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A Conceptual Framework of Customer Value Proposition of CCU-Formic Acid Product

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Abstract: This paper aims to develop a comprehensive conceptual framework of the customer value proposition of formic acid as an actual outcome of carbon capture and utilization (CCU) to support clean production and environmental sustainability worldwide. This study included different phases. The first phase was an extensive reading of the literature, followed by a content analysis of the selected literature. The aim of the content analysis was to identify key concepts and the general categories of these concepts. The final phase was a content analysis of the selected literature with the purpose of identifying the relationship between concepts. The outcome of this paper is to provide a comprehensive framework of the customer value proposition of the CCU–formic acid product and consequently support global research efforts in sustainability. This framework contains two general dimensions: market knowledge and customer value. The first dimension includes five variables: the customers' acceptance of CCU technology, the customers' intention to purchase formic acid produced by CCU technology, the degree of customers' knowledge about CCU technology, the customers' readiness for environmental issues, and the market segments of formic acid product. The second dimension includes seven variables: ecological benefits, the ecological risk of CCU, varieties of formic acid use, the pricing policy of formic acid, the variety of formic acid packages, the order size, and the order frequency of formic acid. The relationship between variables was identified according to the literature and hypotheses were developed. This study has attempted to build a more comprehensive framework containing all proposed value dimensions and market knowledge as well as identifying the relationships between variables.

Keywords: customer value; CCU; conceptual framework; market analysis; formic acid

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1. Introduction

Increased concern surrounding CO_2 capture and utilization has been raised as a result of transforming these harmful emissions into valuable chemical feedstock such as formic acid products [1,2]. Captured carbon may be stored or utilized. The first process is called carbon capture and storage (CCS) and the second is called carbon capture and utilization (CCU). The captured carbon can be stored in a geological site for long-term storage, such as in depleted oil and gas reservoirs, or it can be converted into commercial products [3]. CCS is the most dominant type of carbon-capturing technology. CCS adoption requires high investment and operating costs [3,4].

Adopting CCS on a wide scale requires overcoming many obstacles such as economic and cross-chain risks [5]. As has been reported in previous studies, the contribution of CCU to mitigating global CO_2 emissions is still limited despite its environmental and economic benefits. Accordingly, CCU should be more encouraged [1,3,6,7]. This technology can be more widely adopted by fully deploying sustainable energy and supporting the initial well-developed CCS technologies [1,8].

In the case of the CO_2-based production of formic acid, CCU is a valid approach to reducing greenhouse gas emissions and supporting environmental sustainability and fossil resource use [9]. CCU technology, which is key in achieving net-zero carbon emissions, aims to capture emitted carbon and use it as feedstock to produce other value-added and marketable products (e.g., formic acid) [6,7]. This creates value for both suppliers and consumers. CCU products are helpful from both an ecological and economic perspective [10].

The value proposition is the main component that plays a crucial role in this business model [2]. It is a statement of customer benefit [11]. Tools and guidelines to design a sustainable value proposition have been offered by some studies of sustainable business practices [2,12,13]. However, only a few studies have explored how the design of the value proposition affects customer benefit [2]. The relationship between value proposition, technology, and customer benefit is ambiguous. Integrating customers and technology is important for generating customer value and maintaining the balance between economic and ecological benefits [2].

Previous CCS and CCU (or CCSU) studies are classified into two general streams. The first stream is concerned with proposing the best supply chain and/or logistics process design. These studies have not focused on reporting the customer value of the utilized products and they are based on assumptions of value. For example, these studies have assumed that the demand is fixed and equal to the size of the national market, and that the price is fixed and based on reported prices [14–19].

The second research stream is concerned with reporting customers' attitudes toward CCUS technology. It involves reporting the degree of customer acceptance, the degree of customers' perceived ecological risks and benefits, and other determinants such as the degree of environmental readiness and knowledge about CCUS [7,20,21]. Both research streams have not developed a comprehensive model of customers' value proposition and both lack a clear definition of product features from the customers' perspectives. Additionally, most of the previous studies traced the value of products other than formic acid, which is the focus of this study.

Accordingly, this paper aims to develop a comprehensive conceptual framework of CO_2 capture and utilization, emphasizing formic acid as a product produced from captured CO_2. The generated conceptual model will be examined later at the country level. To that end, this paper attempts to achieve the following objectives:

1- Identify the market knowledge variables of formic acid products.
2- Identify the value variables of formic acid products.
3- Develop a conceptual model and related hypotheses that reflect the relationship between variables.

2. Overview of Proposed Utilized Product

Formic acid is miscible with water and many polar solvents and is partially miscible with hydrocarbons. It is mainly produced through the hydrolysis of methyl formate. Derivatives of formic acid include esters, salts, performic acid, and formamides. The well-known derived salts are sodium and potassium. The esters such as methyl formate, ethyl formate, and performic acid are formed through the equilibrium reaction of formic acid and hydrogen peroxide [22].

Formic acid and its salts are mainly used in leather tanning, grass silage, and anti-icing (for example, to make airport runways preeminently ice-free). Other utilities of formic acid and its salts include use in textile finishing and dyeing; use in producing food additives, animal feed, drilling fluids, and natural rubber; and use in various other chemical processes [22,23]. Accordingly, there are several uses for formic acid, such as in making rubber, textiles, and animal feeds, and in leather tanning. Formic acid products are also consumed as food additives (see Table 1).

The exports of formic acid and its derivatives have increased from USD 179 million in 2002 to USD 900 million in 2018, although there was a decline of 31.5% in export values in 2020 when compared to 2019 because of the COVID-19 pandemic and the resulting global shutdown (Figure 1). Salt of formic acid constitutes the most significant market among the various products, accounting for 57% of the export market in 2020. Formic acid follows with 34% of the market, and the remaining 9% accounts for formic acid esters. In 2020, China was ranked number one globally in exporting formic acid and salt of formic acid. China exported a little over half of all total exports of formic acid globally and 35% of salt of formic acid in 2020. Korea exported the highest amount of esters of formic acid in 2020, accounting for 27% of the total export market. Other important exporting countries for the various formic acid products include the Netherlands, Germany, the U.S., Belgium, India, Canada, the U.K., and Norway [24].

