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CONTINGENT EFFECTIVENESS IN TECHNOLOGY TRANSFER OF TWO ANIMAL FEED INNOVATIONS IN A PHILIPPINE STATE UNIVERSITY'S PUBLIC RESEARCH INSTITUTE

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ABSTRACT

Technology transfer is a recognized mechanism for promoting sustainable development through scientific research. The case study analyzed technology transfer dimensions and effectiveness of two animal feed technologies developed by a public research institute in a state university in Luzon, Philippines, and elaborated on its role in promoting different development goals. Desk review and key informant interviews with the technologies' developer, university technology transfer officers, and technology takers were used to gather data in 2022-2023. Guided by a contingent effectiveness model of technology transfer, directed qualitative content analysis and descriptive analysis were employed to explore and identify key themes and characteristics. Technology transfer of the animal feeds is shaped by the demand for the technologies, based on the differing goals of public and private agencies. It influences the R&D activities of the transfer agent (the institute) that develops transfer object (technology) towards maturity and market readiness, and facilitates transfer via commercialization or extension (transfer media). A transfer recipient (the next user and/or end user) receives the technology for manufacture, marketing, and/or adoption. Effectiveness criteria identified were out-the-door, market impact, partnerships and collaborations, and public value, while the barriers were financial and human resource constraints as well as bureaucratic administrative processes.

Key words: case study; directed qualitative content analysis; commercialization; public value; academe-industry partnership

INTRODUCTION

Science and technology (S&T) play a vital role in society's advancement. One of the mechanisms identified by the United Nations in promoting sustainable development with S&T is technology transfer (Corsi 2019). In universities, technology transfer brings research outputs (e.g. technologies or innovations) to the market and eventually to end-users. It provides opportunity for academe to strengthen its relationship with the industry; promote knowledge sharing; and serve as a source of revenue (Bantigue 2019). In the Philippines, prior to the enactment of Republic Act 10055 or the Philippine Technology Transfer Act, government funded technologies were found to perform poorly in commercialization and were hampered by various constraints (Aquino et al. 2018). Although there are developments since its enactment such as increases in annual IP protection application filings which reached a peak in 2019 prior to the onset of the COVID-19 pandemic (Decena and Dela Peña

2022), the challenges identified in literature in public sector technology transfer in the Philippines include low R&D funding in agricultural research, cultural gap between academe and industry, low awareness of scientists on the technology transfer protocols, lack of resources among technology transfer offices (Catibog 2016); and temporally and financially costly management of joint research projects and complex institutional bureaucracy (Quiñones et al. 2019).

Despite the wealth of studies about technology transfer and its effectiveness, how universities translate their goals to commercialization was still considered an under researched area (Baglieri et al. 2018). The lack of a "one-size-fits-all" managerial model for how technology transfer works (Giuri et al. 2019) implies its context-based nature. Most studies on sustainable technology transfer policies have also been conducted in the context of the United States (Fernandes et al. 2021), limiting the narrative on public sector technology transfer in the Philippines to a handful of studies.

This study analyzed the technology transfer experience of two inventions from the National Institute of Molecular Biology and Biotechnology (BIOTECH) of the University of the Philippines Los Baños (BIOTECH) namely the Animal Probiotics technology and the Protein Enriched Copra Meal (PECM) technology. It sought to better understand this university-to-market process by analyzing key technology transfer dimensions, perceptions of effectiveness, and barriers encountered in the experience of the two selected technologies, within the institute's context.

The study used the Contingent Effectiveness Model of Technology Transfer or CEMTT (Bozeman et al. 2015) as analytical framework. CEMTT categorized technology transfer studies based on the approach in measuring effectiveness. This model, which has its roots on organizational technology (Bozeman 1994) and contingency theory, posits that effectiveness may be measured through the following criteria: 1) out-the-door; 2) market impact; 3) economic development; 4) scientific and technical human capital; 5) opportunity cost; 6) political reward; and 7) public value (Bozeman et al. 2015). Thus, effectiveness or impact can be explained by 'who' (does), 'what' (is transferred), and 'how' (is it transferred) of the technology transfer process.

CEMTT has been useful in demonstrating the effectiveness criteria in the field of bioeconomy in the European setting through an exploratory qualitative study by Borge and Bröring (2017) which brought out a new effectiveness criterion, "resource complementarity". The model was also adopted in developing the technology transfer pathways of a farming decision support tool from a developmental project in Indonesia, which showed how dimensions from the model (transfer object, transfer recipient, and transfer use) lead to effective technology transfer, and highlighted how public or government agencies and multi-stakeholder platforms, as technology recipients, can complement each other and sustain impact (Bugayong et al. 2019).

