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Peer-to-peer consumption in 3d printing design

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ABSTRACT

PEER-TO-PEER CONSUMPTION IN 3D PRINTING DESIGN

by
Weizhi Chen

Three-dimensional printing or additive manufacturing is a new element in new product development that emphasizes on digitalization and innovation. However, due to its new emergence, existing research has rarely explored its mechanism and benefits especially in marketing, new product development and innovation. This research addresses the mechanism of 3D printing under collaborative consumption in the age of personal fabrication. The primary focus of this research lies at the intersection of marketing, 3D printing in collaborative consumption, and data science. Online peer-to-peer 3D printing sharing platform myminifactory.com is utilized as primary study context. In this research, two types of product design orientation, utilitarian design orientation and hedonic design orientation, and their respective effects in the 3D printing consumption process on online peer-to-peer sharing platforms are examined. Furthermore, this research examines two dimensions of relative product advantages, product commoditization and product innovativeness in 3D printing context.

Moreover, the level of complexity of 3D printing designs is introduced as a moderator in the model. The moderation effect of complexity in the relationship between product relative advantages and product consumption in 3D printing context further enlightens the mechanism of 3D printing in peer-to-peer sharing economy. Two types of data resources, secondary data and primary data, are collected for conducting the empirical study. For the empirical study, first, a secondary data of 420 projects from

myminifactory.com are utilized. This information of secondary data sources then is utilized to conduct primary data. For primary data, an online survey is adopted to investigate the effect of product orientation and product relative advantages on product consumption.

Furthermore, the moderation effect of complexity level is investigated. Although the findings suggest that the two different product orientations have opposite effects on product relative advantages, the results emphasize that the two different product orientations both positively relate to the two relative product advantages. In addition, findings suggest that the level of complexity moderates the relationship between product innovativeness and the number of downloads.

PEER-TO-PEER CONSUMPTION IN 3D PRINTING DESIGN

by
Weizhi Chen

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CHAPTER 1

INTRODUCTION

Three-dimensional printing has gained momentum in the recent few years. The use of 3D printing technology is seen as becoming a potential mainstream in manufacturing and bringing out more innovations. 3D printing, also known as additive manufacturing, has been defined as a "process of joining materials to make an object from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies" by the American Society for Testing Materials (ASTM, 2012; Yang et al., 2015). Based on its distinctive manufacturing mechanism of "adding layers and materials" rather than subtractive, 3D printing offers a more efficient way of utilizing raw materials and reducing wastes. That is one primary reason for 3D printing getting popularity in industrial additive manufacturing.

According to Wohlers 2018 Report (Wohlers, 2018), the projected global additive manufacturing market size is $20.5 billion U.S. dollars in 2018 comparing to that of $7.2 billion U.S. dollars in 2016. This sudden surge, however, not only comes from satisfactory performance in industrial additive manufacturing but also in the consumer market. The concept of personal fabrication, defined by Gershenfeld (2008) as "the ability to design and produce your own products, in your own home, with a machine that combines consumer electronics with industrial tool", has emerged in the last decade (Annett et al., 2019; Gershenfeld, 2008; Mota, 2011; Peeters, Kiratli, and Semeijn, 2019). 3D printing, eventually, is no longer solely for industrial use. Mota suggested that a digital fabrication tool becomes a personal fabrication tool at the moment an object is self-produced (Mota,

2011; Peeters, Kiratli, and Semeijn, 2019).With the development of digital fabrication services and personal fabrication, the use of personal 3D printers has increased. Those individuals who use digital fabrication and personal 3D printers often design, produce, and share their ideas through online communities and physical sphere (Peeters, Kiratli, and Semeijn, 2019). There are many online platforms and services allow individual users and small businesses share and produce ideas of 3D printing designs. For example, myminifactory.com is a social platform for 3D printable objects where it allows peer consumers to share 3D designs for personal use in order to print with personal and desktop 3D printers (myminifactory). According to myminifactory, the number of objects downloads as of January 2016 was 52,151, comparing to 458,268 which was the number of objects downloads as of December 2018, it is a skyrocketing increase (myminifactory). The momentum celebrates the successful integration between technology (e.g., 3D printing) and marketing (e.g., consumer market and social platform). Despite the extent amount of research in traditional additive manufacturing, little has been studied in the consumer market section with regards to 3D printing and sharing. Pacing with the rapid growth of technology, entrepreneurs and firms are seeking to exploit the Internet as a new sector to supply, satisfy, and engage consumers. Consumers, at the same time, are approaching new technologies via the Internet. At this stage of technological burst, 3D printing has fascinated a multitude of personal users for both innovative ideas and practical values. It is exigent for academia to examine this area of collaborative consumption.

Concerning the recent promising success, social platforms have played an essential role in the integration of technology and marketing. The advances in technology enabled a more realistic size for personal 3D printing machines; however, peer-to-peer sharing

platforms ensured the exchange among peers and individuals. On many peer-to-peer platforms, the activity of sharing arises. Instances of sharing activity in the new digital age include peer-to-peer file sharing (e.g., The Pirate Bay and BitTorrent), peer-to-peer financing or microfinancing (e.g., Kiva), and content sharing (e.g., YouTube) (Hamari et al., 2016). These sharing activities promoted transactions, generated content, and transferred information. At first glance, 3D printing appears to be dissonance. However, in the stage of personal fabrication, individual consumers possess the ability to acquire, exchange, and obtain innovative ideas, knowledge, intelligence, and products over the Internet. Personal 3D printers have enabled personal users to print and produce, sharing economy, on the other hand, has provided a mechanism for exchange.

Moreover, on peer-to-peer sharing and collaborative platforms, consumers often engage in the tasks of differentiating, evaluating, and eventually making decisions facing different choices. When individuals are making decisions, especially purchasing decisions, many different considerations and motivations will be evaluated. There is a stream of literature that tries to disentangle the consumer choice process by emphasizing on utilitarian and hedonic considerations (Dhar and Wertenbroch, 2000; Ham et al., 2019; Hirschman and Holbrook, 1982; Picot-Coupey, 2020; Ren and Nickerson, 2019; Sawhney and Eliashberg, 1996; Strahilevitz and Myers, 1998). Researchers find that utilitarian goods are function-driven while hedonic goods are driven by aesthetic signals (Hirschman and Holbrook, 1982; Strahilevitz and Myers, 1998). In parallel with utilitarian and hedonic values, product commoditization and product innovativeness contribute to customers' adoption and consumption of products. Literature defines that product commoditization is seen as adding exchangeable values to either a less or even undifferentiated product which

possesses sorely "use value" (Kopytoff, 1986; Kotler, 2002; Lotti, 2010). On the other hand, product innovativeness is often defined as newness (Cooper, 1979; Garcia and Calantone, 2002). Moreover, past literature suggests that innovativeness often gives a reflection of a product about its new and unique attributes comparing to other products (Wu et al., 2004). Considering commoditization and innovativeness are different dimensions of product relative advantages, one product can be rated in both dimensions regarding its intensity. Even though it appears that a product with high exchangeable value often is low in innovativeness, it is not definite as these two dimensions are not exclusive.

In summary, this research taps into the core area where the three fields of disciplines encounter: utilizing data science as a tool to solve marketing problems in the context of sharing economy. The focus of this research is illustrated in Figure 1.1. The ultimate objective of this research is to answer the question: How to promote the adoption of new technology (e.g., 3D printing) on social platforms in the consumer market.

This research contributes to the extant literature and managerial practice in several ways. First, this research distinguishes the sharing of digital 3D printing design files from both access-based consumption and ownership-based consumption. As previous literature only distinguishes access-based and ownership-based consumption, neither of these two is considered as proper in the new context of peer-to-peer 3D printing. This research defines peer-to-peer 3D printing design as a particular case. In addition, extant literature predominantly examines traditional additive manufacturing, and little has been done in the consumer market. This research explores the mechanism of 3D printing design on social platforms. Notably, this research tries to examine how 3D printing adapts peer-to-peer sharing economy and be applied to consumption. Furthermore, this research links product

orientation with product comparative advantages (product commoditization vs product innovativeness) to access the adoption of 3D printing. The overall research focus is illustrated in Figure 1.1.

