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Case study

University-government collaboration for the generation and commercialization of new knowledge for use in industry

Colaboración entre la Universidad-Gobierno para la generación y comercialización de nuevos conocimientos para uso industrial

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ABSTRACT

The concept of Triple Helix relates to collaboration between universities, governments and industry. Such collaboration can take different forms in different countries. This paper describes collaboration between universities and government in China, specifically in the city of Hefei in Anhui province, one of the most rapidly developing regions in the country. The research question is: ***How can bi-lateral research collaboration be a source of knowledge generation and commercialization for use in industry?***

The study is qualitative, involving individual focus group interviews with university team leaders and team members from successful projects. Government representatives in China were also interviewed. We used the SECI knowledge creation method to analyze the findings. We also describe the collaboration process from idea and application through to review, funding, realization and commercialization. Our study shows that the government in China plays a dominant role in the process of knowledge creation and commercialization. We conclude that collaboration is a source of new knowledge generation and that the government plays a key role by funding universities and creating a research environment that meets the policy requirements of industry today. In particular, we show that universities and their research groups use resources, such as skilled manpower, laboratories and equipment, to accomplish tasks within a set timeframe.

Introduction

Today, China's economic development and government policies provide a platform for collaboration between its stakeholders (namely universities), government, and industry. Such developments constitute the continuous transformation of China's economic structure and production (Turriago-Hoyos, Thoene, Bernal-Torres, & Alfonso-Lizarazo, 2015). In recent years, China has become one of the largest and most rapidly growing market economies, largely because it makes up more than 25% of the world's population. It has a different institutional environment compared to that of other countries thanks to its well-defined cultural, social and economic backgrounds (Tang, Tang, Zhang, & Li, 2007).

Existing literature shows that research collaboration has consistently played an important role in the advancement of knowledge through experimental research. Furthermore, research collaboration is rapidly increasing because of new public policies. These policies provide a platform for improved links between stakeholders (i.e., universities and industries) with regard to science and technology-based collaboration (Katz & Martin, 1997).

Universities and industries have collaborated since the establishment of the People's Republic of China in the 1950s. Such collaborations have primarily been based on technology transfers, research and development, technical services, and individual and joint ventures (Wu, 2007). Recently, however, the profile of university-based collaboration has increased in China due to government financial support policies for research and industrial venture capital. Government funding is essential for university-based collaboration. In return for such funding, universities provide practical education and create better opportunities to understand research problems (Etzkowitz & Zhou, 2007; Zhou & Peng, 2008).

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In most OECD-listed countries, governments allocate more grants that focus on research and specific analysis that is aimed at improving institutional structure and research (Aldrich, 2012). The latest research trends demonstrate that Chinese government policies also seek to encourage and support universities for innovation purposes. Consequently, universities have become an important factor in government innovation policies. For example, universities have been subject to indirect government influence and direct industry influence with regard to changes to rules on intellectual property rights (IPR) (Etzkowitz & Leydesdorff, 1998).

Collaboration provides a platform for stakeholders from which they can generate new knowledge. However, an effective strategy for collaboration is required to share resources, as well as in generating, improving, and commercializing existing knowledge (Du Plessis, 2007; Inkpen, 1996). According to Nonaka and Toyama (2003), new (tacit) knowledge comes from direct experience from inside organizations themselves (both universities and governments) in a socialization phase (tacit–tacit). The next step, externalization (tacit–explicit), involves a combination of individuals from each group and includes the conversion of tacit knowledge through dialogue and reflection. The combination (explicit–explicit) phase involves the organization and application of externalized (explicit) knowledge. In the internalization (explicit–tacit) phase, any new knowledge generated by university-government collaboration supports the commercialization of industry, because industry wants to acquire (tacit) new knowledge for practical purposes (Nonaka & Toyama, 2003).

Regarding research collaboration in China, governments are the main source of funding for universities; they also control academia through a government-initiated Triple Helix (TH) model (Zhou & Peng, 2008). In university-government collaboration, government is a key player as it provides financial support to the universities. The majority of Chinese universities are public institutions. Therefore, without government financial support and involvement, it is very hard for universities to take initiative in any research project (Zhao, Cacciolatti, Lee, & Song, 2015). During university-government collaboration phases, government members' role is to ensure the implementation of the government policies and standard procedures, where university members follow the given guidelines to generate knowledge. Furthermore, the Chinese government encourages the joint funding of research projects by local governments and enterprises. Financial collaboration with privately funded educational institutions is also permitted (Wu, 2007).