With the aim of adding to the limited discourse on technology transfer in the country, this study shifted the discussion to the field of "development management" as it used a framework that assumed performance is based on different criteria, depending on the stakeholder/s involved. It also argued for the importance of the "public value" of technology transfer (Bozeman et al. 2015), thus making it a public policy concern. The resulting framework can thus aid in planning or evaluation of the institute's technology transfer development projects.

MATERIALS AND METHODS

The study employed a qualitative case study approach, particularly the single-case embedded design wherein 'units' are explored in a single context (Yin 2014). The single-case embedded design focuses on select units of analysis within a given context (e.g. in program evaluation, the units of analysis may be a few chosen projects under the program, while the program would serve as the overall case context). These units are sampled or clustered depending on the objectives of the study (Yin 2014).

In this study, the single case context was that of BIOTECH, UPLB, and the units of analysis were the Animal Probiotics and PECM.

The importance of context and notions of key people involved in technology transfer (e.g. technology developer, technology transfer officer, technology taker) highlights the value of using a qualitative research approach (Phan and Siegel 2006; Dul and Hak 2008). Aside from providing in-depth details through the recognition of patterns, relationships, and analysis of the "how", "why", and causes of certain events, single case studies can contribute to theory by building on constructs and linkages of cases within their contexts (Ridder 2017). The experiences and insights from key informant interviews (KIIs) with the technology developer, technology transfer officers, and technology takers, and the information gathered from relevant secondary sources through desk review provide not just an account of the technology transfer process but also the basis for the key themes of each dimension in the CEMTT.

Following a contingent framework, the initial criteria for choosing the technologies to be studied were its commercialization status, particularly those that have been formally transferred through commercialization projects, licensing agreements, marketing agreements, and/or spin-off companies (Bozeman et al. 2015).

Data collection involved two main activities: desk review and KIIs. Desk review is a straightforward data collection strategy that does not interfere with the research situation which reduces validity and reliability (Van Thiel 2014). KIIs gather the relevant information and perspectives from experts, authorities, leaders, and/or knowledgeable persons who can also provide reliable counsel on the subject matter (Akhter 2022), and is an adaptable method for gathering data such that the researcher can ask the respondent to elucidate on or clarify the answers (Van Thiel 2014). This type of interview approach was also recognized as suitable for "understanding perspectives, generating recommendations, and identifying issues" which may be used for future quantitative studies (USAID Centre for Development Information and Evaluation, 1996).

Desk review examined the project reports (core and external reports), annual reports, terminal reports, related government-issued documents such as memoranda and special orders, technology valuation reports, licensing and marketing agreements, and other IP-related documents of the two technologies. It also studied data in projects and annual reports and were mainly processed for cross-checking of data and served as other primary sources to complement the findings from the KIIs, which were semi-structured and related to the research objectives, including the roles of the different actors involved in technology transfer, their experiences, and lessons learned.

After an initial desk review of related documents, an interview protocol was prepared, including the informed consent forms which presented how the responses will be processed, and ensured the respondents' confidentiality. Different sets of interview questions were drafted for the technology developer, technology recipients, and technology transfer agents. These were pre-tested through consultations with a technology transfer officer of BIOTECH who was not part of the study respondents. A total of seven (7) respondents were interviewed face-to-face or virtually via Zoom: three were technology transfer officials; three were technology recipients; and one was the technology developer and current project leader for both animal feed technologies. The technology developer has also succeeded the original inventor who has already retired. The interviews were conducted on 13-14 May 2022 (technology developer), 9 June 2022 (technology transfer officer), 2 Oct 2022 (technology adopter), 11 April 2023 (technology transfer official), 14 April 2023 (technology transfer official), 15 April 2023 (technology transfer), and 19 April 2023 (technology transfer adopter).

It should be noted that among the seven (7) respondents, five (the technology developer, technology transfer officer, and three transfer recipients) were directly involved in the technology transfer of both animal feed technologies. The other two university technology transfer officer-respondents were former officials and involved in technology transfer management of the university and were interviewed for their experiences and insights on the overall process.

Analysis of key characteristics of the CEMTT dimensions, perceptions of effectiveness, and barriers encountered was mainly done using a modified Directed Qualitative Content Analysis (DQlCA) method (Kibiswa 2019). Qualitative analysis generally involves data identification, categorization, interpretation, and reduction (Bengtsson 2016).