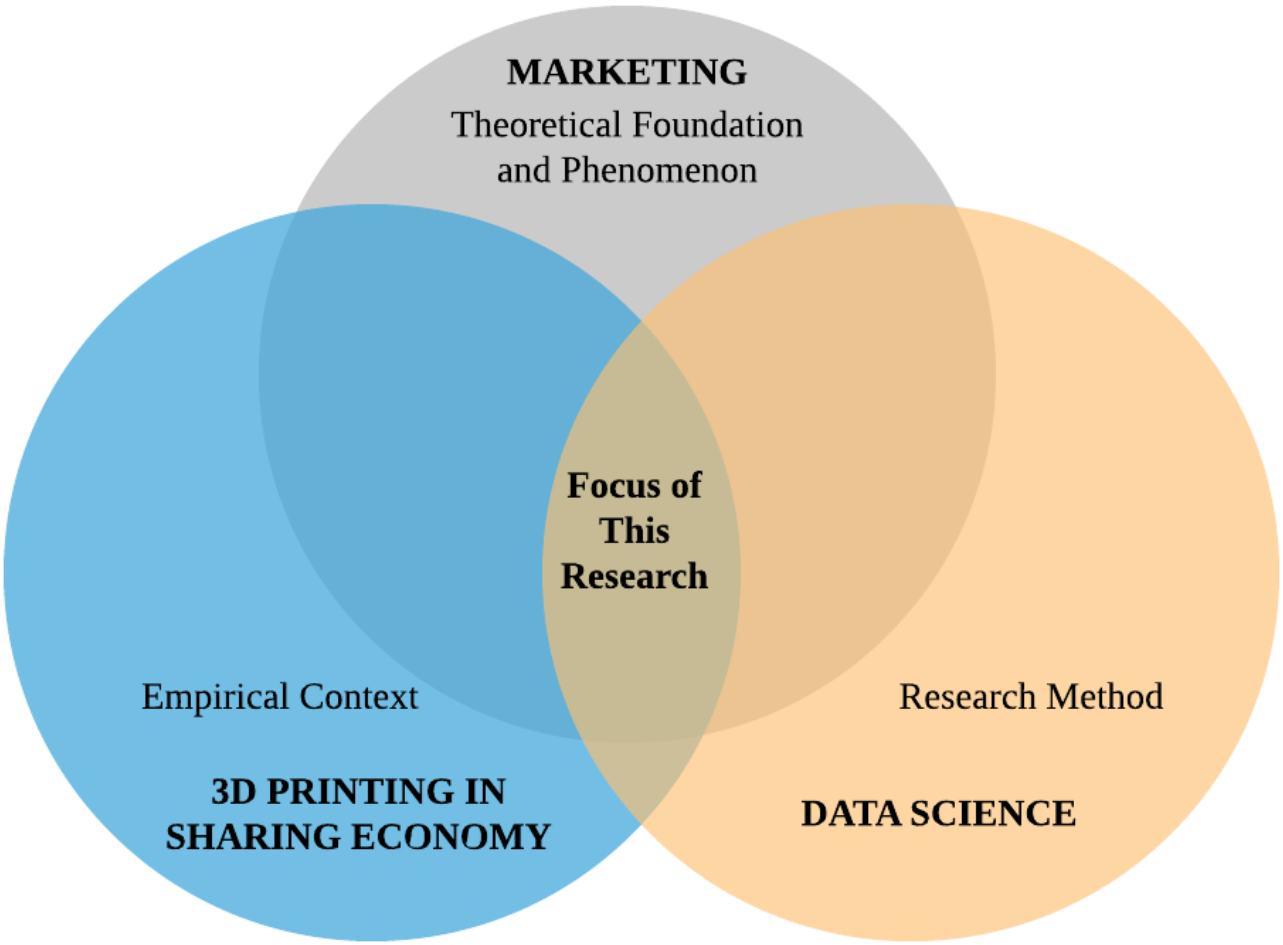


Figure 1.1 Focus of this research.

CHAPTER 2

RESEARCH BACKGROUND

2.1 Utilitarian/ Hedonic Goods and Values

On peer-to-peer sharing platforms, consumers face the tasks of differentiating, evaluating, and eventually making decisions facing different choices. Consumers choices, however, are often impelled by distinctive considerations: utilitarian and hedonic considerations. Past research has defined utilitarian goods as ones whose consumption is more cognitively and functional driven (Dhar and Wertenbroch, 2000; Strahilevitz and Myers, 1998). This definition implies that the consumption of utilitarian products is a relatively practical term. On the other hand, hedonic goods have been defined as those whose consumption is driven by aesthetic arousal, pleasure, joyfulness, fantasy, and fun (Hirschman and Holbrook, 1982). Therefore, even though utilitarian goods as well as values and hedonic goods as well as values are not mutually exclusive, these two distinct concepts still diverse in many different perspectives (Batra and Ahtola, 1990).

Within the context of marketing, classifying product orientations into utilitarian and hedonic categories has been a classic and popular stream that attracted and fascinated many scholars (Chitturi et al., 2008; Chitturi, 2015; Hirschman and Holbrook, 1982; Spangenberg et al., 1997). With regard to product characteristics, past research defines utilitarian goods as functional and objective. Thus, it is much easier for consumers to make comparisons as well as evaluations prior to purchase and consumption (Addis and Holbrook, 2001). In contrast, hedonic goods are considered as “experiential” products since consumers need consumption or experience first in order to actually evaluate among

alternatives (Eliashberg and Sawhney, 1994; Hirschman and Holbrook, 1982; Holbrook and Hirschman, 1982; Sawhney and Eliashberg, 1996). In addition, utilitarian goods possess a lower level of economic risks as consumers are able to make judgements on features, functions, quality, and values prior to purchase (Clement et al., 2006). On the other hand, due to the "experiential" nature of hedonic goods, consumers often encounter a comparably high level of risk as well as the uncertainty of quality, value, and features of hedonic goods before purchase.

In addition to product characteristics, scholars also have endorsed a "want/should" distinction between utilitarian goods and hedonic goods. Bazerman, Tenbrunsel, and Benzoni (1998) suggest that hedonic goods and utilitarian goods can be distinguished by international preferences: either affective preferences (e.g., wants) or cognitive/ reasoned preferences (e.g., shoulds) (Bazerman et al., 1998; Dhar and Wertenbroch, 2000). Therefore, when a particular good has more hedonic value, it is most likely to be subject to want preferences, and vice versa (Dhar and Wertenbroch, 2000). Even though utilitarian and hedonic goods or values are distinct concepts, they are not mutually exclusive of each other. Often, there is a need for trade-offs between utilitarian and hedonic values.

As there is no perfect product that rates high on both utilitarian and hedonic dimensions, differentiating on purchasing behavior, consumers often face the question: whether to choose a product providing more pleasant consumption or a product providing more functional priority. This dilemma also has forced both practitioners and scholars to look over communication and promotion styles with the differentiation on utilitarian and hedonic goods (Lavine and Snyder, 1996; Maclnnis and Bernard, 1989; Meyers-Levy et al., 1999; Shavitt, 1990). As mentioned earlier, hedonic goods have been defined as those

whose consumption is driven by aesthetic arousal, pleasure, joyfulness, fantasy, and fun (Hirschman and Holbrook, 1982). Hedonic purchases often involve the desire for pleasure. On the other hand, utilitarian purchases are motived by practical needs (Hirschman and Holbrook, 1982; Khan et al., 2005; Kivetz and Simonson, 2002). However, past literature has a debate on how to justify the different types of consumption. It is considered that utilitarian consumption is often easier to justify based on the necessary level of functionality (Chitturi et al., 2008; Okada, 2005). The extant literature has indicated that consumers have essential needs in justifying hedonic consumption (Okada, 2005; Sela et al., 2009). A stream of research argues that hedonic consumption is often harder to justify (Frankfurt, 1984; Khan and Dhar, 2006; Kivetz et al., 2017; Okada, 2005; Sela et al., 2009). As to solve the practical issue on justifying hedonic consumption, extant literature also has helped to explore consumers' mechanism on justifying hedonic consumption such as earning rewards, pleasure, and indulgence (Dhar and Simonson, 1999; Kivetz and Simonson, 2002; Strahilevitz and Myers, 1998). Examples of utilitarian and hedonic 3D printing are shown in Table 2.1.