Our main motivation for selecting China is because it is currently one of the biggest economic giants in the world and Anhui province in particular is one of the leading knowledge-based innovation regions of China (Abbas et al., 2018; Gao et al., 2015). More specifically, its capital Hefei maintains and boasts major developments within the industrial, scientific and education sectors. This makes Hefei one of China's leading arenas as a knowledge-based, innovation driven city. In Hefei, there are more than 200 national and provincial research institutes, including 59 higher education institutes. The University of Science and Technology of China (USTC), which features among the top ten listed universities in China, is situated in Hefei. The USTC earned this ranking because of its reputation for innovation and research. Anhui University (AHU) and Anhui Agricultural University (AHAU) are also top-ranked institutions located in Anhui province. Over the past five years, Hefei has ranked 12 out of 20 cities in the world in terms of its rapid rate of economic growth. Indeed, it has experienced a 15.5% GDP increase in the past five years because of effective local government policies (Hefei-China, 2016).

In the past few decades, Triple Helix collaboration has gained more attention from around the world, especially in emerging economies such as China. The main purpose of these collaborations is to improve the firms' performance of innovation through acquisition of commercialized knowledge from university funding (Hanel & St-Pierre, 2006). Dynamic market environments in China force industries to acquire commercialized knowledge through external sources and apply it to their existing systems. Previous research acknowledges this particular management research domain, and explores the process of knowledge synthesis, storage, retrieval, and generation, without paying much attention to the overall commercialization processes (Massingham & Al Holaibi, 2017; Zheng, Zhang, & Du, 2011). In the Chinese Triple Helix model, the government's role is stronger than that of both universities and industries because it is a major source of funding. The Chinese government financial support policy promotes R&D in their respective knowledge-based regions for innovation. The government has already spent 293,546 million US dollars by increasing 500% of domestic expenditures. Because of this, China's GDP improved by 0.91% and is ranked 34 out of 138 countries around the world, and 9 in Asia (Huang, Bai, & Tan, 2017).

In this publication, we seek to explore the relationship between government and university research collaboration for the generation and commercialization of knowledge. Our study helps bridge the literature gap by describing the research collaboration processes, including the roles and responsibilities of each sector at different stages of knowledge generation and commercialization. Also, its transfer to the industry includes the SECI model implementation in the Chinese TH concept. To summarize, the main objective of this study is to fill the literature gap by exploring the relationship between Chinese universities and government research collaboration and its role in creating new knowledge and commercialization.

Thus, our research question is: **How can bi-lateral research collaboration generate new knowledge and commercialization for use in industry?**

Frame of reference

The concept of such a collaboration is based on the Triple Helix model. It reflects a university-government-industry relationship which was first introduced by Ektzkowitz and Leydesdorff during the 1990s. Their work drew on studies of industrial-government relationships in industrial societies carried out by Lowe (1982) and Sábato and Mackenzi (1982) (Triple-Helix-Research-Group, 2013).

The evolution of the Triple Helix model is based on institutional agreements of university-government-industry relationships, in which universities and industries are fundamentally part of the State, and both have direct relationships. This model is mostly used in "existing socialism" – namely, in the former Soviet Union and in Western European countries. Another form of the relationship between the three is the laissez-faire model, based on separate institutional spheres with strong borders and limited relations. The third and last form of Triple Helix is known as the Triple Helix-III. This source of knowledge creation includes overlapping institutional spheres of university-government-industry. The main purpose of the Triple Helix is to create a suitable atmosphere for bi-lateral and tri-lateral relationships so that knowledge sharing can take place between industries, government laboratories, and academic research groups (Etzkowitz & Leydesdorff, 2000).

With reference to Fig. 1 above, knowledge is isolated. Knowledge-creation is a continuous process in which knowledge is generated and then used to generate competitive advantage (Lynch & Jin, 2016). The knowledge creation process itself is not linear. Furthermore, human skills are a basic requirement in the production of new knowledge or the enhancement of existing knowledge. New knowledge can be produced within a team by its members (Fong, 2003). Hence, the collective knowledge of team members (i.e., universities) is combined for knowledge users

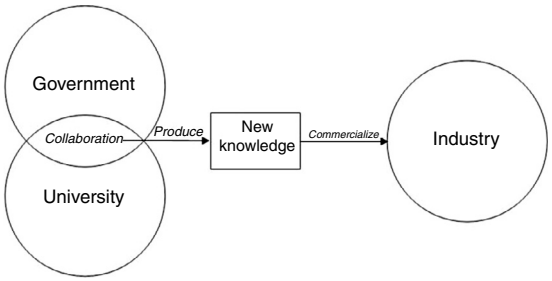

Fig. 1. Theoretical model.

