Transfer and Commercialization of Technologies from Universities to Small Companies in South Africa

S. D. Maphumulo[1], H. Nel[1]
[1]Postgraduate School of Engineering Management, University of Johannesburg, Johannesburg, South Africa
(hannelien@uj.ac.za)

Abstract - World-wide many universities have a significant role in the socio-economic development of their countries and regions. One avenue for universities to achieve this role is through the transfer and commercialization of their technologies to resource-constrained small, medium enterprises (SMEs). A survey-based study was conducted to establish the factors that enable and restrain the transfer and commercialization of technology from South African publicly-funded universities (transferor) to SMEs (transferee), as well as to recommend how the restraining factors could be addressed. The sample consisted of researchers and technology managers drawn from entrepreneurs and six Gauteng universities. Respondents rated each of the ten literature-derived enabling factors and ten literature- derived restraining factors to technology transfer and commercialization from universities to SMEs. Results show the top two enabling factors to be absorptive capacity of the transferee; and transferor's attitude towards TT and commercialization. The top two restraining factors are university bureaucracy and the university performance evaluation system. Measures to deal with the top four restraining factors are suggested and useful insights are provided by the research findings.

Keywords - **commercialization, enabling factors, restraining factors, small, medium enterprises, technology transfer, South Africa**

I. INTRODUCTION

Many universities across the world are now playing a significant role in the innovation and economic development of their countries and regions [1],[2]. One of the avenues for universities to achieve this emerging entrepreneurial role is through the transfer and commercialization of technologies which are developed by researchers and inventors in their various departments to companies, especially the small medium enterprises (SMEs) [2],[3],[4].

The university-SME technology transfer opportunity represents a win-win scenario for both parties. SMEs lack most of the resources and skills which they need to develop their core technologies in-house. By engaging in technology transfer (TT), universities contribute to technology innovation, economic growth of the country, derive additional income and also develop their research and academic programs.

Currently, South Africa is experiencing persistent challenges of unemployment, poverty and low economic growth. SMEs play an important role in job creation and improvement of the quality of lives of South Africans. SMEs operate in wide-ranging sectors and industries such as energy, chemicals, healthcare and many others. In terms of the resource-based view of strategy, technology is one of the critical resources which SMEs can use to develop products, processes and services efficiently and at low cost [5],[6]. These authors further state that technology has a potential to offer SMEs a sustainable competitive advantage in their target markets. For the year period leading to the first quarter of 2017, small, medium and microenterprises (SMMEs) in South Africa contributed about 10.6 million jobs which is about 65 % of the total employment nationally [7].

In South Africa, there are twenty six universities which are subsidized by the national government. The knowledge and technology generated by the local university researchers lead to the interactions and collaborations between the university, government and interested companies, commonly known as the Triple Helix [8].

According to [9], technology encompasses theoretical and practical knowledge, skills and artifacts that can be used to develop products, services and their product and development systems. Finally, literature highlights that the ultimate goal of technology is to provide solutions to problems that are troubling the technology user [10].

The need for the transfer of technology is triggered by the demand from the market in which the technology user (SME) operates or a technology push from the technology developer (the university) that is seeking the suitable technology user [1],[11]. According to [12], in technology transfer the flow of knowledge from the university to the company matters in as much as is the ability of the company to absorb the knowledge. [13] states that that academic technology transfer (TT) involves the transfer of the university-owned technology to industrial technology users for commercial application. Furthermore, the transfer of technology entails the transfer of knowledge and skills associated with the technology use from the transferor to the transferee.

The research studies that have been conducted in South Africa on technology transfer do not provide understanding on the factors that influence technology transfer from universities to SMEs in South Africa, which is the focus of this study.

The objectives of the research are to establish factors that enable and restrain the transfer and commercialization of technology from universities to SMEs in South Africa; and to make recommendations on how to address the identified barriers to technology transfer and commercialization from universities to SMEs in South Africa.

II. LITERATURE REVIEW

The following selected literature derived enabling and restraining factors to TT form the basis of the study (see Tables 1 and 2 below for the complete list):

Enabling (E)Factors

E6 Attitude of researchers towards technology commercialization. The likelihood that the researcher is involved in TT and commercialization is positively influenced by the commitment of the university to TT [28].[29].