Table 2.1 Examples of Utilitarian Values and Hedonic Values in Description

Product Value Orientation	Examples from Myminifactory.com
Utilitarian Orientation (emphasis on product functions and use value)	1. A replacement for your broken or lost Canon lens hood… The addition of a lens hood can help prevent flares--those circles of light that can accompany images where a strong light source is just outside the fame. (Canon EW-73B Lens Hood) 2. It is a joint modeling that can make a storage box using plywood. (Plywood Box Joint (3mm thick) 3. This three-part bicylce handle is articulated at two points to allow it to form to different frame angles. Designed for cyclindrical bike frames, it allows the carrying of your bike at a lower point while keeping your hands and fingers clear from the chain and drive. (Bike Frame Handle) 4. Replacement part for a GE Dryer Control Knob. Designed for GE Dryer Model #: GTP280ED2WW. The part number for the knob itself is a WE01X20374. OEM part kept breaking... This part is redesigned with a reinforced two-part design, but still has the shape of the OEM part. Stem and Knobs parts are a meant to be a snug fit without glue. If desired, you can glue the stem to the knob with a slight bit of Cyanoacrylate Glue. (GE Dryer Knob) 5. Useful to protect your crankarms from rocks and all other type of impacts. Based on your crankarms width, there are two different dimension 30 or 35 mm. Furthermore, for each dimension their is the open or the close model, if you want to get down your edals or not. (Crankarms Protections)
Hedonic Orientation (emphasis on enjoyment, joyfulness, aesthetic appeals, and uniqueness)	1. This super fun triangular mesh fabric is the result of a good bit of experimenting with different ways to print cloth-like materials. While it is not the most flexible result I came up with, it is probably my favorite so far, because it feels and looks so cool. (Triangle Mesh Fabric) 2. Winter is coming! …in the form of an ice-cold drink that you can now open with this handy-dandy bottle opener. Clip it into your keychain, put it on a necklace, dangle it off the pommel of your sword, and enjoy the power to slay the cap off of any bottle! 3. “Pokémon are stronger than humans, and they're warm-hearted too! I am researching ways to enhance Pokémon’s natural power in the pursuit of true strength. There's no doubt that the Pokémon out team have trained are the strongest in battle” This highly Detailed Team Instinct Pokémon Go pendant is a fantastic way to show your allegiance in this new instalment of the franchise. Easily printable and light weight it’s a great creation. (Pokémon Go: Team Valor Pendant) 4. Print this beautiful heart shaped ring for yourself or for a loved one. Cute and romantic (For that special one) 5. This triple heart motif represents The Synergy of Love. As you know, with Love the whole is undeniably more than the sum of the parts. This idea is represented symbolically in this Valentine's Day piece. It also illustrates when falling in love your heart grows. The triple heart is a symbol of family surrounded and anchored in Love. (Synergy of Love)

Extensive research has examined the mechanism of utilitarian and hedonic appeals in marketing aspects. From consumers' perspective, consumers shop for utilitarian and hedonic values (Babin et al., 1994; Batra and Ahtola, 1990; Bridges and Florsheim, 2008; Crowley et al., 1992; Dhar and Wertenbroch, 2000; Voss et al., 2003). Hirschman and Holbrook (1982) describe utilitarian shopping value as functioning as a work perspective (Hirschman and Holbrook, 1982). This work-style utilitarian shopping behavior often emphasizes on rationality and is task-related (Batra and Ahtola, 1990; Hirschman and Holbrook, 1982). Compared to utilitarian shopping value, hedonic is more personal and subjective and thus hedonic shopping behavior enlightens a state of fun and joyfulness (Hirschman and Holbrook, 1982). The difference of rationality-related nature and emotion-related nature has attracted a vast amount of literature in the past (Babin et al., 1994; Dhar and Wertenbroch, 2000; Drolet et al., 2007; Strahilevitz and Myers, 1998). Depending on the distinctive characteristics, the differentiated utilitarian and hedonic mechanism often has been utilized in advertising appeals (Johar and Sirgy, 1991). Johar and Sirgy have categorized advertising appeals into hedonic and utilitarian appeals and defined them accordingly. According to Johar and Sirgy (1991), hedonic or image appeals often emphasize on embracing personality, images, and lifestyles, and utilitarian or functional appeals address product quality and attributes (Johar and Sirgy, 1991). Past literature has examined these advertising appeals with different moderators. A stream of research primarily focuses on the integration between utilitarian (versus hedonic) appeals and products' characteristics or nature (Davis and Lennon, 1989). Chang (2006) however has integrated cultural masculinity and femininity with utilitarian (versus hedonic) advertising appeals and suggests that there is a strong case for arguing the different preferences of

utilitarian and hedonic appeals (Chang, 2006). Lepkowska-White and colleagues (2003) have investigated the integration of individualism (collectivism) and utilitarian (versus hedonic) advertising appeals (Lepkowska-White et al., 2003).

In recent years, new shopping channels (e.g., online shopping, online collaborative consumption, and social media), new shopping habits (e.g., online gaming), and new shopping categories (e.g., green shopping) are facing popularity. Researchers' efforts have been devoted to exploring these new areas and topics with different values and motivations. Li and colleagues have looked into online customer journeys with respects to utilitarian and hedonic purchases (Li et al., 2020). They found that hedonic purchases are more likely to be engaged in social media platforms than utilitarian purchases, and social media use is more effective for hedonic purchases. On the other hand, utilitarian purchases are more likely to be engaged in third-party review websites, search engines, and deal sites than hedonic purchases (Li et al., 2020). Similarly, Shang and colleagues have examined purchase intention during online shopping festivals with regards to utilitarian and hedonic product categories and values (Shang, Jin, and Qiu, 2020). The result revealed that people have higher purchase intention for utilitarian products than hedonic products when they are required to complete a purchase decision task during an online shopping festival.

They explained this result as that when people need to make a purchasing decision efficiently in a short amount of time with various product promotions and time restrictions (e.g., during online shopping festivals), people are more likely to choose a product which is easy to be justified (Shang, Jin, and Qiu, 2020). Therefore, under this circumstances, utilitarian orientation positively relates to purchase intention. As there are more and more peer-to-peer consumption or collaborative consumption activities in recent years, home-

sharing service has been a typical practice in market. Lu, Mody, and Andajigarmaroudi have studied hedonic and utilitarian motivations in home-sharing services (Lu, Mody, and Andajigarmaroudi, 2020). Their findings indicate that guests with hedonic motivation are more likely to switch out of a home-sharing platform when they experience service failure. This finding indicates that when guests seek hedonic benefits from home-sharing platform, they are less tolerant of service failure (Lu, Mody, and Andajigarmaroudi, 2020).

Likewise, So, Oh, and Min also studied home-sharing services by using Airbnb (So, Oh, and Min, 2018). The result of their empirical study indicates that both enjoyment (represent hedonic orientation) and home benefits (represents utilitarian orientation) significantly explained consumers' intentions to Airbnb choice (So, Oh, and Min, 2018). Similarly, Lee and Kim's study also indicates that both hedonic and utilitarian values significantly influenced customer satisfaction, whereas only hedonic value significantly influenced customer loyalty in the context of Airbnb (Lee and Kim, 2018). With regards to online gaming, Sharma and colleagues found that only hedonic value positively impacted continuance intention to play online games. However, at low perceived risk levels, both hedonic and utilitarian values had significant effect on continuance intentions to play online games (Sharma et al., 2020). When it comes to green-shopping, new literature also has been conducted in recent years. Mi and colleagues have investigated the effect of utilitarian values of reference group on low-carbon consumption intention and found that utilitarian influence of reference groups was the most important motivation for low-carbon consumption intention (Mi et al., 2019). Another research also investigated the two different shopping values and their effects on green consumption and found that hedonic shopping values (explained by self-gratification and pleasure) can enhance green attitudes

and behavior. On the other hand, utilitarian shopping values reduced individual's environmental involvement. A possible reason is that utilitarian shopping value draws consumers' focus to concrete benefits of the products and services (Cheng et al., 2020). Even though many literatures have shed lights on these comparably new areas, the links between utilitarian and hedonic orientations and consumption or adoption of online 3D printing designs still remain unknown.