(i.e., industries). Knowledge is generated by two different modes, Mode 1 and Mode 2. In Mode 1, knowledge is generated by an individual party without collaboration with others (such as university), whereas in Mode 2 knowledge is generated through short-term or long-term collaboration with other parties to solve a specific problem (Hsu, Shen, Yuan, & Chou, 2015). Knowledge creation is a process that leads to the creation and development of new knowledge (Du Plessis, 2007). Nonaka's knowledge creation theory has both epistemological and ontological dimensions. Both dimensions represent the processes involved in a knowledge creation spiral. The epistemological dimension is based on the conversion of knowledge from the tacit to the explicit generation of new ideas. In the ontological dimension, social interaction between individuals is important when sharing and developing new knowledge. Knowledge creation theory (i.e., the SECI knowledge creation model) has four phases: socialization, externalization, combination, and internalization. Socialization is the first phase of knowledge creation, whereas internalization is the final phase. The tacit knowledge of each individual is converted and combined through dialogue in the externalization phase. It is then organized and applied as explicit knowledge in the combination phase (Fong, 2003; Gourlay, 2003; Nonaka, 1994; Nonaka & Toyama, 2003). For the generation or creation of new knowledge, an effective strategy is required. Furthermore, for organizational knowledge to survive, it must be translated into new products and services (Inkpen, 1996). Collaboration between organizations facilitates resource sharing and the creation and transfer of new knowledge, thus helping to produce synergistic solutions. Individual organizations cannot produce new knowledge by themselves. They need to collaborate in order to acquire resources and skills that are not produced internally. Collaboration provides a platform on which resources can be combined in order to generate new knowledge and improve individual capabilities. Thus, collaboration not only supports the creation of new knowledge, but also the improvement of skills for effective and efficient innovation (Du Plessis, 2007; Hardy, Phillips, & Lawrence, 2003).

Research methodology

Data collection strategy

For this qualitative case study, we carried out semi-structured focus group interviews with university team leaders and team members from three different universities: University of Science and Technology of China (USTC), Anhui University (AHU) and Anhui Agricultural University (AHAU). We also interviewed anonymous experts from Anhui province over a five-week period in October and November, 2016. Interviews were conducted with four anonymous experts, five university team leaders (two from USTC, two from AHU, and one from AHAU) and one member from each team. Such an approach provided on-site interaction with interviewees and also matched the current conditions faced by local stakeholders and their needs (Johnson & Onwuegbuzie, 2004; Williams, 2011).

Our data collection strategy was based on the SECI knowledge creation model (Nonaka & Toyama, 2003). This model consists of a cyclical process made up of four phases: socialization, externalization, combination and internalization. *Socialization* is the first phase of the SECI knowledge creation model. In the beginning, tacit knowledge comes from individual experience. Thus, in terms of data collection, we interviewed university team leaders and experts. In the second phase — e*xternalization* — knowledge comes from individuals within each group in an organization through discussion and dialogue. To categorize this knowledge, we interviewed team leaders and team members. *Combination* is the third phase of the SECI knowledge creation model. In this phase, we combined the knowledge of all the universities' team leaders and members. *Internalization* is the final phase of the SECI knowledge creation model; in this phase, we interviewed university team leaders and experts to explore relationships in Chinese research collaboration aimed at creating new knowledge and commercialization in industry.

Designing interview questionnaires

We designed a list of interview questions relating to our conceptual framework, as shown in Fig. 2. For data collection, we interviewed university team leaders, team members, and anonymous experts.

For data collection, we first interviewed university project team leaders, because they are responsible for initiating any collaboration with government. Team leaders have experience with research collaboration, project design, and the initiation of government funding. Thus, our first three interview questions for the team leader were based on socialization (tacit knowledge). They explored new ideas, the importance of research collaboration, new knowledge and knowledge ownership. The next two questions were related to the conversion of ideas into new knowledge, including the execution of tasks assigned to team members and the role of team members in a university-government collaborative research project. The following four questions were related to the conversion of tacit knowledge and the combination of explicit knowledge through the involvement of university and government representatives. The final three questions related to the usefulness of collaboration and commercialization, and the benefits that come with such processes.