E7 The entrepreneurial mindset of the university technology developer. This refers to the ability of the university researcher to identify and evaluate suitable entrepreneurial partner before the TT and commercialization project is approved. This contributes towards the success of the TT and commercialization project 1],[18],[26].

E8 Disseminative capacity of the university researcher. The ability of the university technology developer to effectively, efficiently and convincing frame knowledge in the manner that SME can understand and put it into practice contributes towards the success of TT [25].

E9 University reward structure. The establishment of the university reward structure that incentivizes university researchers and inventors to undertake TT projects contributes towards the success of TT and commercialization to SMEs [18],[35].

E10 Frequent communication between the technology developer and SME from the start to the completion of the project contributes towards effective TT [26],[27]

E11 Technology evaluation and IP negotiation skills of the SME. The ability of the SME to evaluate the university-developed technology and to negotiate an agreement with the university Technology Transfer Office (TTO) contributes towards effective TT and commercialization to the SME [1],[30].

E12 The ability of the technology user to recognize the value of new technology from the university as well as assimilate and apply it is referred to as the absorptive capacity [30]. It contributes to effective TT and commercialization [30],[31].

E13 Presence of University intermediaries (TTOs, spin-offs, business incubators and technology parks) contributes towards effective TT and commercialization to SMEs. Universities use TTOs and technology parks to facilitate technology transfer to industry [42], [43]. Universities set up academic spin-off entities in order to facilitate technology transfer to industry for cases when where further technology development work is out of the scope of the university [23], [38], [44]. University use business incubators to provide business support to new start-ups which they establish as the vehicle for transferring technology to industry [45], [46].

E14The creation of open collaborative innovative approach between the university and SME contributes towards win-win outcomes in TT and commercialization to the SME. University-based TTOs use open collaborate innovation approach when facilitating TT in diverse cases where the potential user community is small and is not linked to university resources [17], [40].

E15 The choice of the appropriate governance structure (direct contract between university technology developer and SME versus TTO-managed contract between university and SME) contributes towards effective TT and commercialization to SMEs [21]. [21] advocate that under certain circumstances there is merit for each of these governance structures.

Restraining (R) Factors

R16 University performance evaluation system that does not stimulate university personnel to undertake TT projects has a negative impact towards TT and commercialization to SMEs [19],[20].

R17 Immature university technology. The university technology that is too underdeveloped for the SME to apply commercially at the time of the IP registration application reduces the likelihood that it may be licensed to the SME and be successfully commercialized [18], [23],[38]..

R18 University bureaucracy. University processes and systems which delay the signing of licensing and other collaborative agreements between the university and the SME negatively impact the success of the TT project [1],[2],[18].

R19 Lack of marketability and market value of the university technology reduces the likelihood of successful TT and commercialization to the SME. [18] define the marketability as the degree to which the technology is valued by the industry or other users as important inputs in the development of products and processes that can be sold in the relevant market. [18] and [19] argue that technologies (e.g. university developed technologies) that lack the applicability and marketability characteristics are unlikely to be favoured by the technology users (SMEs) and may not be successfully commercialized.

R20 Huge differences between the expectations and requirements of the university and SME reduce the likelihood of success of TT and commercialization project [2].

R21 The usage of standard intellectual protection strategies in diverse settings by some Technology Transfer Offices (TTOs) negatively impacts successful TT and commercialization to SMEs [17]. This tendency by some TTOs refers to the usage of licensing and legal enforcement of IP rights where cognitive and sociopolitical legitimacy is the key prerequisite to acceptance of technology by the technology user. [17] define cognitive legitimacy as the

knowledge of the new activity and what is required for it to succeed in the industry for both the technology developer and technology user. Sociopolitical legitimacy refers to the value placed on the activity by cultural norms and political factors [17], [32].

R22 Absence of supporting government legislation and policy on university-industry collaboration reduces the chances of TT and commercialization to industry (SME) [41].

R23 The lack of complementary assets, capabilities and resources within the TTO which are essential for university- SME TT reduces the likelihood of success of the TT and commercialization project [9], [17].

R24 Huge licensing costs of university-developed technologies can be a barrier to TT to SMEs who have limited financial resources [23].

R25 Lack of university-SME networks. Lack of networking and other communication forums which can serve to increase mutual trust and create awareness to SMEs of available university technologies can adversely affect TT and commercialization to SMEs [18], [39].