DQlCA is a deductive approach that capitalizes on an existing model—in this case, the contingent effectiveness model of technology transfer by Bozeman et al. (2015). It was described as a method that can apply or extend theories as analytical lens in a context that is different from where the theory or framework was developed (Kibiswa 2019). The contingent effectiveness framework was developed in the context of the United States (particularly public sector technology transfer), and using this as analytical lens, was applied in the context of BIOTECH, UPLB. As a qualitative content analysis approach, processing or interpretation of data does not involve quantification, frequency, or numbers (Kibiswa 2019).

The cloud-based computer-assisted qualitative data analysis software Delve was used to partly aid in the coding process and data reduction of some of the interview transcriptions. Delve was founded in 2017 and is known for its simplicity and suitability for beginner qualitative researchers and has already been cited in several publications and social science research conducted in the United States (Tools & Technology: How to Analyze Qualitative Data Using Delve 2020). It can be used in qualitative research using grounded theory, thematic analysis, and narrative analysis, and can analyze in depth interviews, focus group discussions, texts and other materials (Delvetool.com, 2023). For this study, the original eight steps by Kibiswa (2019) were reduced to the following five steps, due to the difference in the materials analyzed, the nature of confidentiality with the respondents, and time constraints: 1) developing the study's frame and operational definition; 2) determining the unit of analysis and sampling materials to be analyzed; 3) getting a sense of the data; 4) data coding and organizing; 5) making connections, interpreting them, and drawing conclusions.

The coding framework used for categorizing data based on CEMTT elements are detailed in Table 1.

Table 1. Coding framework for main categories of CEMTT (Bozeman et al. 2015).

Category	Description
Demand environment	Statements/descriptions about market and non-market factors describing need for the technology/product.
Transfer agent	Statements/descriptions about the institution or organization seeking to transfer the technology; its organizational characteristics and culture; as well as the characteristics of the technology developer or proponent.
Transfer object	Statements/descriptions about the technology–its content, form, and characteristics.
Transfer media	Statements/descriptions about the formal and informal channels used to transfer or move the technology towards commercialization.

Category	Description
Transfer recipient	Statements/descriptions about the characteristics of the licensees and adopters commercializing or using the technology.
Out-the-door	Statements/descriptions about the licenses issued, IP registrations made.
Market impact/ Economic development	Statements/descriptions about the "commercial success" of the technology and its impact in business.
Political reward	Statements/descriptions about recognition by policymakers or key officials on the technology, and resulting benefits gained by the agent from the transfer.
Opportunity cost	Statements/descriptions about the positive impact of technology transfer on other objectives of the university/institute/laboratory (e.g. alternative use of resources).
Scientific and technical human capital	Statements/descriptions about the development of human and institutional capabilities (e.g. improvement in skills, knowledge, and social resources) brought about by the transfer.
Public value	Statements/descriptions about how the technology promoted or enhanced collective good and broad, societally shared values (e.g. sustainability, poverty alleviation).

For data reduction purposes, DQlCA focused on two groups of topics namely "technology transfer of the two animal feed technologies" and "technology transfer in the institute" and centered on the following questions for themes development: 1) *What was/were successful in the transfer of the two animal feed technologies? What were the gains or positive changes that occurred, in terms of the effectiveness criteria in the contingent model? What were the considerations/attributes of each of the technology transfer elements that possibly influence technology transfer?* and 2) *What are the considerations/attributes of the model's technology transfer elements to have successful technology transfer at BIOTECH? What is successful technology transfer in the institute?*

Despite being a "backyard research" wherein the subject is the researcher's immediate work setting (Creswell and Creswell 2018), the study ensured that data and information collected were not compromised or will not put the respondents in detrimental situations by being transparent with and informing them of the research objectives, and how their responses will be processed or analyzed. The respondents or key informants, who are superiors and colleagues of the researcher as well as stakeholders or partners of the office, were apprised of the study's purpose and analysis methods. They also signed the study's informed consent forms.

RESULTS AND DISCUSSION

The Two Animal Feed Technologies

The two technologies developed by BIOTECH in this case study are composed of both process and product, and thus have tacit knowledge, codified knowledge, and tangible goods to transfer.

The animal probiotics technology has been described a veterinary drug and product that significantly enhances animal nutrient absorption and immune system, while the PECM is a feed mix ingredient that offer a more sustainable and local source of key feed nutrients. The two products are intended for use in livestock, swine, and aquaculture industries. In terms of maturity, both technologies

were assessed by the university's technology transfer office to be on the highest technology readiness level, with the actual production systems of both having been proven in their operational environments. environments. Based on the experiences and sentiments of the transfer recipient-respondents of both technologies, the products have been beneficial in their businesses and livelihood.

