no research has investigated them. Thus, the Directorate of Research Management and Development, of the State Department of University (Higher) Education, Ministry of Education undertook this survey in a section of Kenyan universities purposively selected to get an overview of the progress of translating research outputs into marketable products and services, and document successes in university research, development and commercialization activities of research outputs. The study was to elucidate any areas where

there is insufficient or inappropriate support for such activities; so that advocacy and support could help universities overcome any barriers to commercializing their research outputs.

Ethical Issues

This research involved the handling of human subjects, principally through interviews to collect a substantial body of information. Ethical obligation was met through the following:

- The project did not elicit any information about intimate private details of the participants;
- The project was conducted for legitimate purposes and undertaken by well qualified and experienced investigators using a high level of skill and care;
- Participants were well-informed of the aims, focus, value and benefits of the project, and were provided with background information to permit them to make an informed judgment on whether to participate;
- Informed and voluntary consent was obtained from participants prior to the start of interviews;
- Participants who agreed to be interviewed were free to refuse to answer any questions;
- Anonymity and confidentiality of participants was strictly maintained to avoid attributing any particular point of view or comments to a single individual

Methodology

Survey Questionnaire

A questionnaire was developed (in English) and standardized by being piloted in 3 universities within Nairobi. In light of the comments and recommendations received, changes were made to the survey questions with the aim of clarifying and simplifying the questionnaire. The final questionnaire comprised of 70 short questions, primarily close-ended with a small subset of open-ended questions also included.

The questionnaire was shaped to generate data around seven sub-sections:

1. University Commercialization Environment;
2. Management of Commercialization Activities;
3. Commercialization Office;
4. Intellectual Property Rights (patents and copyrights);
5. Early Stage Financing and Venture Capital;
6. Industrial Linkages; and
7. Technology Parks and Incubators established.

Although universities-industry linkages are a two-way relationship, the scope of this study focused exclusively on the university-side dynamics with a view to informing the development of capacity-building interventions and advocacy tools for the Kenyan universities.

Sample population

Twenty-three (23) well-established of the total 70 Kenyan universities (www.cue.or.ke) were purposively selected to participate in this survey.

Study procedure

To reduce non-response, the approach for this survey employed site visits for in-person face-to-face semi-structured interviews with well-informed persons. We focused survey on mostly well-established major public and private universities and are thought to be far more representative of the average university experience with technology transfer in Kenya. All the Vice Chancellors (VCs) of selected universities were informed of the survey two weeks prior to the visit and requested for their cooperation. Upon visiting the survey university, the study staff visited the Vice Chancellor's office for formal introduction and giving highlights of the study. Where individuals other than VCs were found, the survey staff requested that those persons work through the VC's office to ensure an institutional rather than a personal response. For their part, those VCs contacted directly were asked to designate an appropriate individual to coordinate data collection from across the institution. These instructions were given to ensure that appropriate, well-informed individuals were charged with providing the data.

Interviews were conducted according to a prepared script and structured as a series of focused questions to elicit specific information on known issues of importance in order to obtain the views and experiences of the interviewees. Interviews were conducted at the premises of the interviewees between October 2014 and April 2015, and lasted between 30 and 60 minutes. However, when the questionnaire could not be filled for one reason or the other, it was left behind, and institutions were originally given a total of two weeks to respond, plus an additional one week extension. In the final week, non-respondents were contacted by telephone. In addition, when questionnaire was left behind, any unclear issues were also addressed through a phone call.

Data management and analysis

Study variables were coded and entered in the computer for analysis by Statistical Package for Social Sciences (SPSS) software for windows version 17.0.

Results

Seventeen (17) of the 23 universities responded, giving a response rate of 73.9%, which is most satisfying (Grimm and Jaenicke, 2012). Of the 17 universities, 15 were Public and 2 private. Of the 5 universities that did not respond, 2 were public and 3 private. The majority of respondents who submitted a response on behalf of their institution hold positions at the senior management level (Table 1). The title/position for 82.4% of the respondents was Dean, Registrar, Director or Deputy (Director/Vice Chancellor). Only three of 17 (17.6%) respondents held titles such as Technology Transfer Officer, Research Officer or Research Fellow (Table 1).

Table 1. Position of respondents

Position	Frequency	Percent	Cumulative Percent
DVC	3	17.6	17.6
D/Director	6	35.3	52.9
Registrar	4	23.5	76.5
Dean	1	5.9	82.4
TTO	1	5.9	88.2
Research Officer	1	5.9	94.1
Research Fellow	1	5.9	100.0
Total	17	100.0	

DVC (Deputy Vice Chancellor) TTO (Technology Transfer Officer)

Key areas of Research

From this survey, eighteen key areas of research were identified as, dominated by agriculture, the humanities, engineering and the health sciences (Table 2).

University Commercialization Environment

This survey examined an overview of Kenyan universities research commercialization environment to provide the background of current achievements and resources available for driving research, development and commercialization (RD&C).

Of the 17 respondent universities, 15 had information on number of enrolled students. The mean and standard deviation (SD) of number of students was 13127 (19507), range (1700 - 82000), with a median of 8000, IQR, (5000,

12000) students (Table 3). The increased expectations that universities should contribute to the commercialization of research have led to a number of initiatives at study universities. The most salient feature that emerged from this survey is that all the surveyed universities had a strategic plan (Table 3), which is known to provide an important overarching vision for shaping and directing research priorities (Parker *et al*., 1993).

Table 2. Key areas of research

Area of Research	No. of respondents (n=17)	% respondents
Food/Agriculture and Biotechnology	10	58.2
Human/Social sciences	7	41.2
Engineering	7	41.2
Health Sciences	6	35.3
Physical Sciences	4	23.5
Environment and resource management	4	23.5
Science and Technology	4	23.5
Education	3	17.6
ICT	2	11.8
Biosciences	2	11.8
Energy	2	11.8
Mobile Applications	1	5.9
GIS	1	5.9
Tourism/Hospitality	1	5.9
Dry land Agriculture	1	5.9
Mining and Minerals	1	5.9
Marine/Oceanic sciences	1	5.9
Arts, Culture and Languages	1	5.9

ICT (Information Communication Technology) GIS (Geographical Information system)

Regarding university expenditure on research and development, the geometric mean expenditure on R&D (range) was 21.1M (2M-3.5B) (Table 3). If the country is to transit to knowledge-based economy, then the low level of investment in R&D in studied universities is a matter of concern. It was also noted that the lion's share of research funding is concentrated in a handful of oldest universities, with well-established research reputations, experienced scientists, and are typically receptive to entrepreneurial startups. These top performing universities attract the bulk of research funding while the smaller universities are much less likely to attract significant funding.