III. RESEARCH METHODOLOGY

A mixed method is used for conducting this study. The study consists of a descriptive quantitative component which is complemented by a small qualitative component. For the quantitative component, a Likert-scale based survey questionnaire is used to test ten literature-derived enabling and ten literature-derived restraining factors that influence TT and commercialization for the South African context using views of the judgmental sample of respondents. Such a rating scale (Likert scale) is the most appropriate when a phenomena of interest such as enabling and restraining factors to TT and commercialization are to be evaluated or quantified in an interval or continuum of "strongly agree", "agree","neither agree nor disagree", "disagree" and "strongly disagree"[34]. A population of 315 was decided upon based on the number of technology developers associated with active portfolio of registrable IP, technology and business support managers as well as technology users (SMEs) associated with six chosen Gauteng universities.

Purposive sampling, known as judgmental sampling was employed [33]. This is done in order to ensure that the chosen sample meets the required TT and commercialization and qualification criteria [34]. A sample of 157 respondents is targeted based on literature guidelines [34]. In order to ensure the representativeness of all key TT and commercialization role players, quota sampling technique is used in line with the representation of the TT role players in the university community. For example, the total sample drawn consisted of 60 % technology developers from six Gauteng publicly-funded universities, 15 % SMEs, 10 % TTO managers,10 % business incubation managers and 5 % others who met sampling criteria. In order to confirm some of the results of the survey, a small qualitative study was conducted using follow-up semi-structured interviews with four respondents drawn from the above-mentioned sample for the quantitative component of the study. These respondents are two technology managers, one engineer and one entrepreneur, all associated with some of the above-mentioned universities.

IV. RESULTS

The 33 respondents (21 % response rate) who completed the questionnaire possessed the required educational qualifications (at least thee-year degree or diploma), technology development (at least one year) and commercialization (at least one year) experience as per stipulated sample selection criteria. The 33 respondents consisted of 20 technology developers,3 SMEs, 5 TT managers, 1 business incubators and 4 respondents who met the sampling criteria but were no longer in any of the above-mentioned areas. The low response rate by respondents was due to time constraints and other personal reasons. The survey data from 33 respondents was analyzed using descriptive statistics (mean and standard deviation) for each of the ten literature-derived enabling and ten-literature derived restraining factors to TT and commercialization. The ten enabling factors and ten restraining factors, as rated in decreasing order of the mean by respondents, is given in tables 1 and 2, respectively.

The mean for each of the enabling and restraining factors in tables 1 and 2 represents a typical value for the total 33 responses received for that factor. The value of the mean for each of the enabling and restraining factors indicates how strongly the 33 respondents agree about that factor in influencing TT and commercialization (i.e. highest value of the mean associated with the factor means that factor enjoys strongest agreement rating from the 33 respondents). The standard deviation for each of the enabling and restraining factors indicates the dispersion or how far from the mean associated with that factor that item is [14]. The standard deviation is used to indicate the level of agreement amongst the 33 respondents with the mean rating associated with that factor. The smaller the standard deviation is for the factor means the higher is the level of agreement amongst 33 respondents for that factor.

The reliability of the Likert scale which was used in the questionnaire was confirmed for internal consistency. Internal consistency refers to the degree to which all items or enabling factor related questions (question 6 to 15) or restraining factor related questions (questions 16 to 25) complement each other to measure the item of interest (TT and commercialization). A Cronbach alpha coefficient of 0.90 was obtained for enabling factor related questions and 0.70 for the restraining factor related questions. This represented acceptable coefficients, as the threshold for Cronbach alpha coefficient is 0.70 [15], [16].

The results of the small qualitative study (semi-structured interviews) confirmed the importance following literature-based enabling factors to TT and commercialization: disseminative capacity of technology developer and absorptive capacity of technology user. The restraining factors to TT and commercialization: university

bureaucracy and huge outcome-impact gap between university and SME.