A Contingent Effectiveness Model of Technology Transfer in the Context of BIOTECH

Upon analysis of the identified themes of the CEMTT dimensions, the overall resulting general contingent effectiveness model of technology transfer for BIOTECH is illustrated in Figure 1. Following the answers from the respondents and secondary sources on the technology transfer experience of the two animal feed technologies, the arrows indicate direct interaction/s of the dimensions. This framework presents an account of the technology transfer experience of the two animal feed technologies at the institute, as well as key factors or considerations for each dimension, as denoted by themes.

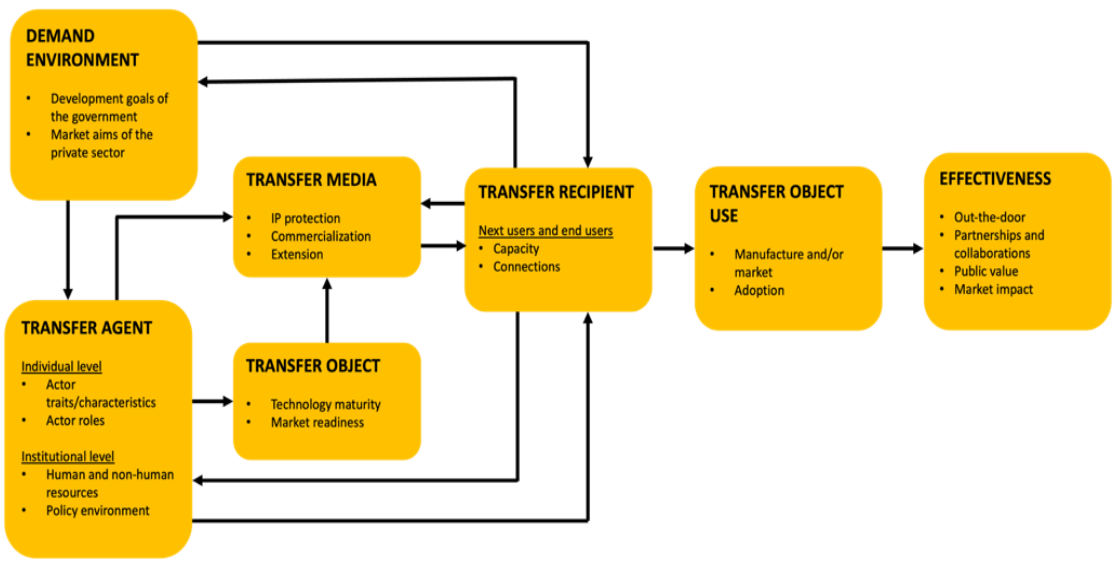

Figure 1. A general contingent effectiveness framework of technology transfer of BIOTECH

Demand environment. The demand environment shapes the research, development, and technology transfer activities of the transfer agent (BIOTECH). As the market and non-market factors that affect the demand for the technology (Bozeman 2000), this dimension also considers the influence of the public sector. The establishment and operations of the institute were determined with corresponding agricultural challenges to be addressed. Technologies developed by BIOTECH, including the two animal feed technologies, are expected to benefit the Filipino populace. Its target end-users or target markets are usually indicated in the research project documents funded by government agencies such as the Department of Agriculture and DOST which have their own thrusts and agendas geared towards national development.

Thus, demand environment is characterized by the developmental goals prioritized by government funding agencies and/or supporting public sector institutions (e.g. funding agency agendas and thrusts which is based on the national development plan). The two animal feed technologies developed at BIOTECH cater to the animal industry as feed additive and ingredient for livestock, poultry, and aquaculture animals in brackish water. For both technologies, the role of funding agencies

and the niche of the products in addressing problems among farmers (e.g. fish kill, animal diseases) were identified by the respondents, thus leading to the theme of developmental goals.

Demand environment was also distinguished by the aims or targets of private sector such as increasing productivity and profits. This was identified from the interview responses of the technology takers who mainly described the significant losses experienced by the animal raisers prior to using the technologies in their farms. These losses were attributed to industrial problems from increasing demand and environmental, climate-related causes. Another key response related to this theme pertained to the increase in agriculture input costs from restrictions brought about by the COVID-19 pandemic in 2020.