2.2 Product Commoditization and Product Innovativeness

2.2.1 Product Commoditization

Since product life cycle takes the heat off the products at maturity stage, new product innovation has been glazing considerable attention among researchers (Cooper, 2000; Eiteneyer et al., 2019; Fu et al., 2008; Haus-Reve et al., 2019; Hauser et al., 2006; Min et al., 2006; Srinivasan et al., 2006). Unlike product innovation and product innovativeness which have gained a considerable volume of research, the term commoditization has not been extensively reviewed by academic researchers. In fact, the terms commoditization, commoditized products, and commodity have been either interchangeably utilized in past literature or have not been distinguished in an unambiguous way. According to Cohen (1988), "commoditization" represents a process by which activities and things are evaluated primarily in terms of their exchange value, in a context of trade (Cohen, 1988). As those things and activities are exchanged, they become goods and services and they are stated in terms of prices from a market (Cohen, 1988). With a broader range in terms of goods and services, Appadurai (1986) describes that things go through socially and culturally defined phases and among which is the commodity phase (Appadurai, 1988). Similar to Cohen's definition, Kopytoff (1986) emphasizes on the characteristics of an

object in the commodity phase is that the object is exchangeable for a wide array of other things (Kopytoff, 1986). In terms of commodity, it is defined as a standardized product that is interchangeable with other commodities belong to the same product category or of the same product type (Almklov and Antonsen, 2010).

Before the concept of the commodity is developed to the definition as Almklove and Antonsen described, it has gone through an evolution. According to Mount (1969), in the first stage of the evolution, the commodity was used to refer to either industrial good or consumer goods. In the second stage, commodity further developed to describe convenience and shopping goods. Later on, a commodity was used to refer to consumer goods with the assumption that the goods are in a homogeneous group and serve the same end use (Mount, 1969). Comparing the various concepts of commodity, it is noticeable that the distinguishing characteristics of a commodity are that those products offer the same functions or end-use comparing to other products in the same type and those similar functions enable the ability for them to be exchangeable.

According to Kotler (2002) and Turner (2006), commoditization is seen as symptomatic of mature marketplaces where the product offered is either less or even undifferentiated in the minds of consumers (Kotler, 2002). On the other hand, Lotti (2010) and Kopytoff (1986) view commoditization as a process in which it adds the exchange value to the objects that possess solely "use value" (Kopytoff, 1986; Lotti, 2010). As Kopytoff described, the commoditization process enables products to be more exchangeable whereas the opposite is singularization which enables products to be more unique and nonexchangeable.

In this research, the objects that are being transferred among users are digital designs of 3D printing products. Based on its concept and utilization, digital designs do not fall into the category of convenience goods, commodity goods, or shopping goods. However, the end product (printed product by using the digital design) sometimes can be convenience goods. Therefore, this research uses the term "commoditization" in neither a "marketplace" view nor a "process" view. In this research, product commoditization is used to refer to a state or the fact that the relative advantage of the specific product is the exchangeable use value that relies on its common functions and attributes. Recalling the definition of a commodity, it refers to convenience or shopping goods. As the end products of the 3D printing designs are not definite any of those, this research does not use the term "commodity", but product commoditization is used instead.

2.2.2 Product Innovativeness

Developing new products and serving them as new marketing offerings have been a vital task for companies as they must face the reality of the product life cycle. When the heat from current products begins to calm at the maturity stage, new products offering new values should take over. Along with the great attention among practitioners, new product innovation has been glazing considerable attention among researchers (Cooper, 2000; Eiteneyer et al., 2019; Fu et al., 2008; Haus-Reve et al., 2019; Hauser et al., 2006; Min et al., 2006; Srinivasan et al., 2006). As a result of the surfeit of studies and literature, the way that “innovation” and “innovativeness” defined has been ambiguous and has not reached to an agreement, even though the various definitions show coherent emblem (Garcia and Calantone, 2002; Prajogo and Sohal, 2001).

Given its denotation, “innovation” can be interpreted as objects that are essentially new for parties to adopt. Manual (2005) defines innovation as “the implementation of a new or significantly improved product (good or service) or process, a new marketing method, or a new organization in business practices, workplace, organization, or external relations” (Manual, 2005). Similarly, Damanpour (1991) summarizes innovation as the “adoption of an internally generated or purchased device, system, policy, program, process, product, or service that is new to the adopting organization” (Daft, 1982; Damanpour, 1991; Damanpour and Evan, 1984; Dewangan and Godse, 2014; Dziallas and Blind, 2019; Zaltman et al., 1973). Both definitions and summaries recognize different typologies of innovation (for example, product or process). Nevertheless, these definitions have the tendency to view innovation as a "static" concept that has neglected its potential to be evolving. In this manner, Garcia and Calantone summarize that the OECD study in 1991 best captures the innovation process as iterative progress which includes the first innovation and reintroduction of improved innovation (Garcia and Calantone, 2002; OECD, 1991). The nature of the iteration of innovation lies the foundation of other types or dimensions of innovation: incremental innovation and radical innovation.

As this research primarily focuses on digital design for 3D printing projects, product innovativeness plays as a prominent role. As on online platforms such as crowdfunding platforms and 3D printing design sharing platforms, peers share their works to peers, innovating within these collaborative systems is highly efficient (Baldwin and von Hippel, 2011; Claussen and Halbinger, 2020; Haefliger et al., 2008; Stanko, 2016). Product innovativeness, however, is a measure for innovation on the dimension of “newness”. It is interpreted that when a product is categorized as “highly innovative”, it

frequently implies that this product rates high on “newness”. Just like its measure, innovativeness is often defined as newness and is operationalized as newness as well (Cooper, 1979; Garcia and Calantone, 2002; Wibowo and Ahmad, 2020). In addition to its core of newness, other dimensions have been recognized by researchers. Wu and colleagues suggest that innovativeness often gives a reflection of a product about its new and unique attributes comparing to other products (Chiang et al., 2019; Wu et al., 2004). Following this stream of research, innovativeness reflects not only the newness of products but also the uniqueness of products. In Fu and colleagues' study about salesperson selling intention, the unique attributes of a new product often reflect a more enormous market potential (Fu et al., 2008). It can be interpreted that the unique attributes can attract more attention resembles continuous efforts. Another stream of literature emphasizes the customer meaningfulness beyond newness (de Brentani, 1989). The meaningfulness helps build stronger customer relationships.

Recalling that innovativeness is a measure for product newness, it is unclear about who considers what constitutes as new. Past literature suggests that an innovation can be new to the market, to the world, to the industry, to the unit, and to consumers (Atuahene-Gima, 1995; Chiang et al., 2019; Colarelli, 1998; Ettlie and Rubenstein, 1987; Garcia and Calantone, 2002; Kleinschmidt and Cooper, 1991; Meyers and Tucker, 1989; Wibowo and Ahmad, 2020). From the company's view, innovativeness can be distinguished by two dimensions: marketing discontinuity and technological discontinuity. From a consumer's perspective, innovativeness resembles consumer discontinuity which is efforts that are required for a consumer to adapt behavior patterns while adopting new products (Danneels and Kleinschmidt, 2001).

Businesses develop new products to remedy or replace old products in order to capture marketing opportunities and benefits. It is expected that the product innovativeness should have a significant and positive impact on financial performance. Nevertheless, past literature does not agree on the impact of innovativeness on financial performance. A stream of literature suggests that there is no direct effect of product innovativeness on financial performance (Calantone et al., 2006; Szymanski et al., 2007), however, Kleinschmidt and Cooper (1991) suggest a U-shape effect where high and low innovativeness are more likely to stimulate good financial performance (Kleinschmidt and Cooper, 1991). The online peer-to-peer platform adopted in this research is myminifactory.com where most of the projects adopt a donation support-based system. That said, most of the projects do hardly require money input in order to download the design file, the reflecting term does not necessarily relate to financial performance. Specifically, the terms "downloads" and "likes" are used as an indicator of consumption or adoption. Nevertheless, financial performance reflects sales in both price and volume (customer adoption or consumption). Therefore, past literature on the relationship between innovativeness and financial performance still gauge a certain tendency. As a result, we examine our conceptual research design in Figure 2.1.