TABLE I
Enabling Factors to TT and Commercialization in Decreasing Order of Mean

Enabling Factor	Agreement Rating (mean)	Level of agreement with Rating (standard deviation)
E12 Absorptive capacity of technology user (SME)	4.12	0.896
E6 Technology developer's attitude towards TT and commercialization	4.12	1.139
E10 Communication	4.09	0.947
E8 Disseminative capacity of the technology developer (university)	4.03	1.045
E11 Technology evaluation and IP negotiation skills of technology user (SME)	4.00	0.791
E7 Technology developer's entrepreneurial mindset	4.00	1.00
E13 Presence of university-linked intermediaries (TTOs, spin-offs, business incubators)	3.97	0.984
E14 Presence of open collaborative innovation	3.82	1.014
E15 Choice of appropriate governance structure for university – SME interaction	3.70	1.212
E9 University's reward structure	3.33	1.407

E6 – E15 correspond to literature-derived enabling factors as presented in the survey questionnaire

V. DISCUSSION

From the statistical analysis conducted on enabling factors (table 1), respondents rate the following top four enabling factors as having the highest mean: absorptive capacity of technology user; technology developer's attitude towards TT and commercialization; communication and disseminative capacity of technology developer. From the statistical analysis done on restraining factors (table 2), respondents rate the following restraining factors as having the highest mean: university bureaucracy; university performance evaluation system that does not simulate researchers; lack of complementary assets, resources and capabilities within the technology transfer office (TTO); and huge outcome-expectation gap between university and SME. The usage of standard intellectual property protection in diverse TT settings received the lowest ranking as the restraining factor. This view is not in line with literature which asserts that usage of standard IP protection strategies in diverse situations limits chances of technology commercialization as demonstration of cognitive and sociopolitical legitimacy is a key prerequisite before technology is accepted by potential users [17] Measures to deal with top four restraining factors, as per second research question, are discussed below:

TABLE 2
Restraining Factors to TT and Commercialization in Decreasing Order of Mean

Restraining Factor	Agreement Rating (mean)	Level of agreement with Rating (standard deviation)
R18 University bureaucracy	4.55	0.617
R16 University performance evaluation system that does not stimulate staff to do TT projects	4.03	0.984
R23 Lack of complementary assets, resources and capabilities within TTO	4.00	0.968
R20 Huge outcome-impact gap between university and SME	3.94	0.864
R19 Lack of applicability and market value of university-developed technology	3.91	1.071
R25 Lack of university-SME network	3.82	1.014
R22 Lack of supporting government legislation and policy	3.55	0.938
R24 Huge licensing costs for university-developed IP	3.55	1.175
R17 Immature university technology	3.45	1.121
R21 Usage of standard IP protection strategy in diverse TT settings by some TTOs	3.39	0.938

R16 to R25 correspond to literature-derived restraining factors as presented in the survey questionnaire

The university bureaucracy refers to rules, procedures, systems and huge decision making layers that determine how the university operates. The views of survey respondents and interviewees seem to concur with what literature states as challenging aspects of bureaucracy, namely, delay in the signing of the contract between the university technology developer and technology user which slows down the progress of the project [1],[2] as well as inflexibility by university management [18]. In order to deal with university bureaucracy, the following actions are suggested : university managers and TT role players should be equipped with essential information and be well prepared ahead of signing TT agreements with SMEs; university TT role players need to establish strong relationship with decision makers and communicate regularly on TT expectations; and reduce unnecessary decision making layers.

The views of respondents on the university performance evaluation system seem to agree with what literature advocates. Literature states that university performance evaluation system which does not stimulate university staff to have positive attitude towards TT has a negative impact on TT and commercialization from university to industry (SME)[19],[20]. The following actions are suggested in order for the university deal with this restraing factor: increase funding support to university researchers who drive TT projects with high commercialization potential; offer a portion of IP revenue to university researcher responsible for IP technology development; and offer university researchers who deliver

successful TT projects technology development incentives (overseas sabbatical at suitable technology institution).

The views of the respondents on the lack of complementary assets, resources and capabilities within the TTO as another important restrainining factor agree with the literature [17]. Complementary assets refer to manufacturing facilities, complementary technologies, distribution and supporting infrastructure which are required for the successful commercialization of the technology [9]. TTOs facilitate the TT and commercialization of technology from universities to industry and other third parties [21],[22]. In terms of the South African IP legislation [24], university-based TTOs are expected to encourage university researchers to disclose and register the IP which they develop for the ultimate benefit of the South African public. In order to address the issue of the lack of complementary assets within the TTO, the following is suggested: TTO to source priority complementary assets which it can afford using its allocated budget; source seed funding to faciliatte TT; partner with other universities [13], [23]; seek industry support [22]; and leverage technical expertise on TT from the rest of the university.