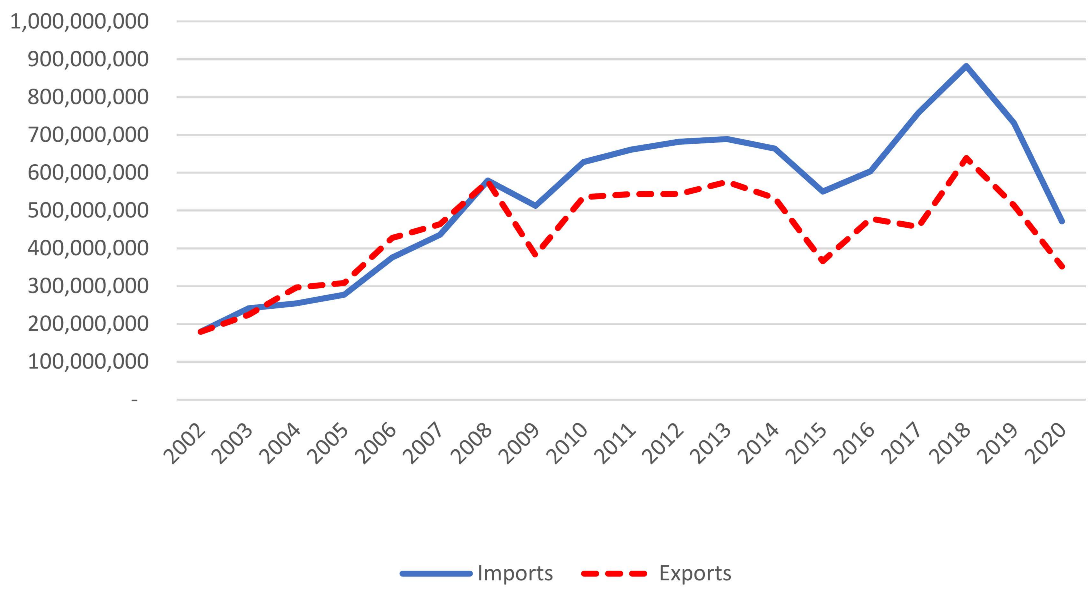

Figure 1. Exports and imports of formic acid, salt of formic acid, and esters of formic acid. Source: [24].

Salt of formic acid is the highest imported formic acid, accounting for 47% of the market. It is followed by formic acid at 43%, with the remaining 10% representing esters of formic acid. The Netherlands is the world's top importer of formic acid, importing an amount worth nearly USD 30 million in 2020 which represented 13% of the global imports of formic acid for that year. India is the top importer of salt of formic acid and esters of formic acid. India's imports of salt of formic acid and formic acid esters represent 13% and 32% of global trade volumes, respectively. Other notable importers of formic acid, salt of formic acid, and esters of formic acid include Germany, Norway, the U.S., Russia, Brazil, the U.K., Spain, Australia, and Turkey [24].

Formic acid could be produced by adopting CCU technology. Accordingly, the captured CO_2 can be used as a feedstock to make formic acid. Four types of production process could be adopted: methyl formate hydrolysis, oxidation of hydrocarbons, hydrolysis of formamide, and the preparation of free fatty acid from formates. The most widely adopted process in Europe is methyl formate hydrolysis. In this alternative, the production process undergoes six stages beginning with compression, followed by reaction, and subsequently involving catalyst recovery, methanol recovery, and finally the formic acid formation and purification [25].

Table 1. The uses of formic acid and its derivatives. Source: Adapted from [22,26].

Type of Product	Pharmaceutical	Agriculture	Leather and Rubber	Textile	Airline	Detergent	Furniture	Food	Oil and Gas	Others
Formic acid (CH_2O_2)	Synthesis intermediate for various medicines such as vitamin B1; widely used for pH adjustment during the manufacture of various chemicals	Grass silage and animal feed additives; as a preservative and antibacterial agent in livestock feed for animals	Leather tanning; coagulating agent for latex to produce high-quality rubber	Textile dyeing and finishing		The active ingredient in commercial cleaning products		Food additives; synthesis; flavoring intermediate for caffeine; protects water against bacterial contamination; effective against salmonella; food preservation in fumigation of fruits to reduce post-harvesting decay (E236)	Drilling fluids; well- acidizing	Desulfurization catalyst for coal-fired power stations
Sodium salt (CHO_2NA)	Buffering and regulating pH		Buffering and regulating pH	Buffering and regulating the pH of sodium dithionite	De-icer	Enzyme stabilizer in liquid detergents	Sodium dithionite	Preservative (E 237)		

Table 1. *Cont.*

Type of Product	Pharmaceutical	Agriculture	Leather and Rubber	Textile	Airline	Detergent	Furniture	Food	Oil and Gas	Others
Potassium salt (CHO_2K)					Anti-icing property is utilized on airfield runways and taxiways				The seal bore holes in oil and natural gas drilling in addition to helping dissipate heat generated during drilling	
Methyl Formate ($C_2H_4O_2$)										Captive intermediate for the production of formic acid and formamide; solvent; insect-control agent
Ethyl Formate ($C_3H_6O_2$)		Soil fumigation (controlling nematodes and other pathogens)						A component of fruit flavors		

3. Overview of Customer Value Proposition Theoretical Perspectives

Customer value proposition (CVP) is a strategic tool a company may use to communicate how it aims to provide value to customers. Therefore, it is a communication device that emphasizes the role of resources and resource sharing and provides an appropriate package of value that is different and superior to what may be offered by competitors [27]. Alternatively, it is defined as the benefit the customer can expect from products or services [28]. Similarly, it is a description of the experience a target user will receive upon the purchase and use of a product [29].

CVP differs from other concepts in marketing as a positioning statement, business model, and selling proposition. In general, it is broader than the positioning statement and selling proposition and is an element of the business model [27]. The customer value proposition is arguably the most important tool in the product marketer's toolset as it is the foundation for understanding how the target users will value the product. In the absence of a customer value proposition, companies are walking blindly in the marketplace [29].

Different conceptual perspectives describe how the CVP is created. These include the transactional view, supplier determinants, and mutual determinants. According to the transactional view, the firm determines value according to an understanding of customers' experience during usage. CVP subsequently sets out an offer that accounts for the customers' experience. The supplier perspective emphasizes choosing the value proposition, providing the value proposition, and communicating the value proposition. However, according to the mutual perspective, the value is embedded in the product and is determined according to active customer involvement [27].

The value proposition conceptual models could be classified into two groups according to the scope of the model. The first group focuses on the customer value proposition definition [28,30,31]. The second group focuses on the customer value proposition formulation process [27,29,32,33].

The first group of models focused on defining the customer value attributes and the role of the customer [30], as well as accounting for concerns surrounding identifying the jobs, pains, and gains [28]. In addition, it also involved classifying the value into four general attributes: symbolic, emotional, functional, and economical, and finding the actual practices that fit the characteristics in a matrix developed for this purpose [31].

The second group of models described formulating or building the value–proposition, antecedents of VP decision and attributes, implementation, and consequences [27,29,33,34]. The second model was also concerned about the sources of value, choosing the value, types of value, the activities required to realize the value or provide the value [11,32], and communicating the value [11].

Figure 2 shows the general flow process of the business model. This process is classified into three stages: customer value proposition formulation, value creation, and value capturing. Accordingly, customer value proposition formulation is part of the business model. The first stage of formulating a customer value proposition includes setting subprocesses, analyzing firm resources, collecting market information (market knowledge), identifying customer value proposition, quantifying customer value, documenting customer value, and designing and communicating customer value. The second stage includes creating value through implementing the proposed customer value. The final stage involves value creation through realizing the competitive advantage and assessing and reviewing the proposed value.