Second, we conducted interviews with anonymous experts, because they are responsible for the selection and evaluation of research collaboration proposals and final reports. Individual experts also have tacit knowledge (direct experience) of research collaboration, project proposal design, the evaluation of proposals and reports, and the funding and ownership of new knowledge. These experts advise the government on research collaboration with universities and the release of funding. Thus, our first six interview questions were related to the generation of new ideas, the importance of university-government collaboration and new knowledge, the selection and evaluation procedure for proposals, the allocation and release of funding, and the ownership of newly generated knowledge by the government. In university-government collaboration, the government and its experts were not involved in the externalization and combination processes. The final three questions covered the internationalization mode and the commercialization procedure of new knowledge and any benefits derived.

Lastly, we interviewed individual university team members because they were involved in converting ideas or executing tasks assigned by the team leaders. Our first two questions were thus related to how ideas were shared in terms of the generation of new knowledge, coordination between team members, and the role of team leaders and members. Our next three questions were related

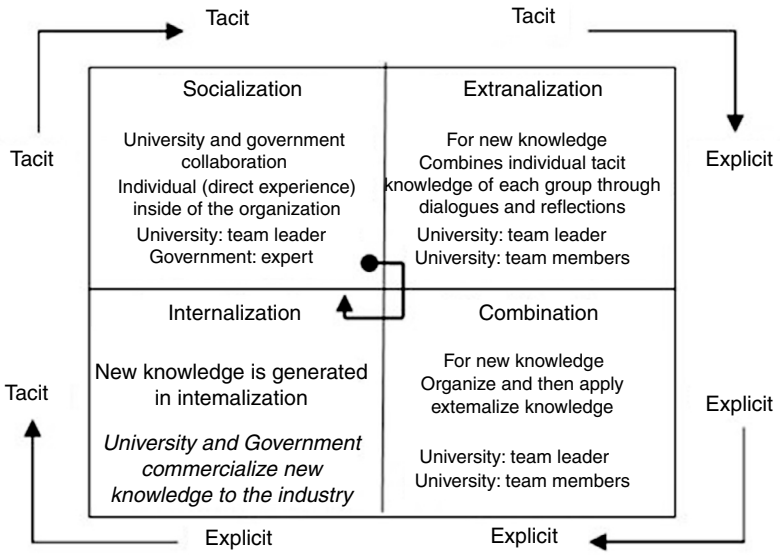

Fig. 2. Conceptual framework (Nonaka & Toyama, 2003).

to the generation and combination of individuals' (explicit) knowledge.

Sample selection

For this research, we applied purposeful sampling, also known as judgment sampling, because it helps researchers actively select the most productive samples related to their research topic and question (Marshall, 1996). We interviewed university team leaders, team members, and experts who were an integral part of the university-government collaborative research project. In our case study, the sample size was not a factor because the main focus of this research approach was the systematic collection of data (Abbas & Faiz, 2013; Eisenhardt, 1989). Consequently, we began by interviewing five team leaders from three different universities in Hefei and four anonymous experts. We questioned them about evaluation and execution, the production of knowledge and the commercialization of knowledge in industry. Afterwards, we interviewed all university research team members involved in university-government collaborative research projects.

Data analysis, validity and reliability approach

We used a deductive approach because it assists in narrowing down research to specific hypotheses for the testing of collected data and the confirmation of original theory (Trochim, 2006). For this study, one researcher conducted and transcribed all recorded interviews and analyzed the data according to the SECI model of knowledge creation, as shown in Fig. 2. The deductive content analysis approach is generally used to analyze data through verbal communication. This method validates collected data related to the research topic, providing new insights with representation of facts, sets of actions, and new ideas for building new models (Elo & Kyngäs, 2008; Vaismoradi, Turunen, & Bondas, 2013). Reviewing literature and carrying out selective interviews are important for the validity and reliability of all collected data. This technique helps researchers to avoid errors as well as bias (Abbas & Faiz, 2013; Yin, 2013). The analysis was qualitative and focused on the form of collaboration, its impact on knowledge generation and the commercialization of new knowledge in industry. We used the SECI knowledge creation model (Nonaka & Toyama, 2003) to identify the process of knowledge generation and commercialization, and its relationship with university-government collaboration. We use literature to support our statements in the form of validity and reliability of collected data.