Respondents agree with literature which states that huge outcome-expectation gaps result in unsuccessful collaborations, which in turn, negatively impacts the TT and commercialization process. Researchers explain that outcome-impact gaps between the technology user and technology developer arise when there are huge differences between the expectations and requirements of the university and the industry player (SME) [2]. Some of the measures that the university and SME can consider to address the outcome-impact gap are the following: university and SME should devote sufficient time understanding goals, objectives and strategic plans of their respective organizations in relation to TT; both parties should establish understanding of each other's needs, expectations, skills and limitations; both parties need to enter into well-considered TT agreement; set realistic time frames; and seek to achieve win-win outcomes.

Some comparisons between the findings of this study and others which had been done in South Africa in the past: Study 1: Drivers of knowledge transfer between university and industry research and development partners in South Africa (2005-2006) [36]. Relevant drivers which this study highlighted as very significant are: the need to extract knowledge for decision making which agrees with the absorptive capacity of SME enabling factor in this study; knowledge as a valuable resource which agrees with the absorptive capacity of SME and disseminative capacity of technology developer as important enabling factors in this study; and return on investment which aligns with the entrepreneurial mindset of technology developer as one of important enabling factors.

This study brings the following distinct aspects when compared to Study 1: focusses on university-SME interaction, in which SME may not even possess any R&D resources; addresses both the enablers and restrainers to TT and commercialization throughout the university-SME value chain.

Study 2: South African National Survey of IP and TT at Publicly Funded Research Institutions: 2008-2014 [37]. This survey focused on 23 publicly funded Higher Education Institutions and 10 Science Councils whereas this study focused on 6 publicly funded universities in Gauteng province; some of the important enablers to TT highlighted by Study 2: availability of dedicate TT funds and HR capacity (which relates to lack of complementary assets, resources and capabilities in this study); internal (institutional) individual relationships; national forum to show case university-developed technologies which relates to lack of university-SME network in this study. Formal and informal engagement with industry which relates to presence of open collaborate innovation and lack of university-SME network in this study.

Some important inhibitors to TT highlighted in study 2: lack of awareness amongst research staff of importance of disclosing and managing IP; lack of/inadequate funding to expand TT function to optimal size which agrees with lack of complementary assets, resources and capabilities within TTO;and lack of funding for IP registration costs (university) which compares with huge licensing costs for university-developed IP.

In summary, the findings of Study 2 and the current study complement each other in many respects. Study 2 covers the complete spectrum of university-industry TT interaction nationally, whereas this research focuses on the challenges which emerging and existing face during the university-SME TT and commercialization process.

VI. CONCLUSION

The transfer and commercialization of technologies from South African publicly-funded universities to SMEs offer the technology-intensive SMEs valuable technology know-how and contribute to their competitiveness. By engaging in TT, universities contribute to technology innovation, derive additional income from IP licensing and grow their research and academic programs.

Successful transfer and commercialization of technologies from universities to SMEs require that both the transferor and transferee take actions that will strengthen enabling factors and eliminate or reduce restraining factors. For the enabling factors to be strengthened or maintained: SME needs to understand and appreciate the value of the new technology from university, ensure that their personnel are well trained on the new technology and are ready to apply and use it; university researcher needs to understand what the technology needs and cognitive limitations of the SME are and ensure that the technology is packaged in a manner that the SME will understand. This requires change of attitude largely on the part of the technology developer and communication by both parties.

For the restraining factors to be minimized or eliminated: the university needs to protect TT projects from its bureaucratic processes, design a performance evaluation system that will stimulate its researchers to pursue TT projects; equip its TTO with resources to effectively facilitate TT. Both parties need to understand each other's expectations on TT and agree on realistic and mutually beneficial TT objectives.

VII. STUDY SCOPE

The scope of the study focused on only six Gauteng-based publicly funded universities. The results of the study may not be generalizable to the rest of the twenty South African publicly funded universities; The paucity of the sample was the huge challenge. Only 33 responses (21 % response rate) were received; and the representation of sectors in the total responses received was poor (10 % for Information Communication Technologies; 10 % for Electronics; and 0 % for Chemicals). Whilst the research findings emanating from this study provide useful insights about TT and commercialization from universities to SMEs, these results may not be generalizable due to the low response rate achieved from the survey conducted.

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