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The Mechanisms of Co-innovation in the Development of Bioplastic Packaging: Evidence from Practice

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Abstract – This study aims to explore the mechanisms of co-innovation in developing bioplastic packaging. We illustrate the co-innovation process in developing bioplastic packaging and identify the key co-innovation elements and their mechanisms, conceptualizing the mechanisms into a framework. This study explored eight cases representing the biopolymer producer, converter and product manufacturer. Data were collected using semi-structured interviews. The findings reveal that co-innovation consists of two stages (developing the packaging prototype and further developing the packaging for a specific application) and three key elements (co-innovation comprising joint activities, joint resources and relationship management). This study contributes to co-innovation literature, particularly the mechanisms and conceptualization.

Keywords – inter-firm collaboration, bioplastics, packaging, sustainable product, co-innovation.

I. INTRODUCTION

Bioplastic packaging is developed with plant-based and/or compostable features and is often promoted as an alternative packaging that is more environmentally friendly or sustainable [1, 2, 3]. However, the uptake of bioplastic packaging remains at a low percentage [2] compared to conventional plastics, despite the fact that packaging is essential for daily needs and used for various industrial applications. Currently, there are significant obstacles to the implementation and commercialization of bioplastics widely in the industry.

Bioplastic packaging was claimed to reduce carbon emissions or plastic pollution [2, 3] when used and disposed of appropriately and sold more expensive than conventional plastic [2]. However, its application to the same fabrication as conventional plastic [1] is not straightforward due to its unique characteristics, and some have limited functionality compared to conventional plastics [4]. Nevertheless, ensuring new technology could fit customers' needs and become a solution for customers' problems is highly essential, and therefore a supplier-customer collaboration is needed [5].

Co-innovation has been widely used in industries [6, 7, 8, 9]; it positively impacts product development and improves company performance. Co-innovation integrates ideas and capabilities between organizations to create value [10, 11]. Co-innovation between supplier and customer is required to develop further bioplastic packaging [1, 3, 12]. Co-innovation is expected to accelerate the development of superior bioplastic

packaging widely used by industry [1, 12]. However, there are limited references that address co-innovation in bioplastic packaging [5]. Most of the existing studies of co-innovation in bioplastic packaging, either directly or indirectly, emphasize inter-firm collaboration as a strategy for advancing product innovation and tackling the challenges in bioplastic application [1, 5]. Furthermore, the existing co-innovation studies provide limited details on how co-innovation works in developing superior bioplastic packaging, thus indicate the research gap that needs addressing [5].

Therefore, this study aims to explore the mechanisms of co-innovation in developing bioplastic packaging. Specifically, this study addresses two research objectives: first, to illustrate the co-innovation process in developing bioplastic packaging; second, to identify the key elements and the relevant mechanisms of co-innovation and conceptualize the mechanisms. The unit analysis in this study is the supplier and customer's dyad relationship during co-innovation. The suppliers are the biopolymer producer, who produces the raw material into biopolymer for packaging and the converter, who process the biopolymer into packaging for the product manufacturer and retailer. The customer is the product manufacturer who uses the packaging from the converter for their product or sells the packaging as part of their product range.

The following sections present the literature review, which explains the theoretical lens used in this study and the initial framework. Then, the methodology, findings followed by discussion will be presented, followed by the conclusion that includes contributions, limitations of this study, and recommendations for future research.

II. LITERATURE REVIEW

Co-innovation is considered a way to synergize efforts and investments from internal and external contributors to create valuable new products, processes or services [10]. Co-innovation involves business partners in a process and mechanisms to create value [6]. This study adopts the underlying principle of co-innovation as a mechanism [10, 11] and process [6, 7], involving inter-organizational collaboration, complementary convergence or integration of multidimensional resources, joint activities [8], knowledge absorption [11] and value creation for customers that are difficult to imitate by competitors [6, 10]. Co-innovation is a longitudinal

collaboration process for new product development and also positively influences performance measured by new product launches and sales [7].