The first phase of this model was based on the socialization process in the form of implicit exchange of ideas for the creation or generation of new knowledge. We then moved onto the externalization phase because it deals with assigning tasks to individuals (team members) and also formalization of knowledge, during which university team leaders and team members were involved in dialogue and reflection. After conducting interviews with university team leaders and team members, we categorized and applied externalized knowledge in a combination phase to combine individual generated knowledge which generated by team members. Then, in the internalization phase we acquired knowledge through university-government collaboration. Finally, as a result of distribution of generated knowledge, we commercialized that knowledge for use in industry.

By analyzing collected data, we also give in-depth information about different types of university-government research projects, role of each sector during university-government collaboration, ownership of generated knowledge and also distribution of rights in China especially in Hefei city of Anhui province.

Results and analysis

For this research, we conducted interviews of the university research teams who were selected from three universities that had collaborated with the Chinese government to get funding and had successfully executed their research projects. Meanwhile, we also carried out face-to-face semi-structured interviews of anonymous government experts involved in the evaluation, selection, and approval of university projects and their funding. We asked questions from interviewees related to the importance of university-government research collaboration, the generation and transfer of new ideas, and the production and commercialization of new knowledge for industrial use in China and any benefit, specifically in the Anhui province of Hefei.

Socialization

Socialization is the process by which individuals from inside an organization use their experience to create new knowledge. We interviewed university team leaders and anonymous experts about

the initialization of university-government research collaboration, funding, and the selection and evaluation process.

The initialization process of university-government research collaboration is reliant on both university and government individuals. The role of the university is to support university-government research collaboration. As such, the university "*brings new and original ideas*" in response to the government provision of resources for research. According to AHAU and AHU team leaders, "*The university is a source of knowledge for the government*". Furthermore, "*The university is the center of knowledge creation*". In addition, another AHU team leader said, "*The university is good at theoretical analysis and research skills and the government's strength lies in the integration of information and resources*". Two anonymous experts said, "*The university and government have strong connections with the area of development*". In China, university-government research collaboration is important because most universities belong to the public sector. Thus, research is mostly sponsored by the government and government always has the "*dominant status*". According to another anonymous expert, "*University-government research collaboration is important due to research funding and university team leaders or scientists getting competitive salaries*". University-government research collaboration in China is "*different from other countries*" because the evaluation process of the research proposal is like a "*peer review*". During the selection and evaluation process of the proposal, "*experts remain anonymous*" to the applicant in a university-government collaboration research project, "The p*eer review process is rare*". This is because relatively few research groups exist in China. Researchers or scientists who are well known in the relevant field are also limited in number. In China, most university-government research projects have been "*designed by the government*". The selection and evaluation of university-government research collaboration proposals is based on the "*proposal design and its contents, research background, research methodology or technique*, *novelty, research contribution and financial plan*". One anonymous expert said that, "*in China, ownership is decided by law and regulations, i.e. Intellectual Property Rights (IPR)*" for newly generated knowledge. In regard to the funding, two anonymous experts were interviewed. One of them said that the procedure for allocating and releasing funding depends on the nature of the project and is strictly audited by the government. For example, in China, the duration of National Natural Science Foundation of China (NSFC) projects is four years. All funding is allocated at the beginning of that period. Upon completion of a project, the government carries out an evaluation. The other said that the release of funding is dependent on the nature of the project, with 30–70% of funding usually released by the government at the beginning of a project. The rest of the funding is released at the end.

Externalization

After university-government research collaboration has been agreed, a university team leader forms a research team to execute the project. In China, such a team, "*has three to five team members and certainly no more than 10*". According to one USTC team leader, most team members are "*university Masters and PhD students*", although this depends on the nature of the project. The research team and its members work together to complete their tasks. The team leader transfers ideas to team members through communication methods that include individual and group discussions, seminars, and emails. The university team leader usually "*recommends some papers from leading journals to their team members to introduce some ideas and then, through group discussion, the team leader will give his opinion*". The team leader plays a key role in university-government collaboration research. According to AHU and USTC team leaders, "*A university team leader is the mediator or bridge between university and government*". The role of the university team leader in university-government collaborative research is "*team leadership*, *the division of tasks, effective coordination, regular meeting arrangements, and the encouragement of team members*". Team members from the AHAU, AHU, and USTC all said that the role of university team members is to "*follow up an idea, convert that idea into practice (i.e. given tasks), report and sometimes give advice to their team leader*".