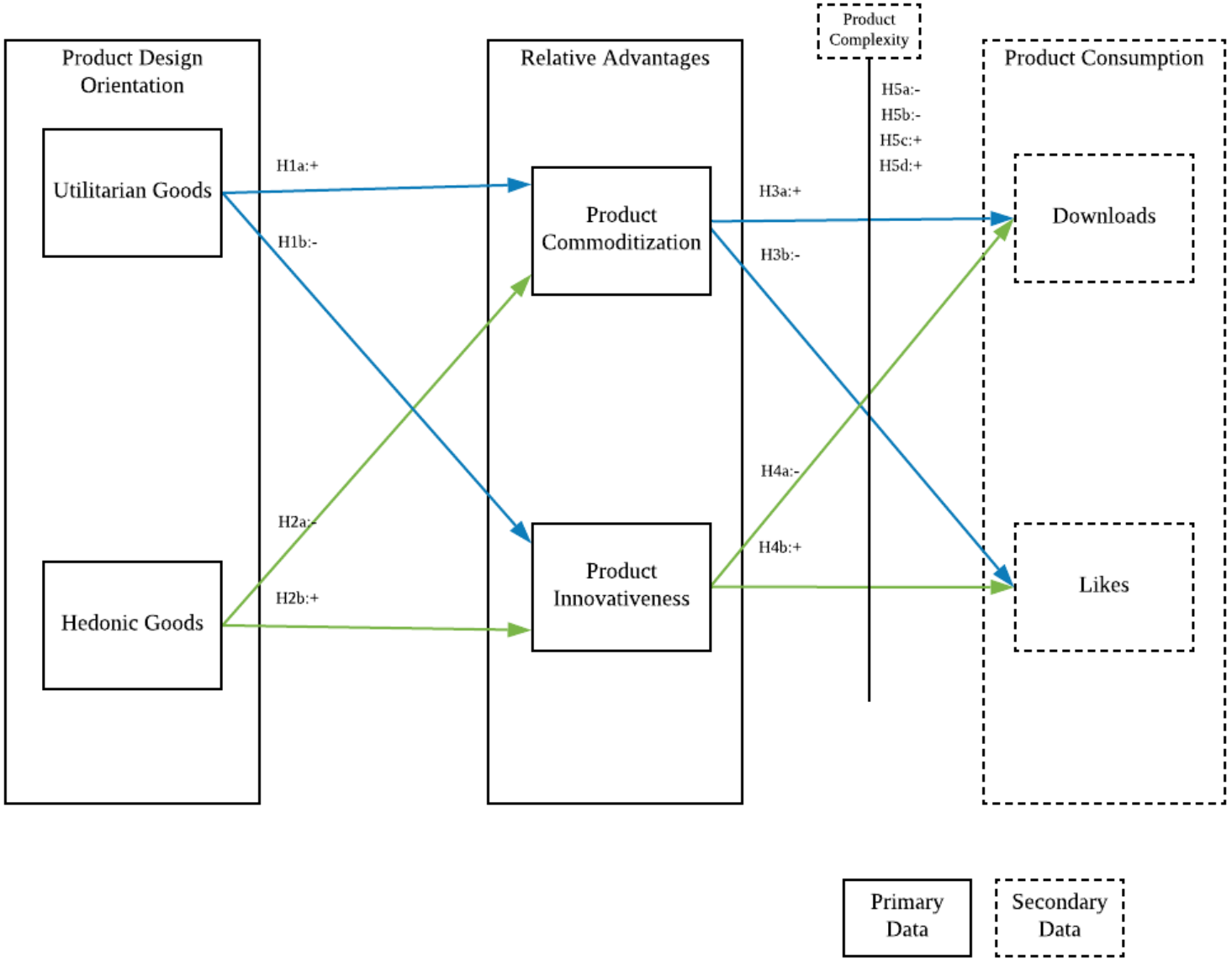


Figure 2.1 Overall conceptual model.

2.3 Additive Manufacturing and 3D Printing

Technological innovation stimulates efficiency, promotes sales, and affects business models and market structure (Geroski and Pomroy, 1990; Vickers, 1986). In the current age of digitalization, digitalized machines have been introduced into innovation and production (Aversa et al., 2020). 3D printing, also known as one process of additive manufacturing, has been considered as an emerging disruptive technological innovation (Hannibal and Knight, 2018; Lipson and Kurman, 2013; Rayna and Striukova, 2014). It is also referred to as rapid prototyping. According to Peltola and colleagues, rapid prototyping technology is used to refer to advanced manufacturing techniques based on an additive process that uses a layer-by-layer mechanism to construct complex structures (Hutmacher et al., 2004; Peltola et al., 2008). Regardless of the boost and rapidly-growing popularity of 3D printing in the Web 2.0 era, additive manufacturing has been in use for a few decades ever since the 1980s (Weller et al., 2015).

According to previous research, there are primarily three steps to perform addictive manufacturing work. First step is to develop a 3D solid model and transfer the model into compatible AM file; Second step focus on sending the model file to AM machine (e.g. 3D printer); last step involves using the machine to build layer by layer part (Huang et al., 2013; Kumar et al., 1997; Lipson, 2013). As the American Society for Testing Materials defined, additive manufacturing is a "process of joining materials to make an object from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies" (ASTM, 2012; Yang et al., 2015). Thanks to its distinctive "additive" mechanism rather than the "subtractive" mechanism, 3D printing offers plenty of advantages over traditional manufacturing methods. It allows a high degree of freedom in

design as it adds “additive layers” rather than cutting from raw materials. Also, its nature of transferring digital design directly to an actual product requires no production tools and thus enables high level of flexibility in manufacturing (Berman, 2012; Bourell et al., 2014; Campbell et al., 2003; Ford et al., 2015; Hopkinson et al., 2006; Lindemann et al., 2012; Petrick and Simpson, 2013; Yang et al., 2015).

To take advantage of additive manufacturing in both manufacturing perspective and design perspective, additive manufacturing has been utilized in many different industries and applications. In the development period of few decades, 3D printing technology has been used in industries such as medical, aerospace, automobile alongside the development of new technologies and applications (Chua and Leong, 2014; Gibson et al., 2010; Vaezi et al., 2013). Past research suggests that in the field of construction, work-related injuries are a potential threat to workers and the industry as a whole (Kittusamy and Buchholz, 2004). 3D printing, however, offers a new way for tracking and monitoring construction site to a safer workplace (Bryde et al., 2013; Tay et al., 2017). Past literature also suggests that 3D printing often assists in producing lightweight and complex geometries that reduce product life-cycle costs (Joshi and Sheikh, 2015; Petrovic et al., 2011; Reeves, 2012). In the aerospace industry, 3D printing has the potential to save costs, especially on fuel savings (Baumers et al., 2011; Campbell et al., 2011; Joshi and Sheikh, 2015).

In addition to the fields mentioned, 3D printing and additive manufacturing have been extensively used in the medical care and health section. Tack and colleagues have identified that surgical guide, the model for surgery planning, custom implant, and model for implant shaping as the most used applications by using 3D printing techniques (Tack et al., 2016). Past literature in medical context suggests that multiple advantages of using

additive manufacturing techniques or 3D printing technology over traditional alternatives such as time reduction, reduced operation time, reduced costs, increased accuracy, and improved medical outcome (Modabber et al., 2012; Shengwei et al., 2014; Tack et al., 2016; Wilde et al., 2014; Zhang et al., 2011). Recent literature has also addressed the new trends of utilizing 3D printing in medical perspectives including bones, dental care, and blood vessels (Fielding et al., 2012; Leukers et al., 2005; Miller et al., 2012).