Though many universities (and public research institutes) now have the words innovation, entrepreneurship, community outreach, extension, enterprise etc as part of their vision, mission or motto, a small number of them neither had an innovation policy nor commercialization as part of their strategic plan (Table 3). For the country's competitiveness, this should also be a point of concern to policy makers and the university management.

Similarly, universities have created offices within their top management ranks such as deputy vice chancellors and directorates in charge of innovation, entrepreneurship, extension and community outreach programmes. Further, nearly all the public universities have some form of technology transfer office (TTO) or intellectual property management office (IPMO), to facilitate the spillover of knowledge by commercializing research undertaken at the universities.

Most universities (and research institutes) have in many cases evolved in isolation from the private sector. As such, they have little experience partnering with firms, sharing knowledge, or participating in commercialization process. This results in an environment where the fruits of public R&D projects rarely become commercialized, as without a history of interaction, firms lack a demand for the output of research institutions, becoming a major institutional impediment to the technology transfer process. Thus, the model of commercialization in most of the studied universities is based on the 'supply push', a linear model of innovation, which is built on the notion that breakthroughs by public research can be channeled through to local marketplace for commercialization and, in doing, so foster innovation and technological development in step-by-step process. However, this model is known to be slow and with increased risk of not commercializing research outputs. This calls for collaboration betweens universities and the industry in order to increase commercialization.

Among the scheme to encourage commercialization is to give staff time off to undertake commercialization, promotion to be based on commercialization or give financial benefits to staff for commercialization. The most comprehensive initiatives to motivate individuals to start new ventures found in this study were entrepreneurship education programs, mainly targeted at students/academic staff (Table 3).

Table 3. University Commercialization Environment

Section	No. of respondents (n=17)	% respondents
Mean (SD) number students 13127 (19507), range (1700-82000)		
University has commercialization in its Vision and Mission statements	16	94.1
University undertakes commercialization	12	70.6
University has an innovation policy	14	83.4
University has Guidelines on commercialization	13	
University has financial goals on commercialization	10	76.5
Schemes that university should use to encourage commercialization		
○ Give staff time off to undertake commercialization	13	76.5
○ Give staff promotion on basis of commercialization	15	88.2
○ Give staff financial benefits for commercialization	16	94.1
Skills Development and Transfer		
University gives students/staff training in entrepreneurship	12	70.6
● Includes in-house training	13	76.5
● Includes external provider training	12	70.6
Geometric Mean Expenditure in KES on R&D (Range) 21.1 (2M-3.5B)		
Median (IQR) Expenditure in KES on R&D 18.3 (9.5-33.0)M	11	64.7

SD=standard deviation 1US$ = 101 Kenya Shillings (KES)

Motivation/mechanisms for commercialization

In an open-ended question, institutions were asked what intangible benefits were received from commercialization. Of

the 17 institutions that responded, 8 (47.1%) mentioned that it is explained in their strategic plans, 5 mentioned increased institutional prestige/visibility and 7 (41.2%) mentioned enhanced graduate employability and community benefits from technology, hence contribution to development (Figure 1). Other reasons mentioned included income generation, training and society benefits from their technologies.

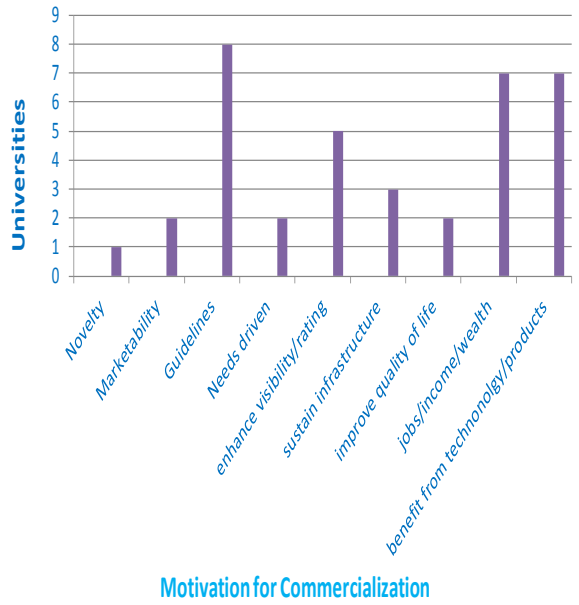

Figure 1. Reasons for university commercialization

Mechanisms of commercialization or terms of sharing income from the research activity appeared however, not clear and this has the potential to slow down the commercialization process. A previous study had shown that "royalty distribution formula," which determines the fraction of revenue from a licensing transaction that is allocated to a faculty member who develops the new technology tend to be more efficient in technology transfer activities (Link and Siegel, 2005).

Management of Commercialization Activities

An important development by most universities in systematizing commercialization is the creation of a TTO, as one-stop service whose role embraces some or all of the following activities:

- Educating and creating awareness of intellectual property processes and requirements amongst researchers;
- Assisting researchers with their intellectual property and patent protection;
- Assessing market potential;
- Identifying potential industry partners and collaborators;
- Negotiating license agreements;
- Forming start-up companies; and
- Finding investors and industry partners.

Kenyan universities have not, until recently, systematically sought to exploit the outputs of science research through commercialization, with only nine (9) of the 15 (60.0%) universities stating that they had a written policy governing the management and operations of the commercialization office (Table 4). More than half (8/15) (53.3%) of the universities had dedicated staff running the commercialization office, while the rest didn't have. Seven (7) of the 15 (46.7%) kept records of financial accounts of the commercialization office. However, these offices are understaffed and under budgeted, and if there isn't a reasonable budget to protect intellectual property – most can't be patented.

The management of the entity was centralized, mostly in the office of Deputy Vice Chancellor (research and extension services). As this knowledge needs to be transferred from a knowledge creation institution, university spin-offs are considered as one major source of entrepreneurial activity (Rasmussen and Sørheim, 2006).