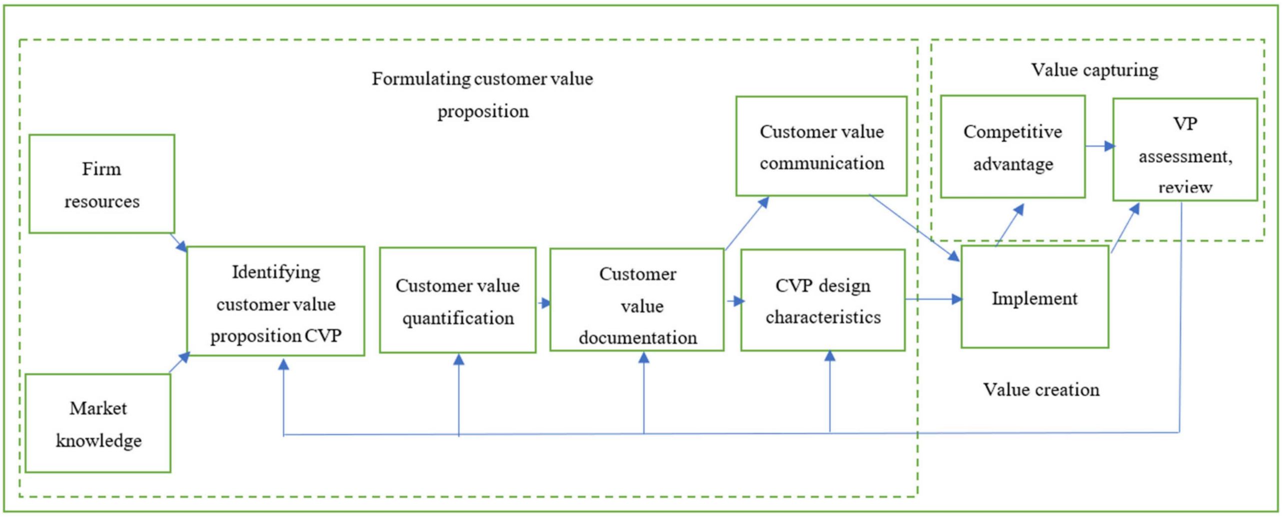

Figure 2. Summary of customer value proposition formulation process. Sources: Adopted from [27,29,33].

A firm's human, financial, and tangible resources are required to realize the customer's value through proper utilization of these resources during daily operations. Managers should be aware of these resources' strengths and weaknesses. Market knowledge requires identifying and selecting key market segments [28,33,34].

After identifying the target market, the value should be identified, designed, and assessed. However, it is very important to involve the customers during the design stage. After identifying the initial value proposition, it should be tested and assessed with selected customers. This process is iterative, which means it should be monitored and refined over time [33].

The value map is one of the tools used to present the relative value proposition of different companies in the industry along the cost–performance axis. This map presents a relationship between performance and cost using the value frontier. The maximum performance is currently feasible for any given cost to the customer and represents different segments offered to customers [11,30].

It is important to quantify the customer value propositions, and this means selecting a meaningful measurement unit that is significant for the key target user. This measurement should be for the results of the actual value experience of customers [29]. Therefore, it is important to quantify the values of the competitors' and the firms' value propositions [33].

Moreover, the customer value should be documented and it is therefore important to build internal value documentation capabilities and tools. It is recommended to include in this document a clear identification of the target customers and a list of quantified benefits related to product attributes, price, and clear value proposition statements [35,36]. The document should include the defined measures for the value attributes to track the progress of the achieved values. The documentation should be presented according to a formal template and signed off on quantified benefits. This document will be affected by the review cycle (e.g., quarterly or annually) to ensure the value documents are kept center-stage with customers [33].

The documents of customer value proposition should be followed by the building of an internal consensus and aligning the product price with the product's defined attributes, followed by creating a marketing message that communicates the value to customers and other key external stakeholders [29]. The documented customer values should reflect tangible attributes of the product design or what is required for the product to be adopted by suppliers as is determined by the CVP [27].

Communication should take place through tailored messages used by sales forces, including specific value propositions. In addition, advertisements and media promotions should include such messages [33]. After implementing the value proposition through the activities of all partners along the supply chain the realized value will be reviewed.

The revision will involve assessing the captured competitive advantage from customers themselves in order to demonstrate the cost-saving or added value they can expect from using the supplier's offering instead of the second-best alternative [37] and by assessing the customer experience in using the product. In addition, companies should seek to authenticate value verification by involving independent external parties such as testing authorities, standard-setting organizations, and universities. Mandatory customer feedback mechanisms are also preferable, such as using research agencies [33].

4. Materials and Methods

The perspective of the conceptual framework adopted by this paper is that the conceptual framework is a network or a plan of interlinking concepts that provides a comprehensive understanding of the customer value proposition of CCU–formic acid products. The framework proposed in this study is a construct in which each concept represents not only a casual analytical setting but an interpretive approach to the customer value proposition of CCU–formic products [38]. This study passed through different phases (see Figure 3). The first phase was an extensive reading of the literature, followed by a content analysis of the selected literature to identify the concepts and the general categories of these concepts. The final phase was a content analysis of the selected literature to identify the relationship between concepts. The details were as follows:

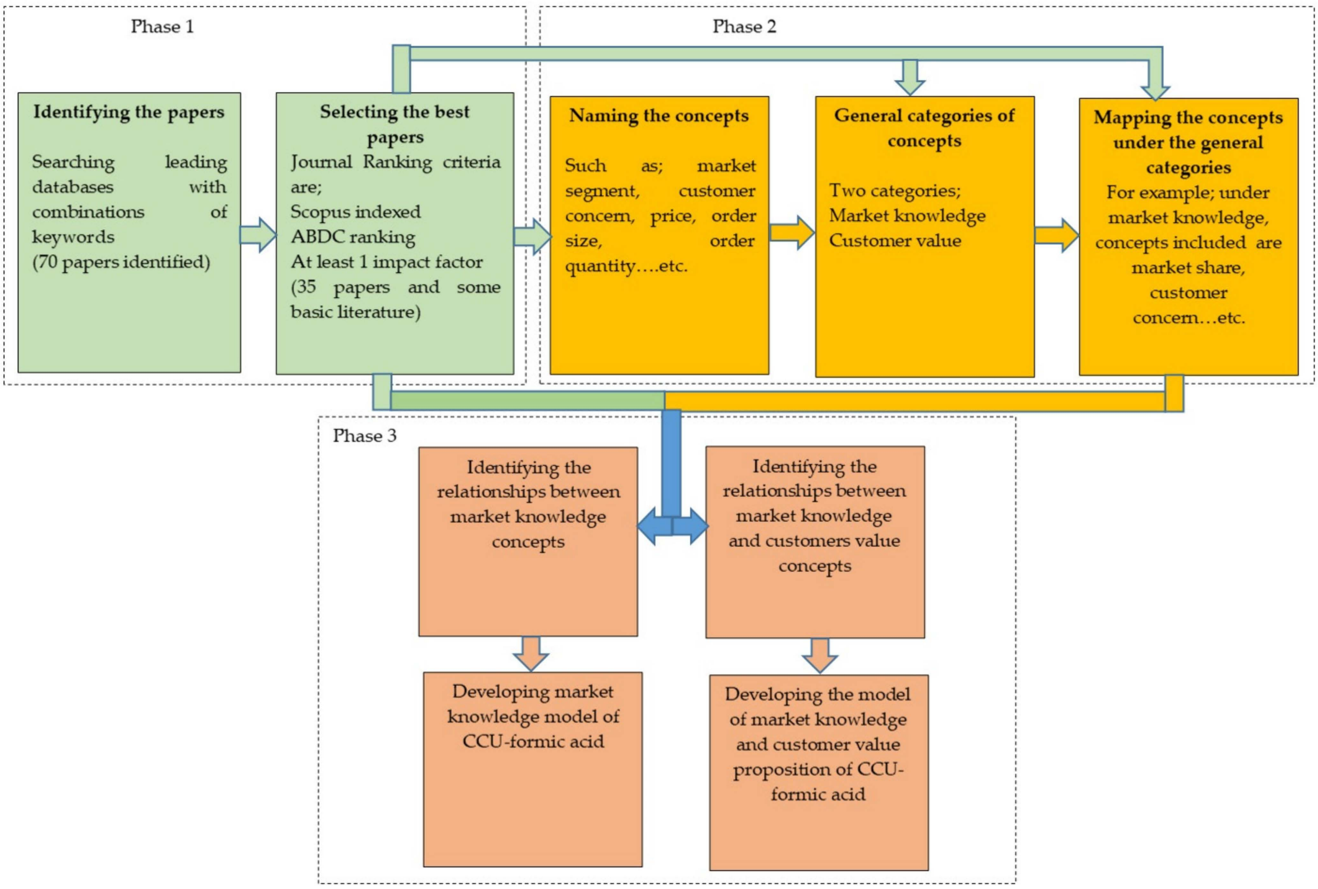

Figure 3. Process–flow diagram of research methodology. Source: Designed by the authors.

Phase 1: Extensive reading and selection of the related literature.

For this study, several research papers dealing with CCU, CCUS value chain, supply chain, and customer attitudes as well as theory-based studies and papers were examined. The literature review and content analysis were applied to scientific articles published in top-ranking journals. The papers and studies were screened with the help of databases such as Emerald, Science Direct, Taylor and Francis, and John Wiley & Sons. These databases are leading in business and marketing literature in general and business models in particular. Additionally, the most up-to-date literature was identified by relating to the keywords listed below, which are published by these databases.

Approximately 70 papers were screened. They were identified by searching with combinations of keywords such as "CO_2 capturing", "CO_2 storage", "CO_2 utilization", "CO_2 value chain", "CO_2 supply chain", "CO_2 logistics", "CO_2 customers' attitude", "value proposition", "CO_2 customer acceptance", "CCU", and "CCS".

Journals were then ranked by adopting selection criteria. The primary essential criteria were Scopus indexed and then ranked as "A*, A, B or C" as is outlined by the ABDC ranking scheme. The preferable criterion was a journal with an impact factor of at least 1. Exceptions to this rule were: essential fundamental articles, statistical reports, books, or book chapters. The total number of papers adopted was approximately 35.

Phase 2: Content analysis of the selected literature to identify the concepts and general categories.

Concepts were first named, followed by an identification of the general category of these concepts. There were two general types that presented: market knowledge and customer value proposition. These two categories were identified according to the literature review of the theoretical perspective of customer value propositions discussed in the previous section. Different concepts related to each category were identified such as target market, customers' concern, customers' knowledge, customer willingness to purchase, price, demand, produce varieties, risk, etc. Each concept was mapped under the general categories mentioned above. It is essential to note that the conceptualization was within the context of CCU and the utilized product, which is formic acid.

Phase 3: Content analysis of the selected literature to identify the relationship between concepts.

This phase was performed in two stages. The first stage was identifying the relationship between market knowledge concepts and then between market knowledge and value concepts. Conclusions were found through reviewing the literature and reading studies in-depth. It was found that some market concepts are related to each other. Moreover, it was found that the two categories–market knowledge and customer value–are interlinked and related. Accordingly, two models were developed. The first model was the market knowledge model of CCU–formic acid products, and the second model described the customer value dimensions and their relationship with market knowledge dimensions. The related hypotheses for each model were formulated.

5. A Proposed Framework of the Customer Value Proposition of CCU

Performance attributes are specifications or features of a product. To create value, it is necessary to identify a product's performance attributes as they are defined by the customers [39]. Designing a differentiated value proposition requires a multi-faceted understanding of what customers value [31]. Customer value constitutes four dimensions: economic, functional, social, and emotional [2].

In the formic acid product context, the design of a value proposition for a product can highlight one or more of these values. The following parts of this study adopted these respective value propositions to develop the conceptual framework of the customer value proposition. With an emphasis on formic acid products, the results of previous studies related to business models were adopted to develop a more comprehensive and sophisticated conceptual framework. These studies include those on who decided to design the supply chain, logistics process studies and studies on the customers' attitudes toward CCU technology.

Utilized products from captured CO_2 target a particular market segment. Accordingly, the product should provide the required value as is defined by the targeted customers. It is essential to start reporting the customers' values and adopt them as product design attributes to be used later in designing the supply chain of CO_2 capture and utilization. The literature surrounding CO_2 capture and utilization that is relevant to business models can be classified into two streams. The first research stream is concerned with designing the value chain of the CCU process [14–19]. The second research stream is concerned with reporting the customer's attitudes toward CO_2 capture, utilization, and storage processes [7,20,21].

The first research stream began by designing the CCU supply-chain process from assumptions related to customer value reported by previous studies. The main value attributes were related to the product's price and the demand size [19]. These studies generally were not concerned about reporting the customers' attitudes toward the product's attributes in detail. Additionally, most of these studies assumed that the size of demand that can be satisfied by the CO_2 capture and utilization process is equivalent to national demand [17]. Moreover, the targeted customers were business customers.

The second research stream, which investigated the customers' attitudes, was concerned with reporting the customers' knowledge and acceptance of CO_2 capture, utilization, and storage processes [20]. The benefit or value of these technologies was reported. The main benefits were the ecological benefits such as fighting climate change, saving CO_2 emissions, saving fossil fuel resources, and their prices [21].