In the sector of 3D printing in personal fabrication, 3D printing has gained great attention due to its ability to produce unique items based on personal needs and unmet needs (Ratto and Ree, 2012; Rindfleisch, O'Hern, and Sachdev, 2017). Contrary to its popular function, extensive research has been conducted in industries including medical, aerospace, and construction, there is limited number of research has been done on online peer-to-peer platforms. Existed literature primarily focuses on marketing perspectives such as customization, openness, and co-creation. The majority of current literature in 3D printing in collaborative consumption uses Thingiverse.com as studying context. Alcock and colleagues (2016) have analyzed the mechanism of Thingiverse (thingiverse.com) and identified barriers for customizing (Alcock et al., 2016). West and Kuk (2015) have identified the complementarity of openness and extended to business strategies in the case of online 3D printing communities (West and Kuk, 2016). Friesike and colleagues, on the other hand, have investigated the resembling function of remixing on thingiverse.com and examined the creativity and productivity of 3D printing on online peer-to-peer communities (Friesike et al., 2019; thingiverse.com). Another focused issue in recent literature involves the privacy and copyright issue with regards to peer-to-peer sharing in 3D printing. Moilanen and colleagues (2014) have identified legal issues in intelligence

property and defined different types of Thingiverse licenses and choices (Moilanen et al., 2014).

As a platform for peers and users to produce and exchange 3D printing design files, online 3D printing service websites utilize the benefis of Internet to interact with consumers. The increased participation of users is one of the benefits of the Internet. Berthon and colleagues suggest that the increased user participation has blurred the line between consumption and production activities (Berthon et al., 2008; Rayna, Striukova, and Darlington, 2015). As mentioned earlier, existing literature of 3D printing or additive manufacturing in marketing and product innovation sectors focused on co-creation aspects, this is due to the nature of high consumer participation and involvement of 3D printing service online platforms. Rayna, Striukova, and Darlington conducted a thorough research analyzing 22 different online 3D printing platforms. They have identified different types of purposes of these different online 3D printing platforms (e.g., design supply, co-design service, design crowdsourcing, design customization, print sales etc.). Overall, they have summarized these different purposes and functions into four broad categories: design marketplace, printing service, printing marketplace, and crowdsourcing platforms (Rayna, Striukova, and Darlington, 2015). Design marketplaces emphasize on activities that hosting and selling designs of 3D objects either from third-party or platform-owned. Cubify and Ponoko are two examples of platforms that belong to this category. A second category relates to providing 3D printing services. The main purpose of this category of platforms is to provide on-demand printing services. Platforms that provide printing services include 3DPrintUK, Thingiverse, and Makerbot. The third category of platforms serves as the intermediaries between individuals or firms. This category of platforms lists all the

information of printer, materials, prices and act as the intermediaries for payment. 3D Hub and Make XYZ are typical examples of platforms in this category. The final group which is crowdsourcing platforms operate as crowdsourcing service and enable users to post ideas at different stages of product development. Additer is a platform that provides crowdsourcing services. Even though there are four categories have been recognized, the platforms often engage in multiple services across different categories. Myminifactory, for example, serves as a design marketplace which hosts and sells different designs of 3D objects from different sources, but also provides print-on-demand services. Also, Rayna and colleagues discussed that firms or organizations engage in the design marketplace for spare-parts, adapters, as well as those objects using known brands or designs (pre-existed) (Rayna, Striukova, and Darlington, 2015). Under this circumstance, this type of co-creation may not reflect innovation. From an economic perspective, Petersen and colleagues suggest that DIY in-home 3D printing focusing on making games and toys can generate higher value items for less money (Petersen, Kidd, and Pearce, 2017). Zhao and colleagues, similarly, also introduced effective method to design personalized 3D printing roly-poly toys (Zhao et al., 2016). Perry also suggests that 3D printing is suitable for apparel and clothing (Perry, 2018). In fact, Perry suggests that 3D printed apparel has many advantages comparing to regular manufactured apparels. The advantages include the ability of customization for special needs, the ability to enter active-wear and help athletes to improve performance, the ability to meet disabled people's needs, the ability to have special patterns, fabrication, and geometric structures, and its sustainability (Perry, 2018). The benefits and advantages identified in Perry's work also confirms 3D printing's ability to produce unique items based on personal needs and unmet needs (Ratto and Ree, 2012;

Rindfleisch, O'Hern, and Sachdev, 2017). From existing literature, it shows that 3D printing can be utilized to produce a variety of products. It also indicates the big potential for 3D printing to be utilized in personal fabrication. These activities of sharing and consuming ideas and designs on platforms such as myminifactory.com and thingiverse.com in personal fabrication age are considered as peer-to-peer consumption.

2.4 Peer-to-Peer Consumption

As mentioned earlier, online collaborative platforms enable individuals' participation and innovation, this type of online collaborative platforms represent peer-to-peer sharing and peer-to-peer consumption. Sharing is an old phenomenon in mankind. Belk once proposed the definition of sharing as "the act and process of distributing what is ours to others for their use and/ or the act or process of receiving or taking something from others for our use" (Belk, 2007). During the last decade, however, after the new phenomenon of "peer-to-peer sharing" was introduced, the boundaries for sharing are no longer limited to intimacy level with regards to recipients. A large number of research has been dedicated to explore the mechanism of peer-to-peer sharing or peer-to-peer consumption in recent years (Cheng et al., 2018; Davidson et al., 2018; Dellaert, 2019; Hamari et al., 2016; Kumar et al., 2018; Martin, 2016; Zervas et al., 2017). Many scholars have dedicated their efforts to define peer-to-peer consumption (Bardhi and Eckhardt, 2012; Dellaert, 2019; Kumar et al., 2018; Ranchordás, 2015). According to Guimarães and colleagues, many terms have been used interchangeably or treated as synonyms with peer-to-peer sharing, such as "collaborative consumption", "collaborative economy", and "peer-to-peer consumption"

(Guimarães et al., 2018). Similarly, after peer-to-peer consumption phenomenon became popular in public, scholars also find that the terms such as "collaborative consumption", "peer to peer economy", together with "peer-to-peer consumption" are often among the most popular to illustrate a process of peer to peer sharing of the access of goods and services which emphasizes on access over ownership (Cheng, 2016; Hern, 2015; Schor and Fitzmaurice, 2015). Therefore, collaborative consumption and peer-to-peer consumption will be interchangeably used in the following manuscript.

In peer-to-peer consumption, the Internet and Web 2.0 have successfully served as efficient and decentralized intermediaries and platforms. Classical instances of peer-to-peer consumption in the new digital age include physical goods sharing using digital platforms (e.g., Zipcar), services sharing by using mobile apps (e.g., Uber and Lyft), peer-to-peer file sharing (e.g., The Pirate Bay and BitTorrent), peer-to-peer financing or microfinancing (e.g., Kiva), and content sharing (e.g., YouTube) (Hamari et al., 2016). All of the instances emerged from the interaction between sharing economy and technological development share similarities but also have blurred boundaries between each other. Yet due to their universal nature of "peer-to-peer-based activity of obtaining, giving, or sharing access to goods and services, coordinated through community-based online services", these instances have been further recognized as peer-to-peer sharing and collaborative consumption under peer-to-peer consumption (Chasin et al., 2017; Hamari et al., 2016).

However, debates over the concept of peer-to-peer consumption and collaborative consumption have never faded away for researchers. There has been a disagreement toward what qualifies a "peer". Comparing to the concept of peers of sharing which primarily emphasizes on the crowds that have higher level of intimacy such as family, kin, friends,

and neighbors, under peer-to-peer sharing or collaborative consumption on the other hand, peers often reflect public users on online communities and platforms, regardless of identification and intimacy level (Belk, 2009; Belk, 2014; Chasin et al., 2017; Hamari et al., 2016; Schor, 2016). For example, if one shares a video clip through BitTorrent, people who later receive or watch the video clip through protocol are considered as the recipient peers regardless of their identity. Nevertheless, Perren and Kozinets (2018) agree that "peers" should be better defined based on expertise (Perren and Kozinets, 2018). Their research emphasizes that on certain platforms "peers" should refer to participants and actors at equivalent levels in terms of expertise rather than amateurs against professionals, and vice versa (Perren and Kozinets, 2018).