One method of dealing with lack of commercialization activities is to enhance training and development programs for TTO personnel, along with additional administrative support for this activity, since many TTOs were found to lack sufficient resources and competencies to identify the most commercially viable inventions. Generally, a university TTO becomes engaged when additional expertise is required for activities such as identifying a potential route to market, protecting intellectual property for promising discoveries, arranging funding of prototyping and technological development (Markman *et al*., 2005). TTO is also involved in negotiating licences or starting-up new ventures and managing and enforcing a contract agreement with industry and licensees, making this office critical to the success of the transfer process.

Table 4. Running of the Commercialization office

Area of Research	**No. of respondents (n=17)**	**% respondents**
There is a written policy governing the role, management and operations of the office	9/15	60.0
Number of employees in commercialization office		
● 0	7/15	46.7
● 1	1/15	6.7
● 2	1/15	6.7
● 3	3/15	20.0
● 4	3/15	20.0
Financial accounts kept about commercialization office		
● Yes	7/15	46.7
● No	5/15	33.3
● don't know	3/15	20.0
Source of funds for running cost of commercialization office		
● University funds	6/15	40.0
● Government	3/15	20.0
How to improve commercialization policies		
● Include TT in curriculum	2/15	13.3
● Government to increase funding for TT	2/15	13.3
● Motivate innovators	2/15	13.3
● Streamline patenting process	1/15	6.7
● Need independent TT office	1/15	6.7
● Have clear guidelines	3/15	20.0

Several suggestions were made on how the management of the commercialization office could be improved including, technology transfer being given as course, increasing funding to the office, motivating the innovators, streamlining the patenting process and need for clear guidelines and having commercialization office as a stand-alone. Employment of more qualified staff in entrepreneurialism, intellectual property right management, and marketing strategies in the commercialization office were also identified as strategies to boost the operationalization of commercialization offices and the development of spin-off companies. In addition, there

may be more effective ways of structuring university TTOs than the present one-office-per-university model, such as consolidating offices either geographically (so that one office operates on behalf of more than one university).

Intellectual Property Rights (IPRs)

Majority of universities 15/17 (88.2%) had written statutes, regulations, policies and/or procedures dealing with intellectual property rights (IPRs), which they all thought were effective regarding management of IPRs (Table 5).

The universities with these policies thought that they could be improved by either being standalone policies or need to be reviewed once every two years (20.0%) (Table 5). Thirteen (13) of the 15 (86.7%) universities stated that IP should be co-owned by researcher/university and any conflict of interested sorted out through disclosure of the conflict or innovation policy or through legal advice. Universities were also of the opinion that IPR offices need fulltime employees and more funding to avoid high turnover of technology transfer officers. In addition, there is need for sensitization/awareness raising regarding embedding innovation and science into the society and sensitizing people on IPR matters.

Patents show a country's capacity to exploit knowledge and translate it into potential economic gains. In this context, indicators based on patent statistics are widely used to assess the inventive performance of countries (Karklina and Erins, 2013). Regarding the number of patents sought in the last five years, 9/17 (57.9%) universities had not sought any patents since establishment or in the last 5 years, with only 3 (20.0%) universities seeking 13-20 innovation in the same period. Of the 47 patents sought, 38 had been issued locally and one elsewhere, while 26 were still pending. Only 6 patents were said to have been issued to industries (Table 5). Twelve of the seventeen (70.6%) had not initiated any start-up company in the last two years, while 5 had 1-3 start-up companies (Table 5).

Kenyan university intellectual property ownership is governed by the individual university research policy; the consequence is the observed poor performance of Kenyan universities in acquiring patents as shown by a previous study in Kenya (Figure 2).

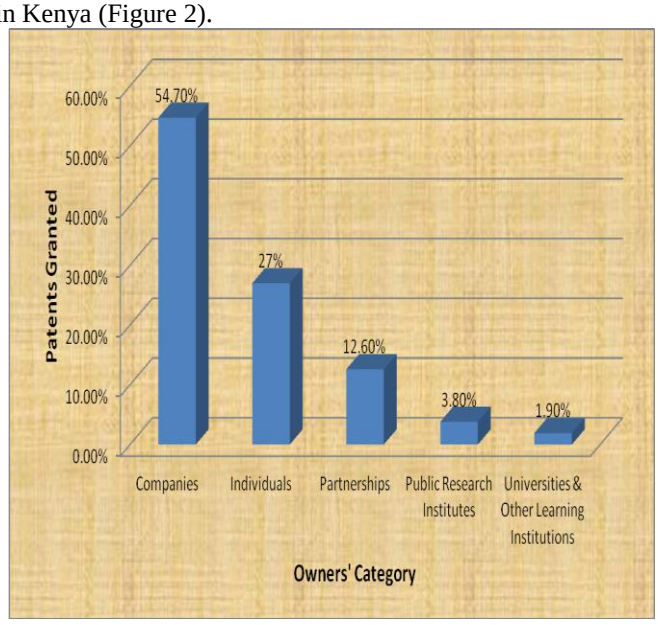

Figure 2. National Patents Granted (1990 – 2013), Kenya (Adopted from Bolo *et al*., 2015b)

Table 5. Intellectual Property Rights policies and patents sought

Area of Research	No. of respondents (n=17)	% respondents
The university have written statutes, regulations, policies and/or procedures dealing with intellectual property rights	15	88.2
Intellectual property rights policy and practice of the university is conducive to commercialization	15/15	100.0
How IPR policies could be improved		
● Have standalone IPR policy	3	17.6
● Review IPR policy every 2 years	3	17.6
● Have fulltime IPR office	1	5.9
● More funding for IPR	1	5.9
● Awareness/sensitization	1	5.9
IPR to be owned by researcher/university	13/15	86.7
How conflict of interest is handled		
● Declare/disclose conflict of interest	4/15	26.7
● Research and innovation policy	4/15	26.7
● Legal advice	2/15	13.3
patents that universities have sought in last 5 years/since its establishment		
● 0	9	52.9
● 2	2	11.8
● 4	2	11.8
● 8	1	5.9
● 13	2	11.8
● 20	1	5.9
Number of spin-off companies started since university started or last 10 years		
● 0	12	70.6
● 1	3	17.6
● 2	1	5.9
● 3	1	5.9

Consultancies

Evidence exists that consultancies often form the first stage in a relationship with an industry partner, which can lead to research contracts, graduate placements etc. Ten (10) universities stated that there was lack of formal linkages with the productive sector as they had not had any consultancies in the last 2 years, while seven (41.2%) had had 1-26 consultancies (table 6).