These studies decided to examine the impact of socio-demographic characteristics of customers on the acceptance of the CO_2 capture and utilization process. In addition, this research direction is concerned with reporting the customers' attitudes toward the human and environmental risks of adopting such technology. Most studies reported the attitudes of individual customers, not business customers. Moreover, minimal studies have reported products' other attributes, such as the degree of customer interaction or the product component attributes, dimensions, etc. Most of these studies have not reported the relationship between market knowledge and value dimensions [7,20,21].

Therefore, this study attempts to bridge previous research gaps by developing a comprehensive framework that defines all market knowledge variables and customers' value of formic acid products. In the next section, the market knowledge dimension of the CCU product, which is formic acid, is defined, its variables are identified, and the related hypotheses are formulated. Subsequently, the customer value attributes of the CCU product–which is formic acid–and the related hypotheses between value dimensions and market knowledge are formulated.

5.1. Identifying the Market Knowledge Dimensions of Formic Acid Product

These sections focus on identifying the variables of the market knowledge dimension of formic acid. This dimension includes a set of variables according to the revision of previous studies. Market knowledge requires identifying and selecting the key market segments [28,33,34]. CVP is specific to a key target user, that is, the intended user of the product.

Moreover, the key target market profile should contain information such as demographics, role, and responsibility. It should also include where the type of business is and the organization where the target user can be found, what the behavior required to achieve the value is (i.e., purchase, installation, registration, etc.), what daily problems are related to the solution, and what the detailed expected use of the product is [29]. After identifying the market segment, the customer and competitor knowledge should be investigated to understand better how the value is defined [33].

The customers can play different roles in which they can be buyers, users, co-creators, and transferors. The buyer determines the needs, assesses suppliers, orders, and pays for the product. The user determines how the end-user derives the predicted performance from product and service. As a co-creator, the customer cooperates with their suppliers to form the expected product value. Finally, as a transferor, the customer determines how the product will be disposed of [30]. Different roles of customers can be reflected in different customer positions across the supply chain.

The customer value proposition should be defined across the multiple customer roles along the supply chain [30]. The business customer, such as a producer, distributor, or supplier, can play the role of co-creator and transferor; in this case, the customer relationship is known as a business-to-business relationship (B2B). Additionally, the end customer can play the role of buyer and user; in this case, the customer relationship is known as a business-to-customer relationship (B2C). Moreover, different customer value propositions require other supply chains [40].

As was discussed earlier, it is essential to identify and define the market segments in order to identify the customer value propositions and the most attractive target market. Moreover, defining the target market and the role of the target market players will result in the value being identified accordingly. The other variables of market knowledge addressed by the previous studies of CCU were customer knowledge and concern about CCU [20,21] and customer readiness toward environmental issues [21].

5.1.1. Market Segments of Formic Acid Product

A market segment is a group of organizations, individuals, or groups who may share the same interests, characteristics, or traits. The process of identifying such groups is called market segmentation. The variables used for market segmentation are: (1) demographic factors (age, gender, income, occupation, education, religion, marital status, family size, and nationality); (2) geographic factors (such as regions of different cultures, climate, natural resources, terrain, population density, etc.); (3) psychographics (such as the cognitive factor derived the customer behavior or correlating the customer behavior with the personality or lifestyle of the customer); (4) behavioral factor (such as the customer purchasing volume or purchasing frequency); and (5) the product-related factors [41]. Segmentation is followed by targeting, which is the process of developing measures of the attractiveness of the segments and selecting the best segment [42].

Most studies of CCU were not concerned about classifying the customers of CCU into different segments. Some studies examined segmentation factors such as customer demographics, education level, gender, and age [20,21]. In addition, some other studies adopted psychographic factors such as customers' perceptions of CCU and ecological risks and benefits, thus classifying the market into three segments: the approvers, the cautious, and the rejecters [7].

Furthermore, the customers of CCU could be classified according to product characteristics such as the degree to which a consumer must physically interact with the product: whether the product must be held to be consumed, must be touched to be used, or is seldom the subject of physical contact [21]. Moreover, some studies investigated the customers' attitudes in regions such as the U.K. and U.S. [18].

As the utilized product investigated by this study is formic acid, the formic acid market could be classified according to product features into different segments. One of these important features is the concentration of formic acid, where the market could be segmented into 75 wt%, 85 wt%, 90 wt%, 94 wt%, 95 wt%, and 99 wt% [22,23]. The 85 wt% segment accounted for 40% of the market share [23]. The other segmentation factor is the use of formic acid by industries such as the leather and textile industry, rubber industry, pharma industry, food additive industry, agriculture industry, and animal feeding industry [22,23]. The size of each segment, according to its uses, differs across regions. Formic acid is most widely used for animal feeding, followed by leather tanning [43].

5.1.2. Customer Concern and Knowledge about Captured CO_2

The customer concern about CCU is related to customer willingness to use or reject the usage of products generated from this technology [20] and the local acceptance of CCUS, such as the acceptance of constructing a CCU plant in the neighborhood [20]. Based on a study by [21], approximately 60% of customers were more likely to consume or use a CCU-based product.

Moreover, the extent to which customers are familiar with and informed about CCU technology and products must be considered [20,21]. The majority of customers–66% [21] to 75% [20]–reported feeling uninformed about CCU. Moreover, the customers' acceptance of the capturing method, whether direct capturing from ambient air (DAC), or indirect capturing from a point source, could impact the customers' concern about CCU technology [21].

A study by Arming et al. [20] found no significant impact of information level on CCU technology acceptance. Customers who had more familiarity with CCU technologies were more accepting of CCU-based products than those without familiarity [21]. Customers were more likely to accept consumed products if CO_2 was captured via direct capture rather than from plastic food containers and shatterproof glass [21].

The study [21] also found that the degree of customers' physical interaction with the product will impact their degree of acceptance. In other words, the less physical interaction with CCU products a customer will have, the more likely they are to accept the adoption of CCU products. For example, customers are less likely to accept carbonated beverages than other products such as plastic food storage containers, furniture made with foam or plastic, or shatterproof glass [21].

As was discussed in the previous section, this study focuses on utilizing the captured CO_2 in the production of formic acid. Formic acid is used to make products consumed as rubber, textiles, animal feed, and food additives. It is also used in the leather tanning process. According to market share, formic acid is used to make products under hold to be destroyed. Accordingly, it is expected that CCU technology will be accepted.