Transfer agent. The arrow from demand environment leading to the transfer agent dimension denotes its influence on the PRI's research and technology transfer activities. For this dimension, the characteristics of the individuals (inventor/s or technology developer/s and technology transfer officer/s) and institutional factors of the PRI are highly relevant in the conduct of R&D and technology transfer. Knowing the background, traits, attitudes and inclinations of both scientists/inventors and transfer officers are vital in promoting mutual understanding to facilitate the transfer process. Respondents also pertained to the importance of an "entrepreneurial mindset" among the researchers/developers, which may be likened to the concept of "academic entrepreneurship" where the academic/researcher goes beyond the traditional academic roles (teaching and research) and boundaries (universities and scientific communities) (Amry et al. 2021).

The roles of the scientists and transfer officers also need to be clearly defined along the process. Institutional support through policies, guidelines, and offices/units/bodies in place are also crucial in implementation. The university has an IP policy as well as an established technology transfer office that oversees its technology transfer activities. The PRI also implements its own technology transfer program to facilitate the process. With its own mechanisms and support institutions, the arrow from the transfer agent towards the transfer media dimension, to signify that the agent decides on the channel (media) to be used for the transfer.

Transfer media. This dimension was distinguished with three themes: IP protection, commercialization, and extension. While IP protection and commercialization are part of the IP cycle (Medrano 2020), extension, with its differing non-profit goal, was added to the transfer media dimension because aside from being one of the university's core functions, it was cited by respondents as a means for the technology to reach target end-users such as farmers.

IP protection entails the assessment for appropriate registration of the IP or technology with Intellectual Property Office of the Philippines (IPOPHL), while commercialization is a process that involves market studies, assessment for investment, negotiation with the technology taker. Both IP protection and commercialization are facilitated through the university's technology transfer office. Extension, meanwhile, with its social orientation, was described a means of introducing or familiarizing the target market with the products. Similarly, extension was also identified by a major government funding agency for S&T research, DOST-PCAARRD, as a major technology transfer strategy (Catibog 2017). The university's technology transfer office facilitates registration of IP assets with the IPOPHL for IP protection and negotiates with private or other organizations for commercialization through licensing, spin-off, or marketing. The PRI also introduces the technologies for adoption among target end-users through its extension activities.

Transfer object. Another arrow leads from transfer agent to transfer object, representing that the agent develops the technology (object). The transfer object is assessed based on their maturity and market readiness prior to being transferred. The university's technology transfer office assesses these through an IP audit tool which rates the technology's development status, maturity, investment required, advantages over existing technologies, existing licensees, potential technical or legal issues, size of

market, IP protection, availability of an expert, and scalability. It also considers the product registration, simple financial analysis, awards, and even the areas of adoption.

The audit tool described above may be likened to the European Union's Market and Technology Readiness Level or MTRL tool which is intended for self-assessment of software innovation projects in relation to the closeness of its product/s to the market (Wallom 2020). The MTRL specifically measures this through nine key categories, two of which focus on technology readiness (project maturity and product development) and seven on market readiness (product definition/design, competitive landscape, team, documentation, IP management, go-to-market, and supply chain). MTRL aimed to give an overview of the project status in reaching its target market and is considered useful for standardized evaluation of a considerable number of projects.

Transfer recipient. A third arrow from transfer agent leads to the transfer recipient which pertains to the receivers of the technology. For this dimension, the capacity of the entrepreneur, private sector taker or adopter and connections with key partners were identified as key attributes in achieving technology transfer effectiveness. Capacity covers their knowledge, attitudes, skills, aspirations, and opportunities in relation to the industry they operate in, while connections include their industry partners, acquaintances, and contacts such as former industry colleagues and clients that provide direct or indirect beneficial support to their venture/enterprise (Mayne 2015). From this dimension, two arrows lead to demand environment and transfer agent dimensions. The arrow towards demand environment shows that the state of the transfer recipients (technology beneficiaries or target end users) influences market demand. An example is a response on how the plight of swine farmers were detrimentally affected by animal diseases such as the African swine fever. Meanwhile, the arrow going to transfer agent establishes the direct relationship or beneficial interaction of the recipient and the agent.

The two arrows denoting the direct and vital interactions between the transfer recipients and transfer agents are lacking in Bozeman et al.'s (2015) contingent model. These links were observed and described by the respondents in the context of the PRI through the relationships of trust and understanding, whether formal or informal, formed by the technology transfer officers and/or technology developers with the industry partners and even end users. This mutual understanding differs from the transfer media which conveys only the vehicle or channel of transfer. This reciprocal linkage also reflects the idea of a two-way information flow in technology transfer which aims for convergence of ideas for the successful use of the technology (Rogers 2003).