Table 6. Number of consultancies established in last 2 years

Variable	No. of respondents (n=17)	% respondents
Number of consultancies in last 2 years		
● 0	10	58.8
● 1	1	5.9
● 4	1	5.9
● 5	1	5.9
● 20	2	11.8
● 26	2	11.8

Of the universities with consultancies in the last two years, only 2 (11.8%) had had repeat consultancies with their previous clients, suggesting less job satisfaction by majority of previous clients.

Early Stage Financing and Venture Capital

It is important to place the issue of finance for new ventures into perspective, as the availability of funds to commercialize a newly patented technology is a critical issue. Government's role in the early stage of the new product or prototype is highly critical especially by providing grants and sufficient funds. Entrepreneurs face challenges in the development of a new business during the initial stages. Most universities stated that government and/or university provides funding for developments such as proof-of-concept or seed funding 12/17 (70.6%) (Table 7). However, only 8/12 (66.7%) universities were of the view that there is sufficient angel and venture capital funding in Kenya relative to IP opportunities being developed at the universities. When asked what needs to be done better to promote angel and venture capital funding in Kenya, suggestions include partnership with industry 5/17 (29.4%), more sensitization of venture capitalists 3/17 (17.6%) or tax relief for investors 1/17 (5.9%) among others (Table 7). From the survey results, early stage funding in Kenya comes from two principal sources, Government or individual universities.

Table 7. Early stage financing and venture capital

Area of Research	No. of respondents (n=17)	% respondents
The government and/or university provides funding for developments such as proof-of-concept or seed funding	12	70.6
University access government or other funds for early-stage commercialization activity	11	64.7
There is sufficient angel and venture capital funding in Kenya relative to the high priority IP opportunities being developed at your university	8	47.1
What needs done better to promote angel and venture capital funding in Kenya		
● Partner with industry	5	29.4
● Sensitize potential venture capitalists	3	17.6
● Increase funding	2	11.8
● More innovative ideas	1	5.9
● Tax relief for investors	1	5.9

Government funding is the mainstay of virtually every nation's investment in truly frontier research, and it is equally true that governments provide support through most of the commercialization chain; certainly up to the point where the commercial potential of an idea has been proven beyond which point private funding usually becomes easier to obtain (Gans and Stern, 2003; Collier and Gay, 2010). In addition, government must have policy to support buying locally developed technology/solution as foreign buyers will often inquire whether local R&D products have had purchases where preferential is given to products that meet regulatory/statutory/technical requirements/compliance. Without policies to support native products and quality of production up to global standards, any level of economic development may be limited, at least in the short-term.

Industrial Linkages

Regarding commercialization, it is impossible and impractical for a university to go it alone and thus, their engagement with industry and government in making commercialization a success is crucial. Linkages between universities, and the external community (particularly industry/productive sector), beside promoting innovation and technology transfer and leveraging additional resources for higher education, these partnerships also ensure that graduates acquire the right skills and knowledge, critical in the labour market for their employability.

Studies on University-Industry relations show that universities with closer ties to industry tend to generate greater numbers of spin-offs and exhibit more entrepreneurial activity (Cohen *et al*., 1998; Roberts and Malone, 1996) creating jobs for graduates. Networks/collaborative linkages between industry and universities are beneficial to entrepreneurs for the long term. Industrial linkages offer additional incentives to attract and retain talented faculty members and students.

From this survey, the majority of universities interviewed 15/17 (88.2%) had the view that Kenyan industry is capable of absorbing/commercializing the research output of the university (Table 8). In addition, 13/17 (76.5%) universities had in place some mechanism by which research with commercial potential can be identified and packaged to make it attractive to industry. These mechanisms include exhibition/open days 9/17 (52.9%) or roundtable discussion, articles in popular daily newspapers or workshops 3/9 (17.6%) (Table 8). The survey however, didn't find the management of university-industry linkages clearly specified, with only a few linkages being handled by Registrar Research and Extension 4/17 (23.5%) or VCs office 3/17 (17.6%). Less than a half 7/17 (41.2%) of linkages were managed by the Director of science parks and/or industrial linkages.

The interviewees also support the suggestion that university should seek to have standing relationships with industry or government as a means of raising research funds or effecting commercialization 16/17 (94.1%). The relationships should mostly be through MOUs 16/17 (94.1%) or agreements 11/17 (64.7%) (Table 8). However, it's of concern that 4 of the 17 surveyed universities (23.5%) did not have strategies for creating awareness for the productive sector to know more about their research products, nor did they have financial targets from commercialization in their guidelines. Some respondents underline that the cooperation with the private sector is still deficient; information flow is low and trust is lacking.

Programmes in place to establish/maintain university/ industry linkages for commercialization include exchange of staff between university and industry 10/17 (58.8%), industry people on university boards/councils to provide business and entrepreneurial advice 12/17 (70.6%) and student placements office (Table 8). Most universities were optimistic that their linkages with indutry were effective (14/17) and there were suggestions that they could be improved by the unit having a separate account 4/17 (23.5%) and more emphasis going beyond student attachments 5/17 (29.4%).

It's important to note that the relationship between universities and industry is positive and productive when they are aware of each other's responsibilities and expectations. Earlier studies have also shown that the lack of awareness of the existing research results and new technologies by industry; the absence of strong involvement of the users in defining the research agenda; and the lack of infrastructure and the irrelevance of some university research results to industry contribute to low commercialization of university research output (Dhesi and Chadha, 1995). Thus, although university-industry linkages require pro-activity on the part of both sides, it is the universities with their traditional focus on teaching

and research who need to undergo the biggest changes by offering up their expertise in collaborations and partnerships or by turning into entrepreneurial actors in order for them to be fully effective in research commercialization. This can be done by them engaging in research that is-fit-for purpose *i.e.*, relevant or providing solutions to needs of society or particular aspects of society/industry.