Hypothesis 1 (H1). *Targeted customers of formic acid are willing to accept CCU technology.*

Hypothesis 2 (H2). *The more accepting by a customer is of CCU technology, the more intention they will have to purchase the formic acid produced by CCU technology.*

Hypothesis 3 (H3). *Targeted customers of formic acid are not well-informed about CCU technology.*

Hypothesis 4 (H4). *There is a positive relationship between the formic acid customers' knowledge about CCU and their acceptance of the CCU technology.*

Hypothesis 5 (H5). *The customers of formic acid are more likely to accept the product if the utilized CO_2 is captured directly.*

5.1.3. Customer Readiness toward Environmental Issues

Customer readiness toward environmental issues is defined as the customer's ecologically-conscious behavior and climate change awareness. The first dimension relates to customers' concerns about adopting environmentally friendly practices, such as purchasing products with a minimal negative environmental impact in manufacturing and usage, using public transportation, bicycles, or walking instead of driving cars, and reducing waste by avoiding unnecessary packaging or plastic pages. The second dimension relates to customer awareness of environmental issues and climate change due to greenhouse gas (GHG) emissions [7]. Customers with higher knowledge and concern about ecological issues and climate change are expected to be more likely to use or consume CCU-based products [21].

Hypothesis 6 (H6). *There is a positive relationship between customer readiness toward environmental issues and the acceptance of CCU products and technology.*

Figure 4 summarizes the market knowledge model; it can be observed that the acceptance of CCU technology by the target market is determined by customers' knowledge about CCU technology, attitudes toward the types of capturing technology, and readiness toward environmental issues. Moreover, the acceptance of CCU technology will affect the customers' intention to purchase formic acid.

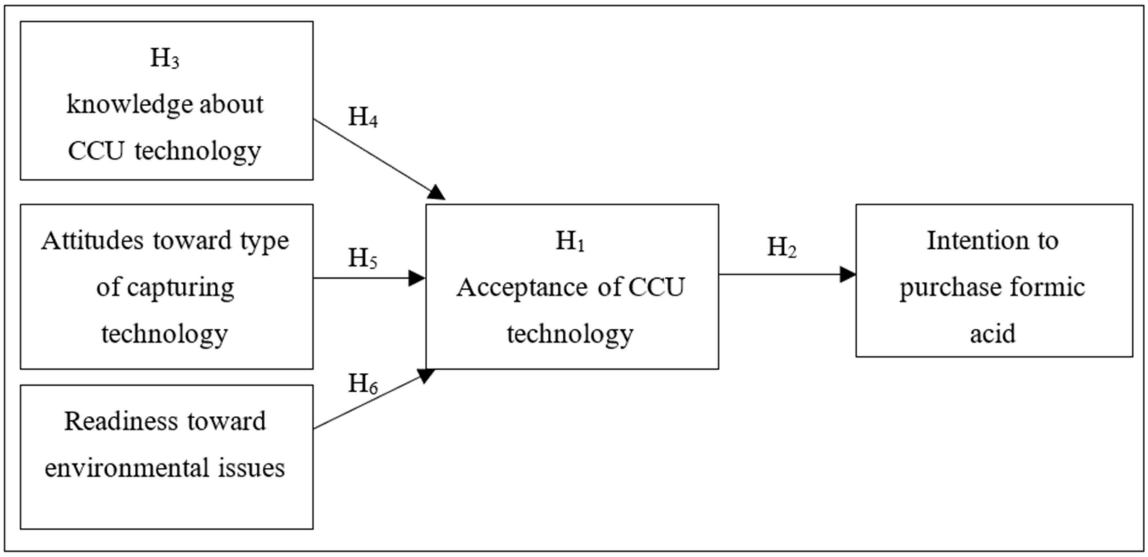

Figure 4. Market knowledge model of CCU–formic acid product.

5.2. *Identifying the Customer Value Dimensions and Their Relationship with Market Knowledge Dimensions of the Utilized Product from Captured CO_2*

As was discussed earlier, value is defined as the product's performance attributes that fulfill the customers' needs across multiple customer roles and the total cost [30]. The value is defined when price is outweighed by net benefit [11]. The product attributes are the product's features, customer service, and support. These attributes can be classified into basic, expected, desired, and unanticipated. Product cost is mainly defined as the price of a product. Broader consideration of cost includes the risk (physical, selection, delay, functional, and psychological) and effort (acquisition, operations and maintenance, and complementary cost) associated with adopting a product [30].

Another classification of value is economical, functional, emotional, and symbolic. The economic value is defined as the economy-related value delivered to the customer. However, the functional value is related to convenient solutions derived from products. Emotion is related to the enjoyment that stems from using the product and is related to the ambient environment of the service. A symbolic value is related to the adoption of high social, environmental, or ethical morals through purchasing the product [31]. This classification is close to [28], which classified value or "customer Jobs" into functional, social, personal, or emotional support. Another close classification was adopted by Condi et al. [32], including values such as cost or sacrifice, functional or instrumental, experience, and symbolic.

From the perspective of business-to-business customers, the value could be classified as economic, technical, and relational. The economic and technical values are short-term benefits, but the relational value is a long-term benefit [44].

Here this study aims to identify and define the value variables of the formic acid products as produced from carbon-capture technology. These variables are functional, such as varieties and demand of formic acid, order size, and the delivery speed of formic acid's value, such as the formic acid price, or symbolic, such as ecological benefits and risk of adopting CCU technology. Moreover, it identifies the relationship between customer value and market knowledge variables.

5.2.1. Varieties and Demand for Formic Acid

The early projects of CO_2 capturing were concerned with storing captured CO_2. Over time, concern shifted toward utilizing the captured CO_2 in making products. These products could be classified into different categories according to the degree to which a consumer must physically interact with the product: must be held to be consumed, must be touched to use, or is seldom the subject of physical contact. Plastic food storage containers and furniture made with foam or plastic are examples of products that must be touched to be used. Shatterproof glass is an example of a product that is seldom the subject of physical contact [21]. An example of consumed products are carbon beverages, which must be held to be consumed.

Some studies proposed a design for supply chains consisting of multi-product mixes of different categories of products. For example, a mix consisting of products that are seldom the subject of physical contact such as methanol, concrete curing, lignin, polyurethane, calcium carbonate, urea, and concrete by red mud or a mix of products which must be held to be consumed such as wheat and tomato growing [17,19].

Other studies focused on one type of product as the subject of physical contact, such as those used to enhance oil recovery wheels (EOR) (e.g., in [15,16]), enhance water recovery, and enhance coalbed methane [45], or products which must be held to be consumed such as formic acid [25].

Some studies investigated customer perception toward CCU, such as Lutzke et al. [21], which reported the customers' attitudes toward the multi-product categories "consumed", "must be held to be consumed", "must be touched to use", and "is seldom the subject of physical contact". Other studies, such as Arning et al. [20], examined the customers' attitudes toward one product category, such as products which must be held to be consumed, an example of which could be a foam mattress. Additionally, Cox et al. [18] examined customers' perceptions of utilizing CO_2 in bioenergy and enhancing rock weathering.

Previous studies on the supply-chain management of CCU were concerned about the demand for utilized products. These studies were concerned with the national market for the product and recognized that demand as a constraint for the production process (e.g., [14,15,17,19,45]). However, the research stream concerned with reporting the customers' attitudes regarding carbon capture, utilization, and storage processes did not investigate the demand for utilized products [7,20,21].