The mainstream of peer-to-peer consumption research primarily restricts to "sharing of physical goods" scenario. For example, Botsman and Rogers (2010) utilized the case of "Zipcar" to examine the collaborative consumption of car sharing (Botsman and Rogers, 2010). Similarly, Bardhi and Eckhardt have tapped into access-based consumption by reviewing the car sharing industry (Bardhi and Eckhardt, 2012). Since 3D printing has only been introduced and applied to online peer-to-peer platforms in recent years, limited literature has been done in this regard. Current literature primarily focuses on the customization and co-creation perspectives of online peer-to-peer 3D printing sharing. Alcock and colleagues (2016) have analyzed the mechanism of the Thingiverse (thingiverse.com) and identified barriers for customizing (Alcock et al., 2016). West and Kuk (2015) have identified the complementarity of openness and extended to business strategies in the case of online 3D printing communities (West and Kuk, 2016). Friesike and colleagues (2019) on the other hand have examined the creativity and productivity of

3D printing on online peer-to-peer communities (Friesike et al., 2019). However, there is no enough previous literature has devoted to examining other mechanisms of 3D printing in the age of personal fabrication in the context of sharing economy.

This research is set to focus on the online peer-to-peer consumption platform with the sharing objects defined as digital 3D printing design files, no preliminary study has been evaluated and conducted in this context. Therefore, in contradistinction to prior streams and debates, this research distinguishes the sharing of digital 3D printing design files from both access-based consumption and ownership-based consumption.

CHAPTER 3

HYPOTHESIS DEVELOPMENT

When consumers face choosing products among a variety of alternatives, utilitarian features and hedonic attributes are often utilized to make judgements and evaluations. As utilitarian goods have been defined as cognitively and functional driven, they often offer customer values through quality, functions, features, and durability (Dhar and Wertenbroch, 2000; Strahilevitz and Myers, 1998). Thus, utilitarian goods will evoke utilitarian motivation when consumers are shopping. As defined, utilitarian motivation is rational, decision effective, and goal-oriented (Batra and Ahtola, 1991; Engel et al., 1993; Hirschman and Holbrook, 1982; To et al., 2007). Past research suggests that utilitarian motivation endorses shopping behavior starts from a mission, a task, and the acquired benefit depends on whether the mission is completed or not (Babin et al., 1994; Batra and Ahtola, 1991; Sherry et al.,1993; To et al., 2007). Therefore, utilitarian goods compete in functions, quality, practical characteristics, and uses to fulfill customer needs.

Furthermore, Lotti (2010) and Kopytoff (1986) view commoditization as a process in which it adds exchange value to the objects that possess solely "use value" (Kopytoff, 1986; Lotti, 2010). Therefore, the commoditization process enables products to be more exchangeable. The different but coherent definitions imply that product commoditization emphasizes on the relative advantage of functioning or similar use value of products. In another word, the concept of product commoditization is defined as the ability of a product to be evaluated by its core attributes that possessing exchange values. Therefore, when a

product offers more utilitarian values, its relative advantage most likely relies on product commoditization.

In contrast, past research suggests that innovativeness often gives a reflection of a product about its new and unique attributes comparing to other products (Wu et al., 2004). Instead of emphasizing on functions and use value, product innovativeness is often considered as unique and innovative characteristics of a product. These attributes, however, are often neglected while evaluating the utilitarian values of a particular product. As utilitarian products primarily emphasize on functions, it is often an advantage for utilitarian products to provide a considerably significant number of functions and features, a high level of compatibility, and universal value.

Products differ in their utilitarian and hedonic orientations, and their utilitarian and hedonic attributes are recognized first and then utilized by consumers to make judgements. In this information processing mechanism, consumers understand products, evaluate products, and then make comparisons between products. In the context of this research, consumers first look at different projects and designs. After realization of each project's orientation, major attributes and product advantages will be compared. As utilitarian goods are functional driven, they often offer customer values through quality, functions, features, and durability (Dhar and Wertenbroch, 2000; Strahilevitz and Myers, 1998). Product commoditization, in this way, represents the comparison by exchangeable values. As hedonic goods are driven by aesthetic arousal, pleasure, joyfulness, fantasy, and fun, they are often compared by its unique values (Hirschman and Holbrook, 1982). In the context of this research, projects emphasizing hedonic values will be compared by their innovative

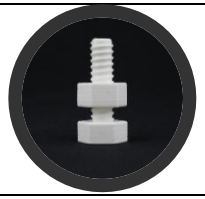
concepts. Therefore, after recognizing product orientations, the two product relative advantages, product commoditization and product innovativeness have been selected.

Therefore, from the point of product nature, a product that is valued as utilitarian product often does not possess the potential to be unique and new. On 3D printing sharing platform, the distinction is also employed. Examples of 3D printing examples on peer-to-peer sharing platforms is shown in Table 3.1. As a result, it is expected that:

H1a: Utilitarian product orientation is positively related to product commoditization.

H1b: Utilitarian product orientation is negatively related to product innovativeness.

Table 3.1 Examples of 3D Design Projects

Category	Title	Image	Perceived Orientation	Description
Office Products	Thor bookend		Hedonic + Utilitarian	Whilst waiting for the Avengers movie to come out this year, I decided to make this Thor / Avengers Bookend featuring the Mjolnir Hammer. The second book end of Captain Americas Shield can be found here, use them to hold up your books, comics or games! Now your books could be held up between the strongest things on Earth and Asgard!
	TOTORO Pen holder		Hedonic + Utilitarian	Totoro is the king of the forest, a mystical and inspiring character from Studio Ghibli's My Neighbor Totoro. This pen holder captures the heartwarming, curious and excitement of childhood. This desk buddy, if nothing else brightens your working day.
Jewelry	Cthulhu Ring		Primarily Hedonic	Cthulhu is a fictional cosmic entity created by writer H. P. Lovecraft and first introduced in the short story "The Call of Cthulhu", published in the American pulp magazine Weird Tales in 1928. Considered a Great Old Onewithin the pantheon of Lovecraftian cosmic entities, the creature has since been featured in numerous popular culture references. Lovecraft depicts Cthulhu as a gigantic entity worshiped by cultists. Cthulhu's anatomy is described as part octopus, part man, and part dragon. Its name was given to the Lovecraft-inspired universe where it and its fellow entities existed, the Cthulhu Mythos.
	The Witcher - Wolf Head Talisman		Primarily Hedonic	The famous talisman of witchers order representing a wolf head. The Witcher game is based on the book series of the same name by Polish author Andrzej Sapkowski. The Witcher takes place in a medieval fantasy world and follows the story of Geralt, one of a few remaining "witchers" – traveling monster hunters for hire, gifted with unnatural powers. The game's system of "moral choices" as part of the storyline was noted for its time-delayed consequences and lack of black-and-white morality.
Spare Parts	Canon EW-73B Lens Hood		Primarily Utilitarian	A replacement for your broken or lost Canon lens hood. Recommending using black or dark grey plastic to avoid color casts in your images. The addition of a lens hood can help prevent flares--those circles of light that can accompany images where a strong light source is just outside the fame. These type of lens flares occur when indirect light rays pass through the front lens elements but do not make it all the way through to the image sensor. Designed for 17-85mm f/4-5.6 IS EF-S and 18-135mm f/3.5-5.6 IS Lenses
	Screw		Primarily Utilitarian	A screw that prints entirely without support material. Use it as a template and integrate it in any of your designs making them movable. We provide here: STL, OBJ and STEP file formats. (IGS file provided on request lisa@myminifactory.com) Why not push your design skills to the limit, use this screw with your own artworks and enter the MyMiniFactory Support Free Christmas Competition.

Contrary to utilitarian goods, past research defines hedonic goods as driven by aesthetic arousal, pleasure, joyfulness, fantasy, and fun (Hirschman and Holbrook, 1982). Hedonic motivation starts from a need for happiness, fantasy, and enjoyment (Hirschman and Holbrook, 1982). The benefit of hedonic motivation is experiential and emotional. Therefore, hedonic goods compete in excitement, joyfulness, happiness, and uniqueness. Unlike utilitarian goods which require consumers to engage in rational considerations based on different attributes, functions, and uses, hedonic goods often engage consumers in sensational or emotional state. Consumers do not "consider" a product as a good product, instead, they "feel" a product as a fine product. Therefore, consumers want to feel the difference, the pleasure, and the joyfulness.