Table 8. University linkages with the productive sector

Area of Research	No. of respondents (n=17)	% respondents
Kenyan industry is capable of absorbing/commercializing the research output of the university	15	88.2
university have in place any mechanism by which research with commercial potential can be identified and packaged to make it attractive to industry	13	76.5
Managers of university/industry relationships		
● Registrar research/Extension	4	23.5
● Legal officer	1	5.9
● Director S&T Parks and Industry linkages	7	41.2
● VC	3	17.6
Means by which the university seeks to have standing relationships with industry or government as a means of raising research funds or effecting commercialization		
● MoUs	16	94.1
● Agreements	11	64.7
● Others	2	11.8
How the university ensures research with commercialization potential is known to industry		
● Round table meetings with industry	3	17.6
● Conferences	1	5.9
● Exhibitions/open days	9	52.9
● Magazines in daily papers	3	17.6
● Workshops	3	17.6
Existing linkages with industry are effective	14	82.4
How management of university/industry relationships may be improved		
● Establish separate account	4	23.5
● Go beyond attachments	5	29.4
● Exhibitions/open days	1	5.9
● Seminars/workshops	2	11.8
● Clear policies	1	5.9

The emphasis by respondents in this survey on the need for internal capacity-building, round table meetings with industry, conferences, exhibitions/open days, disseminations through magazines and popular daily papers, workshops etc (Table 8), rather than on non-conducive external conditions such as lack of national policies, industry weaknesses, suggests a strong recognition by respondent universities to take responsibility and action for strengthening their own internal capacity to work with the productive sector.

One challenge is that universities (and research institutions) have in many cases evolved in isolation from the private sector. Thus many universities have become rather disconnected from the demands of local firms and industries, due to the supply-push policies that have shaped their development (Rodriguez-Pose and Hardy, 2014). This has overtime created a cultural rift that inhibits dialogue and technology transfer between research and industry. For instance, a recent study in Kenya by the United Nations Industrial and Development Organization (UNIDO, 2014) found Kenya's national innovation system to be dysfunctional, with very weak or no active interactions among the state/government, industry and academia (Figure 3). Under the Triple Helix model, the successful commercialization of university technologies needs strong interactions among academia, industry, policies and stimuli supported by the government.

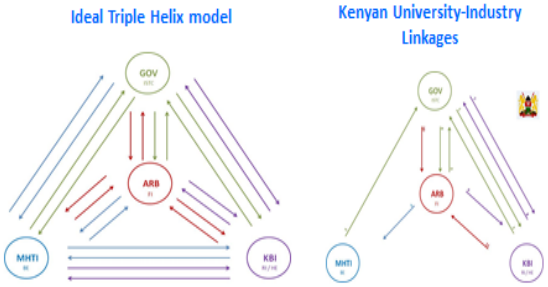

Figure 3. Academia-Industry linkanges in Kenya (adopted from UNIDO, 2014)

Until recently, Kenya lacked a coordinating mechanism to improve the effectiveness of research and industry links and hence the long innovation progression gap between research outputs and the market/commercialization. Consequently, the ST&I Act (2013) established the Kenya National Innovation Agency (KENIA) to promote research commercialization and boost the innovative spirit among Kenyans, by internalizing innovation as a practice among the people. In addition, the Kenya Private Sector Alliance (KEPSA) entity – Linking Industry With Academia (LIWA) Trust, established in 2010 is an intermediary between the universities and the industries to promote commercialization activities. LIWA is similar to the USA's Battelle Memorial Institute, a major participant that was established in 1929 and has been involved in bridging industry-university activities for decades.

Technology Parks and Incubators

During the last decade, African countries have embarked on projects for creation of technology parks and incubators. This is aimed at spurring and sustaining economic growth, meeting the needs of jobs for new graduates and transition into the knowledge economy.

The International Association of Science Parks (IASP) considers that the term "Science Park" could include "Technology Park", "Technopole" and "Research Park" (Link and Scott, 2011), and defines it as "an organization managed by specialized professionals, whose main aim is to increase the wealth of its community by promoting the culture of innovation and competitiveness of its associated businesses and knowledge-based institutions" (International Association of Science Parks, 2014).

On the-other-hand IASP defines an incubator as "an organization designed to accelerate the growth and success of entrepreneurial companies through an array of business support resources and services that could include physical space, capital, coaching, common services and networking connections" (IASP, 2014). Many technology parks explicitly incorporate business incubators into their developments to provide facilities for the nurturing of firms at all stages of their business and technological life cycles, as they are a key mechanism for technology transfer. They are seen as a mechanism to support and establish new businesses/start-up and fledging companies to promote job creation, economic development, innovation and high growth, by providing a wide variety of services that are typical to most starting ventures: physical space and infrastructure (office space, secretarial and administrative services), business consulting and training, funding applications (government and private), IP protection, technology transfer, and networking (Jamil *et al*., 2015). Incubator program gives a chance to projects that are unable to attract commercial investors in the initial stages of development.

Technology parks and incubators in general use universities as a source of technology (O'Neal, 2005), and they play an important role in transferring academic research from universities to industry. They are geared to support and nurture the development of small and medium-sized enterprises (SMEs) and strengthen the country's economic competitiveness. For such ventures to succeed and yield benefits to both universities and industry, high caliber faculty with the appropriate qualifications and skills are critically important. For universities to commercialize their research outputs, technology parks and incubators have been identified as key intermediaries to fill the gap between R&D and commercialization. As a result, many countries have supported these institutions as tools for commercialization and major contributors to knowledge-based economies. They are considered as linkages between universities and industries in excelling/accelerating commercialization (Jamil *et al*., 2015).

Generally, science parks and business incubators are an emergent phenomenon in Kenya like in most of Africa, and are found only in a handful of universities. Globally, the traditional technology park model is centered upon world-class research intensive universities and is associated with high technology and cutting edge innovation. As noted, technology parks are designed to become ideal environments for establishing and growing knowledge-intensive firms. However, comparable quality research intensive universities are highly scarce within most emerging economies, including Kenya. For instance in this survey, few universities appear to have established such structures, as only less than half 8/17 (47.1%) of universities in the survey reported being involved in managing science parks and university incubators (Table 9).

The less involvement in science parks was associated with low funding 4/8 (50.0%), poor university research infrastructure 4/8 (50.0%), lack of qualified staff to run the park (3/8) (37.5%) or the park not being clearly placed/integrated within the university organogram 3/8 (37.5%) hence too little coordination between key stakeholders (Table 9).

Most science parks/incubation centres are dependent on a few interested individuals (philanthropists) at their particular institutions such as the Chandaria incubation centre at Kenyatta University to help students launch their own innovative businesses. The result is technology parks with small dimensions due to low initial levels of investments. In fact, as observed elsewhere (Kharabsheh *et al*., 2011), many technology parks in our survey were simply extensions of university departments or incubators in transition, failing to upgrade local technological capacities to any great extent.