This study focuses on utilizing the captured CO_2 in producing formic acid. The demand for formic acid differs globally across industries. Formic acid is widely used for animal feeds (34%), followed by leather tanning (32%), in textiles (13%), as intermediaries (9%), in rubber production (4%), as a coating (2%), and in other applications (6%) [43]. The demand for formic acid differs across regions. For example, the Asia–Pacific region leads more than 50% of the share of the global market of formic acid. Textile and rubber industries are the prominent consumers of formic acid [23]. There are no clear, precise statistics about the demand for formic acid in different sectors, which is a part of the gap bridged by this study.

Hypothesis 7 (H7). *There is a significant difference between market segments of formic acid in the uses of formic acid.*

The product package is also one of the features of the delivered product. Formic acid products could be delivered in different sizes of packages such as 1 kg, 5 kg, 10 kg, 20 kg, 25 kg, 30 kg, 35 kg, 220 kg, 250 kg, 1200 kg, or in a plastic drum, but the widely adopted package sizes are 25 kg, 35 kg, and 250 kg [46,47].

Hypothesis 8 (H8). *There are no significant differences between market segments of formic acid in highly adopted package sizes of 25 kg, 35 kg, and 250 kg.*

5.2.2. Formic Acid Product Price

Determining the price of a product involves different steps, beginning with estimating the size of the demand for the product and investigating its target market. It is essential to consider the target market customers' attitudes toward the price they are willing to pay. Companies could adopt different strategies, for example, captive product pricing, price skimming, penetration pricing, premium pricing, freemium pricing, free trials, product bundling, volume pricing, and tiered pricing. Each pricing strategy is suitable for particular conditions such as the type of product, brand recognition, and intensity of competition [48,49].

Most studies regarding CCU that were concerned with designing a supply chain did not report the customer's attitudes toward price and considered the price to be stable or fixed. However, some of these studies conducted a sensitivity analysis to examine scenarios involving different NVPs and payback periods for the proposed projects [17,19,50]. However, the studies examining customer attitudes toward CCU products did not investigate the customers' attitudes toward the acceptable price level.

As was mentioned earlier, this study focuses on producing formic acid from the captured CO_2. According to some revisions of prices announced by competing companies, it is clear that the prices are almost within a range. For example, some companies set the price between USD 450 and USD 950 per ton for a 85% concentration, and there is often a minimum order size (for example, five tons). Other companies set a price range between USD 500 and USD 700 per ton regardless of concentration (e.g., 85%, 90%, or 94%), but instead set the minimum order size at 50 tons. In addition, some companies set a threshold for negotiating price; for example, price is negotiable if the quantity is more than 1000 tons [51].

On the other hand, different pricing policies are adopted by companies according to different concentration (85%, 90%, 99%, etc.), package size, grade (whether for an industrial-grade or pharma), and the responsibility of freight, especially for imported formic acid (FOB or EXW). It is known that price increases at higher concentrations of formic acid. Moreover, the pharma-grade price is the highest, and FOB fetches a higher price than EXW [47].

Hypothesis 9 (H9). *There are no significant differences between formic acid product market segments in adopting a volume-pricing strategy for formic acid products.*

Hypothesis 10 (H10). *There is a significant difference in pricing policy between different concentrations used by the target market of formic acid.*

Hypothesis 11 (H11). *The pharma industry segment adopts the highest-grade price of the formic acid product.*

Hypothesis 12 (H12). *Customers of formic acid products prefer a volume–pricing strategy.*

Another aspect to consider is to what extent the price of CCU products differ from that of similar products produced by the conventional production process. Evidence from previous studies is minimal; only one study decided to examine this, which compared a CCU plant that made formic acid with a conventional one. The comparison result showed some advantages of the CCU plant in saving heavy fuel and water that was required for cooling. However, there was an increase in consumed electricity and overall production cost. Despite this, the price-per-ton of CCU products was very close to the price of conventional products [25]. Previous studies did not investigate the customer attitude, so there is no evidence of whether customers are looking for more competitive prices for CCU products compared to conventional products or not. Thus, the following hypothesis is articulated.

Hypothesis 13 (H13). *Customers of formic acid are indifferent regarding the price of formic acid produced by CCU technology when compared with conventionally produced formic acid.*

5.2.3. Order Size and Delivery Speed of Formic Acid Product

Order size is the amount of product ordered or expected to be ordered by customers over a period. The customer order size is a primary determinant for factories' production planning and inventory management policy. The delivery speed is the time interval between the customer's order date and the receiving date of the product. These two factors could be the main determinants of a particular product-selection process. In the chemical industry, customers often place orders every month. The order size can be almost in bulk for different options related to the chemical product, such as different package sizes and chemical product formation.

The inventory management policy is essential in determining the factories' ability to satisfy the order size placed by a customer during a reasonable time. The choice of the production and inventory policies is determined by many factors such as the product transition, shelf-life expiration, and allocation of intermediaries' storage capacity. Production and inventory policies are determined by many factors such as product transition, shelf-life expiration, intermediaries' storage capacity allocation, demand uncertainty, production planning, and scheduling rules. Some companies could adopt make-to-stock (MTS), postponement, or combined MTS/postponement strategies. A hybrid policy is applied with low- to medium-demand and high expiration, providing the lowest cost without impacting on-time customer order fulfillment. MTS applies to the remaining products [52]. Formic acid is ordered in bulk quantities, in different packages, and with a high shelf life extended for two years [53]. Accordingly, it is better to adopt the hybrid strategy in managing inventory by companies.

Hypothesis 14 (H14). *There is no significant difference between formic acid market segments in the bulk quantities and packages size of orders.*

Hypothesis 15 (H15). *There is no significant difference between formic acid market segments in ordering products every month and delivery during a week.*

5.2.4. Ecological Benefits and Risks of CCU Technology Used in Making Formic Acid Product

The ecological benefits of CCU refer to the extent to which the customer perceives that this technology is a relief for the environment and can help fight against climate change by saving fossil fuel resources and extracting CO_2 [7,20]. A limited number of CCU studies were concerned with designing the supply chain and investigating the impact of adopting such technologies in protecting the environment [25]. However, most of the studies in this field were concerned about reporting the amount of captured carbon without concern for net emissions [17,19,50]. Other studies, such as those conducted by [7,20,21], investigated customer attitudes and revealed that the customers perceived CCU technologies as beneficial to the environment. Taking this into consideration, the following hypothesis is proposed:

Hypothesis 16 (H16). *Customers of formic acid perceive CCU technology as beneficial for the ecological environment.*

Another issue is determining to what extent the perceived benefits of CCU products will affect the customer acceptance of this technology. Some previous studies found that the perceived benefits of CCU technology had a significant positive impact on CCU acceptance [20]. Consequently, the following hypothesis is proposed for an empirical investigation:

Hypothesis 17 (H17). *The formic acid customers' attitudes toward the benefits of CCU technology will positively impact their acceptance of this technology.*

CCU technology risk relates to how customers perceive CCU as harmful to the ecological environment and human beings. These risks are controllable [20,21]. Some previous studies that reported customers' attitudes showed that the perception of CCU risk was comparably low [7]. One study investigated the customer-perceived risk across the process chain of CCU. This study found that the respondents slightly elevated the risks of the process-chain steps. There is a significant difference between CCU product disposal, production, and product usage risks. The highest-perceived CCU-related risk was reported for the disposal of CCU products [20]. Therefore, the following hypothesis is articulated:

Hypothesis 18 (H18). *Customers of formic acid products perceive CCU technology as low-risk for the ecological environment and human beings.*

Another issue to consider is the extent to which the perceived risk of CCU products will affect customer acceptance of this technology. Previous studies found that the perceived risks related to CO_2 capture, transport, storage, and production had no significant impact on CCU acceptance [20]. Therefore, the following hypothesis is proposed:

Hypothesis 19 (H19). *The customers' attitudes toward the risk of CCU technology will negatively affect their acceptance.*

Figure 5 shows a proposed conceptual model. It can be seen that the proposed model contains two general dimensions: market knowledge and customers' value dimension. This model includes two market knowledge variables and seven customer value variables. Moreover, the formulated hypotheses in the conceptual framework are presented on the variables' relationships.

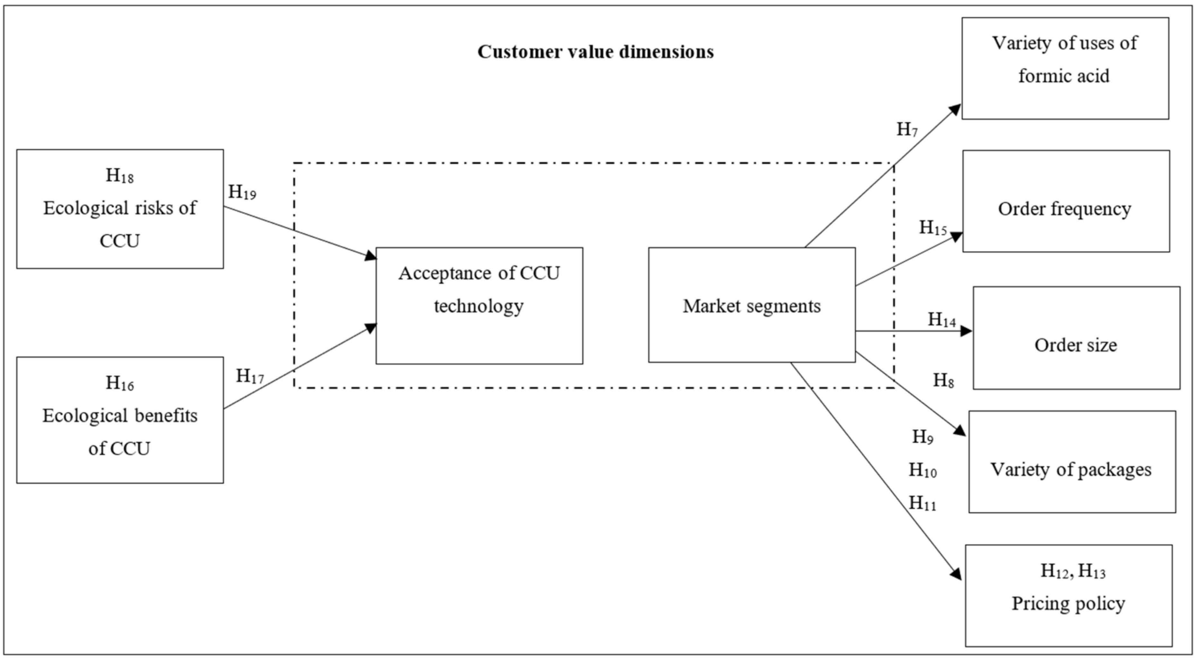

Figure 5. The proposed CCU–formic acid conceptual model of customer value dimensions and their relationship with market knowledge dimensions.

6. Discussions and Conclusions

The previous models and frameworks of CVP have developed general classification schemes of customer value attributes which could help categorize concepts of the conceptual models such as jobs, pains, and gains (e.g., [28]). In addition, they have classified the value into four general attributes: symbolic, emotional, functional, and economical [31]. However, the detailed classifications and theoretical and operational definitions of sub-attributes or product features are unclear.

Moreover, these models have not discussed the embedded relationships between the values' attributes or between market knowledge attributes and value attributes. Furthermore, most of these models were general in their industry scope and dealt with the conventional production process CVP. Accordingly, this study attempted to build a more comprehensive framework containing all proposed value dimensions and market knowledge and also to identify the relationships between variables to produce a more comprehensive understanding of the customers' value propositions of CCU.

The emergent technology of CCUS has been well known and widely adopted by many countries worldwide. Despite academic concern over studying this technology, the contribution related to a business model in general and to the value proposition is still in its infancy and requires more attention. The nearest research stream to this issue is still limited; some scholars who are concerned about designing the supply chain assume value characteristics for some attributes such as demand and price based on the literature. However, other studies are concerned with reporting the customers' attitudes toward CCUS technology, such as the concerns and the determinants of adopting CCUS.

This paper is based on reviewing the marketing literature that defines the dimensions of value propositions and the process of developing customer value conceptually. The outcome of this paper is a comprehensive framework of the customer value proposition of CCU technology with an emphasis on formic acid products. This conceptual framework contains two general dimensions: market knowledge and customer value. The first dimension includes five variables: the customers' acceptance of CCU technology, the customers' intention to purchase formic acid produced by CCU technology, the degree of customers' knowledge about CCU technology, the customers' readiness for environmental issues, and the market segments of formic acid product.

The second dimension includes seven variables related to customer value: ecological benefits, ecological risk of CCU, varieties of formic acid use, pricing policies for formic acid, variety of formic acid packages, order size, and the order frequency of formic acid. The relationship between variables has been identified according to the literature, and a set of hypotheses has been formulated. These hypotheses will be examined later at a country level.

The conceptual model developed by this study could be used by the researchers for empirical studies purposes and could also be adopted for teaching purposes by CCU lecturers. Although this study is conceptual, its developed models can help the CCU–formic acid project managers to understand the market factors that should be taken in consideration in designing the capture or utilization processes.

Although this study contributes significantly from a theoretical perspective, there are some limitations related to the scope of the product. This study focused on one product that utilized captured CO_2, so it is recommended that future studies develop a conceptual model for multiple products. Moreover, this study focused on the value–proposition dimension of a business model. The value creation and value capturing of CCU, whether for a formic acid product or other products, are out of the scope of this study. These two dimensions of business models could be research focuses for future studies.

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