A systematic literature review was conducted to explore previous studies relevant to the co-innovation mechanisms specific to bioplastic packaging. There were 68 articles retrieved from five databases: EBSCO, Scopus, ProQuest, Emerald and Science Direct. Based on the thematic analysis, an initial framework was synthesized. The framework was underpinned by the relational view theory [13] and absorptive capacity theory [14] (Fig. 1).

The framework illustrates that the mechanisms of co-innovation lies in the joint activities, joint resources and relationship management between supplier and customer. This is in accordance with the concept of co-innovation related to synergizing various internal and external ideas, actions and resources to create new value that is difficult to be imitated by competitors [6, 10]. Underpinned by the relational view theory [13] and the absorptive capacity theory [14], co-innovation between customer and supplier is enabled by integrating complementary resources and knowledge to create greater benefits that cannot be achieved individually.

Joint activities refer to supplier-customer reciprocal activities to develop the bioplastic packaging. Joint activities emphasize knowledge-sharing routines [13] and continuous innovation-oriented learning [15]. In the co-innovation for bioplastic packaging, joint activities include sharing new bioplastics technology and manufacturing, industry and regulation. The supplier and customer conducted many trials to apply the new packaging to the product to meet the customer's expected functionality or specifications. These activities create a new combined knowledge that will contribute to product development success.

Joint resources indicate the tangible and intangible resources and capabilities invested in the collaboration by the customer and supplier. Joint resources refer to the relation-specific assets in the relational view theory [13]. Resources needed in co-innovation are, for instance, location, cost, cross-functional team, production unit [9], R&D investment, provision of HR training in environmental management [15] and other infrastructures. Joint resources would increase the productivity of individual resources, reduce cost, and increase product development success.

Maintaining and developing a fruitful collaboration requires relationship management, including partner selection, goal alignment, and dialogue [16]. A compatible partner with complementary capability will contribute to the heterogeneity of resources that benefit the quality of input in product development and learning. Communication, coordination, lessening the organization boundaries [9, 16] and building a close relationship [3] will promote effective and productive activities, reconciliation and problem solving [11], therefore are likely to achieve bioplastic packaging innovation.

The outcomes of co-innovation in this study refer to the bioplastic packaging product innovation, measured by

the indicators comprising product quality, sustainability, cost and innovation. The product quality indicators integrate the specific characteristics of bioplastics packaging, i.e., improved use and functionality [11] and eco-friendly final product image [1]. The sustainability indicators refer to the use of renewable resources, biodegradability to corroborate the closed-loop principle in the circular economy. The cost indicators present the efficiency and cost of production [1], which can become an important target of co-innovation due to the customer and end-user sensitivity to price. Moreover, the innovation indicators adopt incremental or radical innovation to indicate the creation of a new or improved product or process [8].

III. METHODOLOGY

This study used a qualitative approach to address the research questions and provide an in-depth understanding of people's social behavior, perspectives, and real conditions within a context [17]. A multiple case study allows an in-depth comprehension of the process and its outcome, test refinement an initial framework based on the empirical evidence [18], thus adopted as the research strategy. The number of cases recommended for multiple case studies is 5 to 10 [18], considering too many cases impact the quality of the analysis that is less profound and conversely, too few points can be generalized [18].

The case selection is based on theoretical consideration [19], paying attention to the occurrence of supplier-customer activities, processes in a co-innovation project for developing bioplastic packaging. The object of the study is the supplier and customer's organizations. Case selection used purposive sampling with several criteria. First, the suppliers were the biopolymer producers and the converters or packaging manufacturers; the customers were the product manufacturer, all of which could show a past or ongoing, including successful or failure co-innovation experience in developing or using bioplastic packaging

Secondly, the case study focused on the application of bioplastics packaging in industries where the product is widely used by the consumers, such as those in the food and beverages industry, convenience goods or pharmacy. This setting demonstrates the complexity of the co-innovation related to the application of the packaging in the manufacturing process, functionality, health and safety when consumed by the end-user. Last, cases were selected from the UK considering that bioplastic packaging has been used in many consumer goods available in the UK market and several notable innovations are from the UK; there is higher awareness on the use of sustainable packaging. An explorative study could start in limited industries and geographical areas to identify key issues and could later be expanded [18].