Transfer object use and technology transfer effectiveness. With the use of the technologies through marketing and/or direct adoption, technology transfer effectiveness is achieved and can be measured based on following four criteria, as revealed through analysis of the KII responses and desk review:

- *Out-the-door.* Although the criterion was considered a "perfunctory response to external pressures", this criterion is valuable for any technology transfer initiative in government organizations including universities (Bozeman 2000). Out-the-door's assumption is that the transfer is successful "once the technology has been converted into a transfer mechanism, either formal or informal, and another party has acquired the technology" (Bozeman et al. 2015). This is reflected in one of the interview responses from a technology transfer officer who said that successful technology transfer starts with a licensee and term sheets. The university's technology transfer office has also recognized various metrics as accomplishments aside from the "transfer" itself. In 2022, the office posted as its achievements the number of copyrights licensed, invention disclosures, S&T locators leased, technologies being processed through the Fairness Opinion Board (for commercialization), lease and agreements submitted, licensing agreements processed, technologies with initial market validation, and inventions managed for protection, among others. These are outputs associated with IP protection and commercialization.

There are three types of the out-the-door criterion: pure out-the-door, out-the-door with transfer agent impacts, and out-the-door with transfer partner impacts (Bozeman et al. 2015). Pure out-the-door is limited only to the "transfer" itself and does not consider other implications. Out-the-door with transfer agent impacts and out-the-door with transfer partner impacts, meanwhile, pertain to the benefits gained by the agency and its partners, respectively. For the two animal feed technologies, pre-commercialization marketing sustained the production operations and product development of the technology developer's laboratory at BIOTECH. It also benefits the university and the partner foundation because part of the sales (administrative cost) goes back to the university. The marketing partners (transfer recipients) meanwhile have profited from the technology, as manifested as well by their repeat orders from the institute.

- *Market impact.* This measure mainly comes from the point of view of the transfer recipient or the marketing partner for one of the animal feed technologies. Both respondents attributed the increase in their profit to sales of the technology. The transfer agent, particularly the technology transfer officer, also recognizes market impact or "commercial success" not only for the marketer/dealer/distributor, but also for the producer and the end-user (pertaining to aquaculture farmers), as a measure of technology transfer effectiveness.

- *Partnerships and collaborations.* This criterion highlights the relationships formed by the institute (its researchers, technology transfer officers) with different groups (entrepreneurs, private companies) involved in the transfer. It differs from "out-the-door with transfer agent impacts" which requires the technology to be fully transferred such that the IP was bought from the university, or a buy-out (Bozeman et al. 2015). Partnerships and collaborations pertain to the trust and rapport built between the transfer agent and recipient that may result in sustained benefits for both parties. With the differing goals and limited resources of the key actors and offices/entities involved in the technology transfer process, "good relationships" were deemed valuable, and therefore effective in technology transfer, for the potential benefits it can generate. Academe-industry linkages have also been studied in the context of other Philippine HEIs as providing opportunities for universities (Bernarte 2014).

- *Public value.* Public values were broadly described as the bases for public policy and aims for broad societal outcomes such as "social justice" and "sustainable development" which are deemed difficult to systematically evaluate (Bozeman et al. 2015). Public value was included as an effectiveness criterion for technology transfer in the context BIOTECH because of the inclusion of extension as a key transfer medium of the model, as identified by both the institute and the university's technology transfer office. Although no formal impact assessment or evaluation have been conducted yet with regards to the adoption of a product of BIOTECH, analysis of the responses highlighted the importance of extension in introducing the technology to the market and end-users. Likewise, as a research institute that mainly utilizes public funds, notably through the General Appropriations Act in 2019-2023, public value highlights the significance of the BIOTECH's developed technologies to the populace, particularly beyond the economic benefits it may bring, which is the essence of this criterion. Non-economic impact of the technologies such as how it can improve the environment (e.g. enhancement of soil health, reduced stench/ammonia emission in livestock farms) were recognized as well by the respondents.

Notably, the other effectiveness criteria from the model (opportunity cost, political reward, scientific and technical human capital, and economic development) were not identified as significant markers for the two technologies. Although these were asked in the interviews, there were no meaningful responses identified for these criteria, compared with the abovementioned four which were

emphasized by the respondents in terms of the experiences they recounted for the two animal feed technologies and in technology transfer at the university and the institute. Scientific and technical human capital, as "People Services", are considered productivity indicators in government R&D projects (DOST-PCIEERD 2021). However, this and the other criteria may not have been the prioritized as success measures for technology transfer with the pool of respondents considered in the case study, compared with those identified.