Combination

In university-government research collaboration, a university research team is formed. Tasks are then assigned and executed. We asked questions about the collaboration of individuals' knowledge during university-government research collaboration. In the combination mode, individuals' knowledge is combined under the supervision of the university team leader with respect to the project guidelines. AHAU and AHU team leaders said that "*this combination of individual knowledge depends on: the discussion and work refinement of each team member and the exchange of information for integration*". These factors are essential for the generation of new knowledge. Each team member "*completes their assigned tasks by using their research skills (e.g., survey design, data collection and analysis) and the latest tools and techniques to meet the task requirements*". USTC team leaders said that "*team leader selects best results of each member and then integrate using theoretical thinking and practical experience*".

Internalization

We posed questions to university team leaders and anonymous experts about internalization and the commercialization of newly generated knowledge and any benefits derived from such knowledge. One anonymous expert said the "*whole procedure of converting new knowledge to commercialization is already in place. First, you get IP, then you transfer it to industry*" and another expert said "*University research team applies for IP and then they commercialize it for use in industry*". After the commercialization of new knowledge, the university receives benefits in the form of new projects and more funding from government. One AHAU team leader said that the government can offer support in terms of the "*promotion and commercialization of new knowledge*". An AHU team leader also stated that, "*commercialization is the responsibility of government*", because it is the government that wants to improve some areas of industrial development. For this reason, the government arranges business meetings with industry representatives. The government itself does not directly benefit from the commercialization of new knowledge. After commercialization, however, benefits can include the promotion of industry, the creation of more job opportunities, the boosting of the economy, and the generation of more revenue through taxes. An anonymous expert stated that, "*industry gets new knowledge for the improvement of their products*". Thus, industry acquires intellectual property, which allows them to produce new products and improve existing products so they can gain more profit. All anonymous experts and university team leaders agreed that, after the successful commercialization of new knowledge, all stakeholders benefit either directly or indirectly. The university and its team benefit directly because of intellectual property rights related to new knowledge and its commercialization. Both the government and industry also benefit indirectly. The government can use the acquired knowledge to reform their policies, promote businesses, increase the employment rate, enhance economic growth, and generate more revenue whilst industry can improve their products using the newly acquired knowledge and

gain greater profits in the competitive marketplace after selling their products.

Discussion

In this section, we discuss how bi-literal research collaboration can bring about the generation and commercialization of new knowledge for use in industry. To answer this question, we interviewed anonymous expert individuals from universities and government, because they were involved in university-government research collaboration for new knowledge generation and the commercialization process. Furthermore, individuals from both the government and universities initiated the proposal of research topics for university-government collaboration. In this case study, we carried out an in-depth exploration of the different collaboration processes involved in knowledge generation and its commercialization, as shown in Fig. 3. University team leaders, members, and anonymous experts shared their experiences about the knowledge generation and commercialization process in Hefei, a knowledge-based innovation city in Anhui province. Previous research studies have focused on different modes of knowledge-creation theories. This study aims to locate and represent each process of university-government collaboration in the knowledge based innovation region of China. This research also provides details about initiated knowledge creation, evaluation of research project proposal and final research results, allocation and audit of funding, and commercialization of academic research results to the industry for innovative product development. Our investigation was related to the knowledge-creation processes used in practice during university-government research collaboration and the commercialization process of acquired knowledge in Chinese industry.

Socialization

During the initial process of knowledge creation, individuals in universities or government initiate university-government research collaboration. The purpose of this collaboration is to help each other; in other words, a university brings new and original ideas on how to create new knowledge. In return, a government has the resources, specifically funding, to support them. The exchange of ideas and promotion of collaboration can only be done through communication between partners such as university and government (Ben Letaifa & Rabeau, 2013). In China's case, university-government research collaboration is particularly important because most universities are governed by local, provincial, or state governments. The government collects data from industry in order to identify any requirements. The collected data is then handed to the universities so that they can conduct research. Universities can also propose projects to the Chinese government about any industrial or social needs. Two kinds of university-government research projects exist in China: theory-oriented projects and practice-oriented projects. Theory-oriented research projects support basic theory development where new ideas are created in line with research trends around the world. These trends can be identified by attending meetings, reading published papers, or by communicating with well-known experts or scientists. An example of theory-oriented project is communication research project, conducted by Chinese quantum physicist Jian-Wei Pan at USTC to explore the basic theory of quantum communication (Cartlidge, 2017). Practice-oriented research projects are based on a need within an industry for some new knowledge or technology. For example, Chinese scientists from USTC invented the first quantum computing machine based on a single photon that is hundred time faster than normal computer (Xinhua, 2017).