Data from eight cases representing supplier and customer's views were collected using semi-structured interviews and analyzed using within-case and across-

case analysis. Table 1 shows the cases used in this study. The data analysis process included data reduction, presentation and conclusion drawing [18]. Interviews were transcribed, and then data relevant to the research objectives were extracted by giving codes using a short phrase. Subsequently, cross-case analysis was conducted by comparing cases to justify propositions, minimizing false conclusions due to informant-processing biases [19]. Data were processed using NVivo.

IV. FINDINGS

A. The process of co-innovation

The initial stage of the product development is the internal development at the biopolymer producer. When the material is deemed viable, it is then introduced to the converter to trial and develop a packaging prototype for the product application using the existing real production system. Next, the biopolymer producer works with the converter to create a bioplastic packaging prototype or viable product to sell. The product manufacturer is not involved in this process because the product manufacturer is interested only when the product is ready to use with a few adjustments needed or able to be produced on a small scale. The subsequent development is to apply the bioplastic packaging to the product, in which the product manufacturer, converter and biopolymer producer are involved in co-innovation.

Co-innovation follows two stages. First, co-innovation between the biopolymer producer and converter to create a packaging prototype. In this stage, the biopolymer producer works with the converter to improve the material, packaging design, adjust tools, and conversion process. The material works for small scale production but is not fully ready for industrial-scale and does not necessarily fit the product manufacturer's standard. The next stage is to develop the packaging further into the final product qualified for the product manufacturer's use. In this stage, the co-innovation mechanisms vary depending on the complexity of the packaging application.

B. The key mechanisms in co-innovation

The case study shows that joint activities, joint resources and relationship management are key elements

of co-innovation and work as integrated mechanisms. Joint activities occur at the later stage of packaging development. Extensive mutual adaptation among partners and providing support are essential to implementing the bioplastic packaging at the customers. The joint resources mechanisms emphasize sharing the existing tangible resources, while co-investment to build dedicated assets for bioplastic packaging are limited unless the bioplastic packaging development showed high feasibility to scale-up and commercial benefits in the future. Relationship management is essential to start the collaboration and determine a long-term collaboration in simple and narrow co-innovation.

Two distinct co-innovation projects are found. First, the simple development project, which mainly involves small companies, such as in Cases D, G, and H. Co-innovation, aimed to implement bioplastic packaging for the product manufacturer. The project is mainly managed by the converter and hardly required any material adjustment. The implementations were quite challenging. Many adjustments were needed to meet the product manufacturer's packaging design or functionality. The product manufacturer needs to adapt and adjust the packing process to work with the bioplastic packaging.

Next, as seen in the Cases A, B, C, E and F, co-innovation to develop more complex packaging with extensive application takes a long development period and involves product manufacturer, converter and product manufacturer, who was also an industry leader. In this co-innovation, material and process improvements and adjustments were made to accommodate the product manufacturer's comprehensive requirements. In this extensive and complex co-innovation, the industry leader implemented a stringent partner selection mechanism, standard and comprehensive requirements and have the power to bring more partners to expand the project's capabilities.

Accordingly, although owning the technology, the biopolymer producer would have to accommodate the industry leader's complex needs as much as possible and share partial ownership of the technology with the co-innovation partners. The findings also indicate the supplier absorptive capacity enables improvement in the material, packaging, process and support that better accommodate the customer's need for the packaging to work in the industry.