Barriers to technology transfer. BIOTECH, through the university technology transfer office, has licensed out three of its technologies (including one of the animal feed technologies), and is marketing several products as pre-commercialization with its limited scale production. The initial challenges acknowledged from the interviews were on upscaling production and lack of licensees who are willing to manufacture the institute's other matured technologies. Upon content analysis or DQlCA of all the KII responses, the main barriers in this case study were limited financial and human resources for both transfer agent and transfer recipients, and bureaucracy, or the administrative procedures involved in the university technology transfer, particularly the long period of processing of requirements for IP protection and commercialization.

Funding constraints for technology transfer and costly research projects have also been identified in other Philippine studies to affect poor IP protection and commercialization performance (Catibog 2016; Quiñones et al. 2019). The Institute manages the financial challenge through its income generating projects (from limited sale/pre-commercialization marketing of its products and provision of technical services) to support its RDE activities, and through externally funded projects by the researchers and project leaders. The successes in pre-commercialization (as implied by out-the-door impact to agent) demonstrate its capacity to overcome such constraints and move forward with technology transfer, especially with increased funding.

Bureaucratic processes, meanwhile, were recognized in the interview responses as disadvantageous in encouraging the private sector from technology transfer engagements with the university. The long turnaround processing time for IP protection and commercialization documents and even product registrations were also cited in the interviews as incompatible with the rapid advancements in scientific innovations. In the Philippines, the Technology Transfer Act requires publicly funded research in state universities and public research institutes to undergo a review process with a Fairness Opinion Board which spans a minimum of 90 days before licensing (Bantigue 2019). Cases of private sector partners directly engaging with technology developers to avoid the delay caused by following procedural processes have been cited, yet the researchers were still posited to benefit from following rules and guidelines such as getting legal advice from the legal office (Bantigue 2019).

A mind map of how the two identified barriers (bureaucracy and limited financial and human resources) could influence the identified effectiveness criteria is shown in Figure 2. Bureaucracy discourages researchers to venture into commercialization, widens the gap between academe and industry because of the delayed processing and temporal costs, and poses risks of information leakage due to the many "layers" of a bureaucratic process (Catibog 2016; Quinones et al. 2019). With BIOTECH's experience, despite having established units as authorities for technology transfer (e.g. technology transfer office, administrative offices) of the university, there was no specific or official tool that provided guidance for all actors involved in the commercialization/IP protection process such as a citizen's charter, thus prolonging the processing time. Meanwhile, it was gleaned that limited funding and staff (resources) and costly projects lead to weak technology transfer skills or capacities among the transfer agent actors (technology transfer officer, technology developers). All these challenges negatively affect (depicted by red arrows) the establishment of new partnerships or maintenance/strengthening of existing collaborations that in turn provide different kinds of resources to achieve successes in terms of out-the-door criteria (which would need operation costs for licensing or marketing), market impact (which require investment costs, conduct of market research and

promotion), and public value (which entail funding for extension or outreach projects). Overall, bureaucratic and resource constraints present consequences to quality and quantity of technology transfer outputs and outcomes of the institute, particularly through the vital linkages formed or potentially established with external parties.