Table 9. Technology Parks and Incubators

Area of Research	No. of respondents (n=17)	% respondents
the university runs, or is associated with, a technology park or incubators	8	47.1
Manager of the Park		
● Park coordinator	3	17.6
● Director of research/Partnerships	4	23.5
● Steering committee	1	5.9
What need done to improve park management		
● Enhance Funding	4	23.5
● Improve Infrastructure	4	23.5
● More qualified staff	3	17.6
● Industry liaison office	2	11.8
● Need to be placed in university organogram	3	17.6

Success stories

Regarding success stories, several products have been certified by respective authorities such as the Kenya Bureau of Standards (KeBS) and Kenya Plant and Health Inspectorate Service (KEPHIS) for plant breeders rights (Table 10). As shown, most of the start-ups were concentrated on low-hanging fruits such as agro-based or from the biological/physical sciences to serve small to medium-scale firms producing for local markets, and require low technology application.

Table 10. Products produced for commercialization by Kenyan universities

Area of Research	No. of respondents (n=17)	% respondents
University has a dedicated entity for commercialization	6	35.3
Details about the success of university-inspired start-up companies available	5	29.4
● Maize meal	3	17.6
● Animal feeds	1	5.9
● Innovation firm	2	11.8
● IT companies for students	3	17.6
● N/A	10	58.8
Success stories/name of products		
● Detergent	2/14	14.3
● Tamide dye	1/14	7.1
● Myan Gold	1/14	7.1
● Agro-vets	1/14	7.1
● Eldo Mavuno/Baraka wheat	1/14	7.1
● Maize/Beans varieties	2/14	14.3
● Kimathi Coffee	1/14	7.1
● N/A	5/14	35.7
Received KeBS/KEPHIS Approval 2010-14	5/9	55.6

N/A (not applicable)

Limitations of the study

(i) While 17 institutions participated in this survey, it was not possible to manually verify the accuracy of data provided

(ii) The survey only focused exclusively on university-side capacity factors and does not address demand-side factors

relating to industry. Future studies need to look at both supply and demand side factors

Challenges to Commercialization of University research in Kenya

- Only few members of university staff are engaged in research and development. This is due to too much teaching at the expense of research
- Staff promotion policies demand prolific publications and dissemination of research results at conferences thus losing the patentability of inventions. This requires need to move from 'publish or perish' to' 'innovate or perish'

Recommendations

To address the above challenges, the following have to be done:

Development and Strengthening of Policy in universities to promote relevant research

- Kenyan universities should adopt strategies that aim to turn universities into entrepreneurial institutions and not just teaching intensive centres; and in this regard, support of university senior management is essential
- Professional incentives and reward systems that consider contributions to technological generation and knowledge transfer are also required
- Improve funding for TT&C of research and innovations *e.g*., through recently established Kenya's National Research Fund (NRF) and the Kenya National Innovation Agency (KENIA). They should provide early stage financing and seed-capital for starters
- Universities should avoid the silo mentality and promote multi- and trans-disciplinary research teams (*e.g*., in materials sciences, life sciences, social and environmental sciences) to be able to tackle complex societal problems such as poverty eradication, environmental sustainability and climate change, food insecurity and youth unemployment. It is also important that universities establish meaningful, beneficial extensive and practical relationships (linkages) with appropriate industrial and commercial stakeholders that can convert research outcomes into practical applications. This can be operationalized through:
- Organizing open days to showcase university innovations, especially those which can be taken up by industry and be produced so as to solve societal problems
- Employing dedicated Industrial Relations Officer(s) to spearhead relations with industry and other external stakeholders

Industry and other stakeholders should also contribute to funding; and formulation and review of university curricula to be in tandem with market needs and offer student attachments for research and internships.

Establishing and Strengthening of TTOs

TTO is considered a bridge between industry and academia (Ismail *et al*., 2012; Perkmann and Salter, 2012). Universities require to establish fully fledged technology transfer units or consultancy bureaus, equipped to undertake patent searches, assess the novelty of innovations, pay the cost of processing patent applications and take care of the marketing of the invention and their commercialization, as well as the negotiation of the licenses and royalties. In addition, many TTOs should provide assistance in business planning, introduction to venture capitalists, assistance in recruiting start-up teams, and providing incubator space (Alice 2011).

Monitoring and Evaluation

- Individual Kenyan universities should set targets on IP to be commercialized every given agreed period and commit budget for its implementation
- In addition, there is need to develop an implementation strategy with guidelines for key performance indicators of all commercialization initiatives developed by Kenyan universities to help monitor and measure their outcomes.

Capacity-Building in Relevant Skills and Policy Development

- Lack of entrepreneurial culture by staff (some faculty members have a purely academic orientation and don't have a lot of interest in dealing with private companies) need to be promoted
- Support for training to students and early career researchers in commercialization to develop entrepreneurial skills and intellectual property management among academic staff and students is very key

Science Parks and Technology Incubators

- Supporting the establishment and management of science parks and technology incubators for the purposes of technology transfer and management skills to run the facilities is strongly recommended

Way Forward

- Fields, like the humanities, may have limited possibilities for research commercialization. However, "Innovation should also cover humanities areas such as governance, social, rural, urban, industrial corporate, education, health care, transportation, social safety nets and branding" (Hussain *et al*., 2014).
- There is thus, need to foster a culture of entrepreneurship throughout the whole Kenyan education system including universities to produce knowledge for the greater public good. This should include social, environmental and artistic innovations. Researchers and developers should be encouraged to work collaboratively in multi- and trans-disciplinary teams.
- Universities also need to widen and deepen engagement with industry and other potential financial supporters.

In addition, industries and other research output users need to be brought on board at the inception stage (of any research with commercial potential) as active partners, while governments need to take responsibility for architecting a national innovation system with appropriate frameworks and policies that govern and incentivise university-industry interactions to promote commercialization of research outputs in Kenya.

Acknowledgements

We gratefully acknowledge all university staff and their respective administrations for their valuable cooperation and participation. The Kenya Government through the Ministry of Education for supporting the study.

Authors' contributions

JGA, GMK and GAO conceived the study, and participated in its coordination. All authors participated in the design and carried out the study and in the data analysis and interpretation. JGA drafted the manuscript. All authors read and approved the final manuscript and confirm that the content has not been published elsewhere and does not overlap or duplicate their published work.