TABLE I
CASE DESCRIPTION

Case	Position	Product	Established	Employees	Interview partner
A	Sup: biopolymer producer	Biodegradable, water soluble polymers	> 10 yrs	> 100	CTO
B	Sup: converter	Plastic and bioplastic packaging	> 10 yrs	> 100	Technical Director
C	Sup: converter	Plastic and bioplastic flexible packaging	> 10 yrs	> 100	Technical Manager
D	Sup: converter	Bioplastic packaging	> 10 yrs	10 to <50	Director/ owner
E	Cust: product manufacturer	Medicine, healthcare products	>10 yrs	≥ 100	Head of Packaging R&D
F	Cust: product manufacturer	Various consumer goods	>10 yrs	≥ 100	Sustainable Packaging Specialist
G	Cust: product manufacturer	Beverage product: fresh ground coffee in compostable coffee pods	≤5 yrs	< 10	Co-Founder
H	Cust: product manufacturer	Food product: organic chocolate, packed in plastic free packaging	>10 yrs	< 10	Founder

C. The refined framework of co-innovation

This section explains the extent to which the evidence from the case study is relevant to the initial framework and propositions developed from the systematic literature review. First, joint activities generate new knowledge, improvements and solutions that enable bioplastic packaging fabricated in the existing process at the converter and product manufacturer. Higher joint activities that positively impact the bioplastic packaging innovation rely more on the knowledge sharing or transfer of knowledge, iterations and extensive mutual adaptation. These findings support the first proposition (P1) in the framework, which said that in the bioplastic packaging co-innovation context, higher supplier-customer joint activities would increase the success of bioplastic packaging product innovation.

Next, the customer and supplier contribute both tangible and intangible resources and capabilities to co-innovation. However, intangible joint resources are more likely to occur, such as sharing information, expertise and knowledge, leading to the creation of specific know-how related to the bioplastic technology and its application, joint intellectual properties of packaging design or processing. Furthermore, the creation of asset specificity is limited; partners very carefully invested in the tangible assets dedicated for bioplastic packaging and prefer working on the existing main infrastructure. Thus, the evidence does not fully support the second proposition (P2): In the bioplastics packaging co-innovation context, higher customer-supplier joint resources will increase the success of bioplastics packaging product innovation.

Co-innovation depends on relationship management, and the key is approaching potential partners to engage in co-innovation. Furthermore, agreement and commitment, educating the user and managing expectations are essential to build customer understanding and promote cooperative behavior in developing advanced bioplastic packaging through co-innovation. These findings support the third proposition (P3): In the bioplastics packaging co-innovation context, higher customer-supplier relationship management will increase the success of bioplastics packaging product innovation.

Accordingly, communication, building trust and honesty, educating users and facilitate knowledge transfer encourage customers to be more open. At the same time, agreement and commitment bind all partners to contribute to problem-solving. These efforts also affect customer willingness to adapt, including adjusting the process and accepting the limitation of the bioplastic packaging until a certain point. These facts also support the fourth proposition (P4): in the bioplastic packaging co-innovation context, the higher the relationship management, the higher the joint activities dedicated to co-innovation.

However, efforts to build relationships through communication, user education, and commitment do not appear to have implications for joint resources, limited to using existing assets and sharing information. Relationship management does not increase technological

integration or sharing the existing tangible. Thus, the fifth proposition (P5), in the bioplastic packaging co-innovation context, the higher the relationship management, the higher the joint resources dedicated to co-innovation, is not supported.

In the bioplastic packaging co-innovation, interdependency is not determined by joint activities and joint resources. Inter-dependency among partners will develop after the co-innovation successfully deliver the agreed outcomes and partners are committed to exclusivity agreements or joint intellectual properties. Interdependency will likely grow stronger when each partner could exploit more benefits from using the bioplastic packaging. These facts implied a lack of support to the proposition 6 (P6): In the bioplastic packaging co-innovation context, the higher the joint activities, the higher the supplier-customer interdependence, and therefore the bioplastic packaging product innovation; also, proposition 7 (P7): in the bioplastic packaging co-innovation context, the higher the joint resources, the higher the supplier-customer interdependence, and therefore the bioplastic packaging product innovation.