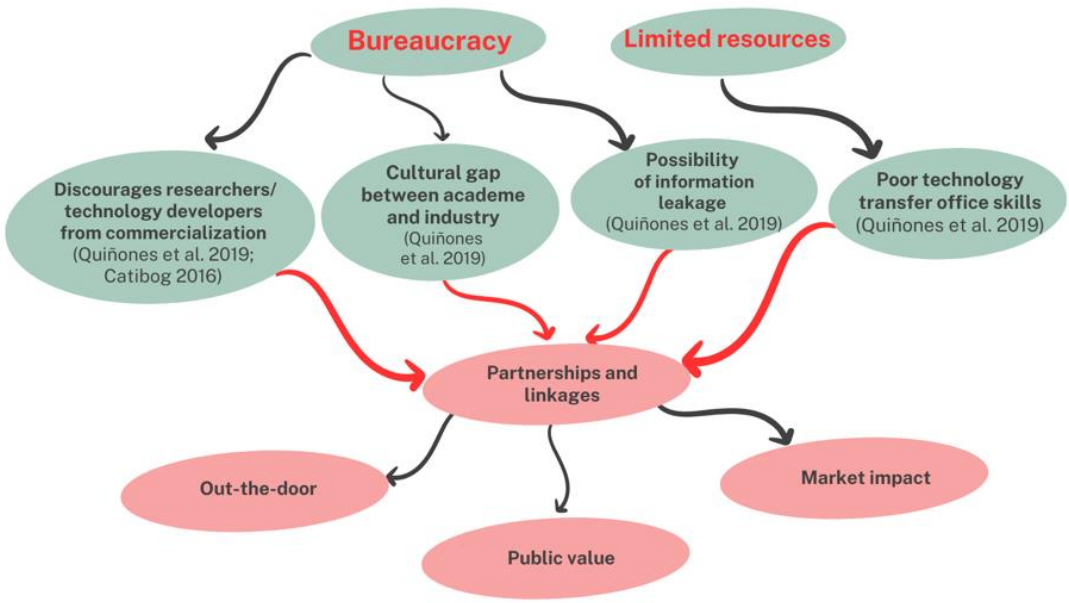

Figure 2. Mind map of technology transfer barriers in the context of BIOTECH

Technology transfer in a public research institute and development management and governance. As a recognized mechanism in achieving sustainable development outcomes, technology transfer in universities necessitates the concept and practice of "development management" in its projects, programs, and policies. Development management is aimed at "social goals" that are external to the organization and employs management tools and resources from different sources (Thomas 1996). It emphasizes the importance of context or situation (political, economic, social, technological, legal, and environmental), historical background or process, and the involvement of various parties, sectors, and therefore, interests and values in its view of "development".

Based on the findings of this case study and following Bozeman and co-workers' (2015) contingent effectiveness model, technology transfer in BIOTECH is shaped by different views of development in its use of commercialization and extension activities as transfer media. This is characterized by their development indicators: commercialization focuses on economic indicators (e.g. profit, yield, productivity, etc.) and extension aims at social indicators (e.g. knowledge and behavior change, quality of life, empowerment, etc.). Such differences entail corresponding nuances in the management tools, skills, and strategies to be used. Commercialization-related pathways may require more conventional management approaches, while the means of extension would follow more participatory strategies. It follows the need for "adaptive and flexible" application of project design, management, and appraisal; and the view of the "development arena" in its entirety of the different agencies involved, with shared values, through negotiation and brokering (Thomas 1996).

Institutional development and capacity building are also key development management areas needed for technology transfer at BIOTECH. These themes were also identified using Bozeman's model in the context of interdisciplinary bioeconomy research in Europe (Borge and Bröring 2017) with the formation of relevant units that facilitate collaboration and sharing of resources to achieve a common goal.

Public sector technology transfer, as in the case of BIOTECH, also entails coordination among the different offices and sectors of the academe, industry, and governance. The emphasis on partnerships and collaboration as a success criterion for technology transfer at the institute reflect the shift of governance approach from rigid public administration which focuses on policy implementation and hierarchy, and input-output-oriented "new public management" which highlights "traditional contracts" and "market competition"; to "new public governance" which emphasizes ties and collaborations, service processes and outcomes, and trust or relational contracts as its mechanism (Dickinson 2016).

CONCLUSION

This case study underscores the value of characterizing key dimensions of technology transfer, the relationships and interactions of the actors, and their individual capacities and backgrounds to reach "convergence" of understanding in technology transfer and use. Also distinct in the resulting framework are the divergent goals of commercialization and extension, both of which are considered important means for effective technology transfer. Notably, with BIOTECH's pre-commercialization marketing and extension initiatives, the transfer agent dimension also has direct, two-way linkages with the transfer recipients, unlike the Bozeman et al.'s (2015) model. This finding highlights the importance of public and external relations in the institute's technology transfer, which also reflects the development management concept of partnerships and values as influenced, negotiated, and/or leveled off, and not "directed or imposed" (Thomas 2007). In terms of technology transfer effectiveness, out-the-door (e.g. number of technologies and IPs protected and/or transferred commercially) and market impact (sales, profits) pertain to the commercialization criteria, while partnerships and public value provide for the measures used in extension. Constraints in funding and capacities necessitate the development management areas of partnership management, negotiation, and capacity building; while long-winded bureaucratic procedures need a more systematic approach as the process, protocols, and procedures involve different offices with different mandates, interests, and values. These barriers all corroborate the findings and conclusions of other studies and reports in Philippine SUCs.

Despite using a model to capture key dimensions in technology transfer of the research institute, this study is limited by its qualitative methodology. The results or themes derived from the key informant interviews were confined to the experiences and recall of the respondents. Other possible factors (e.g. demographics of the respondents) that may be related to technology transfer effectiveness were not considered. With its qualitative analysis approach, this study is not predictive but descriptive and explanatory. It can thus be expanded by looking at a larger, more significant sample set (e.g. surveying different technologies or research institutes) and employing quantitative or mixed method studies that will explore the relationships of variables related to the technology transfer dimensions.

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