Competing interests

The authors declare that they have no competing interests.

References

Acs, Z., Audretsch, D. B., Braunerhjelm, P., & Carlsson, B. (2010). The missing link: The knowledge filter and entrepreneurship in endogenous growth. Small Business Economic, 34(2), 105–125. African Higher Education Summit, Dakar, Senegal, March, 2013

Al Natsheh, A., Gbadegeshin, S. A., Rimpilainen, A., Imamovic-Tokalic I., & Zambrano, A. 2015. Identifying the Challenges in Commercializing High Technology: A Cas

Alice L. (2011). What motivates academic scientists to engage in research commercialization: 'Gold', 'ribbon' or 'puzzle'?. Research Policy, 40(10), 1354-1368.

Association of University Technology Managers (2007). U.S. Licensing Activity Survey FY2006: A Survey Summary of Technology Licensing and Related Activity for U.S. Academic and Nonprofit Institutions and Technology Investment Firms. Deerfield, IL: Garcia P, Hippenmeyer P, Rauw B, Ruey N.

Audretsch, D., Keilbach, M., & Lehmann, E. (2006). Entrepreneurship and economic growth. New York: Oxford University Press.

Audretsch DB. (2014). From the entrepreneurial university to the university for the entrepreneurial society. The Journal of Technology Transfer, 39(3), 313-321.

Banal-Estañol A, Macho-Stadler I. (2010). "Scientific and Commercial Incentives in R&D: Research vs. Development?", *Journal of Economics and Management Strategy*, Volume 19, Issue 1, pages 185–221

Bolo M, Osir E, Rugutt M, Desai K. (2015a). Stimulating innovation and entrepreneurship in Kenyan universities and public research institutes Is performance-based research funding model the answer? Scinnovent policy Brief 01, Nairobi, Kenya.

Bolo M, Odongo D, Awino V. (2015b). In Pursuit of the third Mission: universities and Public research institutes as progenitors of technology and innovation in kenya. The Scinnovent Centre Discussion Paper 03. Nairob, Kenya: The Scinnovent Centre.

Carayannis EG, Campbell DFJ (2009). "Mode 3" and "Quadruple Helix": toward a 21st century fractal innovation ecosystem. *International Journal of Technology Management*, 46:201–234. 10.1504/IJTM.2009.023374

Carayannis EG, Campbell DFJ. (2010). Triple Helix, Quadruple Helix and Quintuple Helix and how do knowledge, innovation and the environment relate to each other? A proposed framework for a trans-disciplinary analysis of sustainable development and social ecology. *International Journal of Social Ecology and Sustainable Development* 2010,1(1):41–69.http://www.igi-global.com/bookstore/article.aspx?titleid=41959

Cohen WF, Florida R, Randazzese L, Walsh J. (1998). Industry and the academy: uneasy partners in thecause of the technological advance. In: Noll, R. (Ed.), Challenge to the Research University. Washington, DC, pp. 163-191.

Cohen WM, Nelson RR, Walsh JP. Links and Impacts: The Influence of Public Research on Industrial R&D. Management Science. 2002; 48(1):1–23.

Collier A, Gray B. (2010). The commercialization of university innovations. A qualitative analysis of the New Zealand situation. Centre for Entrepreneurship School of Business University of Otago, Research Report May 2010

Colyvas J, Gelijns A, Mazzoleni R.(2002). How University Inventions Get into Practices. Management science. Vol. 48, No.1, pp. 61-67.

Dhesi, AS. and Chadha V. (1995). "Factors Influencing Technology Transfer from R&D Institutions to Manufacturing: Empirical Evidence from India" in *Science Technology & Development*, Vol (2), 225-237.

Etzkowitz H, Leydesdorff L. (2000). The dynamics of innovation: From National Systems and "mode 2" to a Triple Helix of university-industry-government relations. *Research Policy*, *29*, 109-123.

Freeman, C. (1987), *Technology and Economic Performance: Lessons from Japan*, Pinter, London.

Gans J and Stern S (2003), Assessing Australia's Innovative Capacity in the 21st Century, Melbourne Business School Working Paper 2003-16, University of Melbourne, 2003

GoK (2007). (Government of Kenya). Kenya Vision 2030. The popular version. GoK (2013a). (Government of Kenya). The Science, Technology and Innovation Act, 2013 No. 28 of 2013 *Kenya Gazette Supplement No. 43 (Acts No. 28)*

GoK (2013b). (Government of Kenya). The presidency ministry of devolution and planning.

Second medium term plan, 2013 – 2017. Transforming kenya: pathway to devolution, socio-economic development, equity and national unity Grimm HM, Jaenicke J. (2012). What drives patenting and commerzialisation activity at East

German universities? The role of new public policy, institutional environment and individual prior knowledge. J Technol Transf (2012) 37:454–477 DOI 10.1007/s10961-010-9195-2

Howells JR. (2005). Innovation and regional economic development: a matter of perspective? Res Policy 34: 1220-1234.

Hussain WMHW, Ab Rahman MN, Zaino HA, Yaakub NI (2014). Mechanism and Government Initiatives Promoting Innovation and Commercialization of University Invention. Pertanika J. Soc. Sci. & Hum. 22 (S): 131 - 148

International Association of Science Parks. (2014), Knowledge bites science park (IASP official definition). Available from: http://www. iasp.ws/knowledge-bites. [Last retrieved on 2014 Sep 06].

Ismail K, Tengku Azhar TN, Yong CY, Aslan AS, Omar WZ, Majid I, Ajagbe AM. (2012).

Problems on Commercialization of Genetically Modified Crops in Malaysia, Procedia-Social and Behavioral Sciences, 40, 353-357.

Jamil F, Ismail K, Mahmood N. (2015). A Review of Commercialization Tools: University

Incubators and Technology Parks. International Journal of Economics and Financial Issues, 2015, 5(Special Issue) 223-228.

Jensen R, Thursby MC. Proofs and prototypes for sale: the licensing of university inventions.

American Economic Review, 91 (2001), pp. 240–259

Karklina S, Erins I. (2013). Patents as Indicators of Innovative Environment. International Journal of Social, Behavioral, Educational, Economic and Management Engineering Vol:7, No:12

Kesselheim AS, Rajkumar R (2011). Who owns Federally Funded Research? The Supreme Court and the Bayh–Dole Act. The New England Journal of Medicine

365: 1167–1169.