In China, the National Natural Science Foundation of China (NSFC) supports universities by funding research for a maximum duration of four years. This funding is allocated only at the start of a project and projects are evaluated by the government on their completion. For the projects in this case study, the University team leader used funding to pay a salary to team members rather than pay expenses. In the case of the failure of a university-government project, applicants are not eligible to apply for further NSFC funding (although this also depends on the nature of the research project). In the case of small projects, applicants are eligible to apply for funding again after four years. For large projects, applicants are not eligible to apply for future funding. In China, the government usually encourages practice-oriented projects, despite the high risk involved. Theory-oriented university-government research projects are a key source of new knowledge creation aimed at helping industry and aiding economic development. Chinese government financial investment policies encourage research and development activities (Huang et al., 2017). The purpose of this is to encourage the creation of new knowledge. The government in China allocates approximately 40 billion Chinese Renminbi (RMB) every year to support these research projects.

In China, the government appoints experts to select and evaluate research proposals and write a final report. For the selection of research proposals, the reviewer remains anonymous. Experts only select those proposals that follow the guidelines or format endorsed by the government. In addition, they take into consideration: new ideas, research background and methodology, theory contribution, expected outcomes, past research experience and research team profile. Evaluation is based on research results, including practicality/feasibility aspects, novelty, research contribution, and financial execution plan. The ownership of new knowledge is decided by "IPR law". University-generated knowledge is only protected through patents (Baba, Shichijo, & Sedita, 2009). Sometimes, both the university and government retain co-ownership. Other times, ownership is dependent on the set of terms and conditions stated in the university-government research proposal.

Externalization

After university-government collaboration is initiated, the university team leader assigns tasks to their respective team members. A university professor is always the team leader and the research team typically consists of three to five members. Usually, team members are Masters or PhD students. A government officer or official is always in charge of a university-government research project. Individuals in each university team, including team leaders and members, arrange and participate in group discussions to share their new ideas. Team leaders act as mentors and act as a bridge between the government and the university during the research process. Team leaders are responsible for engaging the externalization mode. They lead their team, assign tasks to each member according to their skills, arrange individual or group meetings, and encourage and advise each team member. Team members are responsible for following team leader instructions and advising them on how to accomplish assigned tasks within a given timeframe. In the externalization mode, it is imperative that university team leaders and members communicate their findings and coordinate their activities.

Combination

Thereafter, it is through combination process, that explicit knowledge is collected from individuals and then combined to generate new knowledge (Nonaka & Toyama, 2003). In order to generate new knowledge, the individual results of each team member are combined following group discussions and meetings. The

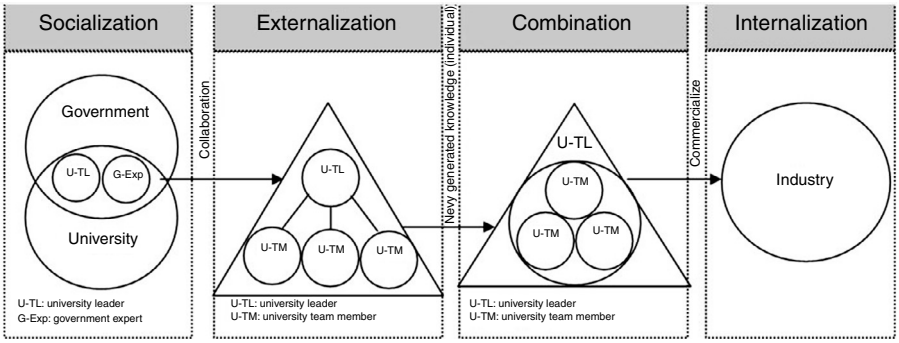

Fig. 3. The university-government research collaboration process for the generation and commercialization of new knowledge for use in industry.

exchange of information about integration uses theoretical and practical research skills. Team leaders use their practical research experience to combine individual results.