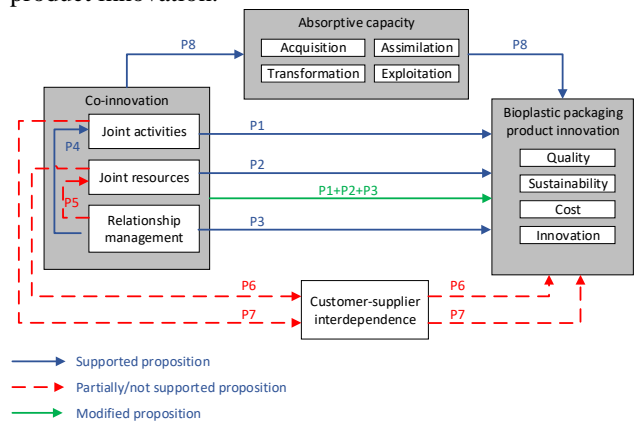


Fig. 1. The refined framework of co-innovation.

The findings also support the four capabilities: acquisition, assimilation, transformation and exploitation that result in value creation. The absorptive capacity mediates the co-innovation process with outcomes, supporting the ninth proposition (P8): In the bioplastics packaging co-innovation context, the absorptive capacity mediates the relationship between co-innovation and bioplastics packaging product innovation (see Fig. 1).

V. DISCUSSION AND CONCLUSION

This study signifies the importance of co-innovation for developing bioplastic packaging and corroborates previous studies [1, 3, 5, 12] and further demonstrates how co-innovation enables a better understanding of the weaknesses of bioplastic packaging to meet broad industry needs and facilitate material, packaging and process improvement. This study unveils that the co-innovation process in developing bioplastic packaging

occurred in two stages, first, developing the materials and its fabrication into packaging [1], and second, further packaging development for various product applications.

Subsequently, the key mechanisms of co-innovation were conceptualized in the initial framework [5]. Our empirical evidence supports several propositions and refines the framework, thus addressing the second research objective. This study signifies the joint activities, sharing the existing complementary resources [8] and relationship management as key integrated elements of co-innovation. Joint activities and joint resources are mainly related to knowledge transfer, and the absorptive capacity [14] is improbably omitted to facilitate the accumulation of new knowledge that brings product improvement and generation of commercial benefits for the supplier and customer [13].

This study substantiates co-innovation dimensions of collaborative, complementary and coordination [6] and firm capabilities [3], a framework using a process view underpinned by the relational view [13] and absorptive capacity theory [14]. Furthermore, the conceptualization of co-innovation varies in the literature, one of which is underpinned by open innovation [10] and co-creation [11], emphasizing interactions with user community [16]. This study proposes the concept of co-innovation based on inter-firm collaboration [5, 13], which is exclusive and accumulated new knowledge is exploited for co-innovation partners' benefits.

The co-innovation framework provides a working mechanism for business practices, showing how the supplier-customer collaboration combine their actions and resources to advance the bioplastic packaging innovation. This framework would be a valuable reference for the biopolymer producer to bring bioplastic packaging to broad implementation at an industrial scale and commercialization. Moreover, working with product manufacturers who are also industry leaders in an extensive co-innovation project would become an opportunity to improve materials, packaging, processes, and commercial benefits for all co-innovation partners.

This study provides an in-depth understanding of a process and outcome to refine a theoretical framework using a case study, which is context-specific and influenced by unique phenomena in each firm being studied. Further study is suggested to continue testing the proposed framework using a quantitative approach. This study captures the mechanisms based on the informants' current views; whilst co-innovation in bioplastic packaging occurred in a long-term project, more exploration, such as a longitudinal study, is needed to understand how the mechanisms progresses over time.

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