Kenney M, Patton D. (2009). Reconsidering the Bayh-Dole act and the current university invention ownership model. Research Policy, 38(9), 1407–1422.

Kharabsheh R, Magableh IK, Arabiyat TS. (2011). Obstacles

of success of technology parks: the case of Jordan. Int J Econ Financ 3:219-226.
Kirschenbaum SR (2002). Patenting Basic Research: Myths and Realities. Nature Neuroscience 5: 1025–1027.
Landry, R., Amara, N. and Ouimet, M. (2007), "Determinants of knowledge transfer: evidence from Canadian university researchers in natural sciences and engineering", Journal of Technology transfer, Vol. 32, pp. 561-592.
Laredo P, Mustar P. (2001). Research and innovation policies in the new global economy. An International Comparative Analysis. Edward Elgar, Cheltenham.
Leydesdorff L, Etzkowitz H. (1996). Universities and the Global Knowledge Economy: A Triple Helix of University–Industry–Government Relations. Pinter, London.
Link AN, Siegel DS. (2005). Generating Science-Based Growth: An Econometric Analysis of the Impact of Organizational Incentives on University-Industry Technology Transfer. *European Journal of Finance*, Vol. 11, No. 3, pp. 169-182.
Link AN, Siegel DS, Bozeman B. (2007). An empirical analysis of the propensity of academics to engage in informal university technology transfer. Industrial and Corporate Change 16, 641–655.
Link AN, Scott JT. (2011). Research, Science, and Technology Parks: Vehicles for Technology Transfer (No. 11-22). p1-22. Available from: http://www.uncg.edu/bae/econ/.
Loise V, Stevens AJ (2010). The Bayh-Dole Act turns 30. Sci Transl Med. 2(52): 52cm27.
Lowe, C. R. 2005. Commercialisation and Spin-Out Activities of the Institute of Biotechnology. Journal of Commercial Biotechnology, 11(4): 206–317.
http://dx.doi.org/10.1057/palgrave.jcb.3040131
Markman GD, Gianiodis PT, Phan PH, Balkin DB. (2005). Innovation speed: Transferring university technology to market. Research Policy, 34, 1058-1075.
Meyers, A. D. 2009. Book Review: Commercialization of Innovative Technologies: Bringing Good Ideas to the Marketplace. Journal of Commercial Biotechnology, 15(4): 374–375. http://dx.doi.org/10.1057/jcb.2009.18
Molas-Gallart J, Salter A, Patel P, Scott A. and Duran X. (2002). *Measuring Third Stream Activities: Final Report to the Russell Group of Universities*, Science and Technology Policy Research Unit, University of Sussex.
Mowery DC, Sampat BN. (2005). The Bayh-Dole Act of 1980 and university–industry technology transfer: a model for other OECD governments? The Journal of Technology Transfer 30 (1/2), 115–127
Mowery DC, Nelso RR, Sampat BN, Ziedonis AA. (2004). *Ivory Tower and Industrial Innovation: University-Industry Technology Transfer Before and After the Bayh-Dole Act in the United States*. Innovation and Technology in the World Economy. Stanford, Calif.: Stanford Business Books.
Nelson R. (ed.) (1993), *National Innovation Systems. A Comparative Analysis*, Oxford University Press, New York/Oxford.
OECD (1997), *Diffusing Technology to Industry: Government Policies and Programmes*, Paris.
OECD. (2003). Turning science into business: Patenting and licensing at public research organisations. Paris: OECD.
O'Neal, T. (2005). Evolving a successful university-based incubator: Lessons learned from the UCF technology incubator. Engineering Management Journal, 17:11-25.
Parker DD, Zilberman D. (1993). University technology transfers: Impacts on local and US economies. *Contemporary Policy Issues*, 11(2), 87.
Perkmann M, Salter A. (2012). How to create productive partnerships with universities.MIT Sloan Management Review 53, 79–88.
Perkmann M, Tartari V, McKelvey M, Autio E, Broström A, D'Este P, Fini R, Geuna A, Grimaldi R, Hughes, A, Krabel S, Kitson M, Llerena P, Lissoni F, Salter A, Sobreror M. (2012). Academic engagement and commercialisation: A review of the literature on university–industry relations. Research Policy 42, 423– 442
Pirnay F, Surlemont B, and Nlemvo F. (2003). Toward a typology of university spin-offs. *Small Business Economics* 21: 355-369. Economics.
http://www.rpi.edu/dept/economics/www/workingpapers/
Powers JB, Campbell EG (2011) Technology Commercialization Effects on the Conduct of Research in Higher Education. Research in Higher Education 52: 245–260.
Roberts EB., Malone DE. (1996). Policies and structures for spinning off new companies from research and development organizations. R&D Management 26 (1), 17–48.
Rodriguez-Pose A, Hardy D. (2014). Technology and industrial parks in emerging countries. Panacea or pipedream? Springer, London, UK. pp 110.
Slaughter S, Leslie LL. (1997). Academic Capitalism: Politics, Policies, and the Entrepreneurial University. Johns Hopkins University Press, Baltimore.
Siegel DS, Phan PH. (2005). Analyzing The Effectiveness Of University Technology Transfer: Implications For Entrepreneurship Education, In G. D. Libecap, (Ed.). University Entrepreneurship and Technology Transfer. Advances In The Study Of Entrepreneurship Innovation And Economic Growth, 16, 1-38.
Stevens, A.J. 2004. The enactment of Bayh-Dole. Journal of Technology Transfer 29(1): 93-99.
Tahvanainen A, Nikulainen T. (2010). *Commercialisation at Finnish Universities: Researchers' Perspectives on the Motives and Challenges of Turning Science into Business. Discussion Paper 1234.* Helsinki: The Research Institute of the Finnish Economy.
UNIDO (2014), United Nations Industrial Development Organization. The Kenya National System of innovation. Measurements, Analysisi and Policy Recommendations.
Valentine A, Claasen G. (2002). The University Complex: A threat to public funded institution? Science in Africa.
Vanderford NL, Weiss LT, Weiss HL (2013). A survey of the barriers associated with academic-based cancer research commercialization. *PLoS One*; 8(8): e72268.
World Economic Forum, *The Global Competitiveness Report 2010–2011*, page 8.