Internalization

University-government collaboration provides a platform that enables universities to generate and protect their knowledge before commercialization through IPR law. To commercialize the newly generated knowledge to the industry, universities must follow their internal rules and procedures, as well as government issued policies and guidelines (Baba et al., 2009; Perkmann et al., 2013). The procedure for the generation and commercialization of new knowledge is built into the collaboration process. Direct methods include collaboration and licensing. Once intellectual property rights are applied for, the newly created knowledge is commercialized so that it can be used in industry. The government helps to commercialize new knowledge by arranging meetings with industry representatives. The most common method in China for distributing intellectual property rights is "*622*". Here, the research team gets 60% of the intellectual property of any new knowledge, while 20% belongs to the school or department, and 20% goes to the respective university. Any variation depends on the intellectual property-related terms and conditions mentioned in the university-government research collaboration proposal or contract. Both the government and universities are co-owners of any new knowledge, which also belongs to the nation. Through the commercialization of new knowledge, the university and government act as producers. Industry, as the user of new knowledge, reaps any benefits, whilst the university benefits directly from the intellectual property rights attained. They are also eligible to apply for more projects and government funding. Triple Helix collaboration helps to enhance relationships between all stakeholders and ensures acquisition of mutual benefits from generated knowledge (Aldrich, 2012; Etzkowitz & Leydesdorff, 1998, 2000). The government derives benefits from the commercialization of new knowledge in the form of new policies to promote businesses, increased job opportunities, increased GDP, and greater revenue generation through taxes. Industry can then use newly acquired knowledge for practical purposes. For example, they can improve existing knowledge, seek competitive advantages, get subsidies from government, and gain more profits to enhance their business.

Conclusion

Therefore, we can conclude that university-government research collaboration in China, specifically in the city of Hefei in Anhui province, is important because of knowledge-based innovation. We have successfully examined the application of SECI theory creation model and the outcome of this research shows that the model is acceptable in the Chinese Triple Helix context. Our designed university-government research collaboration process model highlights the role and responsibilities of each actor at different stages of knowledge generation and commercialization. The government in China funds projects in universities and thus creates a research environment that meets the requirements and flexible policies of industry. In such collaboration, universities and their research groups can use resources such as skilled manpower, laboratories, and equipment to accomplish tasks within a set timeframe. To ensure transparency, a group of anonymous experts is allocated by the government to peer review any university-government research collaboration proposals and carry out an audit of a final report. After the successful generation of new knowledge by a university research team, an application is made for intellectual property. The newly created knowledge is then commercialized for use in industry. The government in China can further support universities in the commercialization of new knowledge by arranging meetings with industrial groups. Thus, the industry can use new or existing knowledge to create or improve products, ultimately generating more wealth. The Chinese government can also earn more revenue through taxation, whilst universities can get more government funding for research projects. Finally, industries are able to receive subsidies from the government.

Theoretical contribution and practical implication

The main theoretical contribution of this study is to highlight the role of both university and government collaborations in order to catalyze the generation and commercialization of new knowledge for their respective industries and to encourage innovative product development within a Triple Helix context. We have also outlined the role of the university. The government has assigned a new role to universities in the knowledge segment where they act as a source of new knowledge generation for industrial innovative product development and regional based research activities. Finally, our studies confirm that the SECI knowledge creation model is applicable at an inter-organizational level for the generation and commercialization of new knowledge, especially in a Chinese context.

The practical implications of this research are that, firstly, the university as a hub of knowledge creation, needs to better develop their university based technology transfer offices. This is so that they can identify the worth of new scientific results (university generated new knowledge) and protect them under the government given IPR guidelines to avoid any future conflicts regarding infringement in the society. Secondly, the government can encourage research in universities and in regions by allocating specific research grants for the generation of new knowledge. The government can also explore opportunities to design some flexible, short and long term policies that give subsidies to the industry so they can

better acquire knowledge from universities. Moreover, industry as a user, can perhaps arrange expos as a means to encourage universities and their research groups to participate and show their scientific research results. These platforms could form a much-needed bridge between university research groups and industrial experts to share ideas, research results, and requirements. It is possible to engineer a meeting ground where the government supports industries and promotes research and business activities to encourage economic development within the region and subsequently, economic growth.

Limitations and future work

One particular limitation of this research study was that we selected only the top three Hefei city-based public sector universities and anonymous government experts from Anhui province of China. The selected interviewees were fluent in English, although they sometimes needed help from a translator or language translation software tools to translate and explain questions using the Chinese language. It was difficult to arrange interviews with Chinese university team leaders and experts because most of them were not proficient in English and few had flexible schedules.

To further extend this research, it might be beneficial to explore studies on how innovations in certain industries could be initiated from within the industry itself, as opposed to the outside, e.g. university. It is possible that industry could also initiate university-lead projects. A future research project to understand these facets of discussion might involve the study of how these options differ amongst their performance and general effects.

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