Product innovativeness, on the other hand, reflects not only the newness of products but also the uniqueness of products. In Fu and colleagues' study about salesperson selling intention, the unique attributes of a new product often reflect a more enormous market potential (Fu et al., 2008). Products that rate high on product innovativeness are often distinguishable from other products. When consumers are evaluation hedonic products, they tend to look for uniqueness and joyfulness rather than shared utilities and functions. In terms of product characteristics, product innovativeness resembles the unique and newness of a particular product rather than the usefulness and practicing uses. Instead of emphasizing on functions, features, and practicing uses, product innovativeness is often emphasized on the unique attributes and new concepts it offers.

Contrary to product innovativeness, product commoditization resembles and emphasizes on exchangeable values. Exchangeable values are those functions and uses that a product possess and comparable to other products belong to the same type. Therefore,

product commoditization offers the comparable advantages when comparing products possess similar end uses. However, hedonic goods compete in excitement, joyfulness, happiness, and uniqueness. A product rates high in hedonic orientation often do not possess relative advantage in exchangeable values. Instead, a product that is valued as hedonic product primarily competes in its emotional ties to consumers. As the commoditization process enables products to be more exchangeable, product commoditization emphasizes on the relative advantage of functioning or similar use value of products. As product commoditization addresses similar and comparable use value and function, it is difficult for consumers to perceive a state of joyfulness and excitement, as a result, it is expected that:

H2a: Hedonic product orientation is negatively related to product commoditization.

H2b: Hedonic product orientation is positively related to product innovativeness.

On online 3D printing design communities, such as minifactory.com, contributors upload their designed digital 3D printing model file most likely for no charge. People who are interested in the design can download the digital file in order to print by using the 3D printer or click "like" to express a state of liking. In terms of adoption, this research considers "download" as a signal or a pre-step for printing the actual product. Thus, a "download" primarily represents a state of consumption of the digital design document. Conversely, a "like" does not contribute to the consumption of the shared file, it only resembles a state of liking and enjoyment of the design. Thus, a "like" does not guarantee consumption. Instead, it is a signal of interest.

As mentioned earlier, the concepts of product commoditization vary but are coherent. As Kopytoff described the commoditization as the process that enables products

to be more exchangeable whereas the opposite is singularization which enables products to be more unique and nonexchangeable (Kopytoff, 1986). Others see commoditization either as a mature marketplace where the product offered is either less or even undifferentiated in the minds of consumers, or a process in which it adds exchange value to the objects that possess solely "use value" (Kopytoff, 1986; Kotler, 2002; Lotti, 2010). Combining the coherent definitions, product commoditization represents the relative advantages in uses and functions among less differentiated common, convenience, and shopping products. In terms of convenience and shopping products, consumers can have a probable gain (not distinguishing substantial gain or small gain) from making price and quality comparisons among alternatives (Holton, 1958). Thus, when a product emphasizes product commoditization, it is often a signal for being less differentiated convenience and shopping good. Therefore, real functions and use values come with the product. Comparing to a digital design file, the end products (printed objects) offer more realistic and using values.

Moreover, in the context of online peer-to-peer 3D printing projects, as product commoditization often addresses and emphasizes on the functionalities of end products rather than superior differentiated attributes, the projects that primarily rely on product commoditization often require common materials or less tangled product concepts. According to Lin and Chang (2011), technology readiness significantly affects consumers' perceived ease of use, perceived usefulness, and behavior to self-service technology (Fisk et al., 2011). In the context of this research, when the required materials are common, and complexity is not high, it is reasonable to expect consumers to feel more ready with regards to technology. Besides, consumers should perceive a comparably high level of ease of use.

Furthermore, from an economic perspective, when the required materials are common and less rare, the perceived value and usefulness increases. It indicates that the cost is not considerably high.

In contrast to consumption, “like” expresses a state of joyfulness, excitement, and interest. On myminifactory, a “like” differs from a “download”. A “like” indicates that the viewer has an interest in the particular design or the printed product concept, but it does not necessarily guarantee a “download” and a “print”. When a product distinguishes itself from other alternatives based on product commoditization, it signals less or undifferentiated designs but comparable functionalities. Therefore, it often requires rational comparison and evaluation rather than pure enjoyment. Since the benefits come from product commoditization are only in effect when designs are turned into actual products, there is no functional value prior to actual consumption. Thus, a sorely “like” does not offer a product value. Furthermore, product commoditization stands for a functional perspective of products, it does not base its advantages on aesthetic, innovative, or sentimental aspects. Therefore, product commoditization does not necessarily enlighten the state of enjoyment, interest, or joyfulness. As a result, it is expected that:

H3a: Product commoditization is positively related to the number of downloads.

H3b: Product commoditization is negatively related to the number of likes.

In contrast to product commoditization which emphasizes on use values and functionalities, Wu and colleagues suggest that product innovativeness often gives a reflection of a product about its new and unique attributes comparing to other products (Wu et al., 2004). Thus, product innovativeness represents the relative advantages in newness and uniqueness among different products. Often, contrary to product

commoditization, innovativeness is reflected from the design itself, the overall intangible concept, and bold invention of ideas rather than end product use value. Therefore, from a materialism and functionality view, the digital design possesses better potential and value rather than the end product.

Moreover, from a consumer's perspective, innovativeness resembles consumer discontinuity which is efforts that are required for consumer to adapt behavior patterns while adopting new products (Danneels and Kleinschmidt, 2001). Past literature suggests that there is consumer reluctance to adopt innovative products. Comparing to the benefits that can be offered to consumers, the novelty and unfamiliarity of new innovative products often lower consumer acceptance (McNally et al., 2010). With regards to the products that offer a high level of innovativeness and consumer discontinuity, consumers often need to change their consumption behavior and pattern to adopt the new products (Rogers, 2010). Thus, it requires extra efforts and time for consumers to actually adopt and consume products that rate high on product innovativeness.

Furthermore, in the context of online peer-to-peer 3D printing, an innovative design often captures rare elements and concepts. From an economic perspective, the required materials are less common and sometimes more expensive. Comparing to the functionalities of the end product, the cost often surprises its use value. It indicates that the cost is considerably high. With the high uncertainty comes from unfamiliarity, it is not beneficial to actually consume the product. Kleinschmidt and Cooper (1991) suggest that highly innovative products are less familiar to consumers which implies more risk, greater possibility of things go wrong, a less likelihood to be adopted by consumers, and a greater likelihood of financial failure (Kleinschmidt and Cooper, 1991).

On the other hand, when the digital design rates high on product innovativeness, it often attracts more attention, possesses high level of differentiation, has higher likelihood to be considered as aesthetic favorable, and embraces enjoyment and excitement. Comparing to actually consume the product, there is no financial risks to enjoy an innovative design. As a result, it is expected that:

H4a: Product innovativeness is negatively related to the number of downloads.

H4b: Product innovativeness is positively related to the number of likes.

In the context of digital design of 3D printing projects, a product complexity takes considerations of the processing of layers of materials. As mentioned earlier, product commoditization often addresses and emphasizes on the functionalities of end products rather than superior differentiated attributes, the projects often require common raw materials and less complex design. According to past literature, the difficulty of technology often affects consumers' perceived ease of use and perceived usefulness (Fisk et al., 2011). When the project complexity is not high, consumers have the tendency to feel the functionalities possess higher level of usefulness comparing to material input (that said, comparison between the ease of use and perceived usefulness). Under this circumstance, the ease of use represents the effort cost, whereas the perceived usefulness represents benefits or returns. However, when the project complexity is high, the difficulty level for consumption tends to be higher accordingly. Under this circumstance, consumers have the tendency to feel the functionalities possess lower level of usefulness comparing to material input (that said, comparison between the ease of use and perceived usefulness). In this regard, the effort cost surprises the benefits or returns. Therefore, when product complexity is considerably high, the perceived value of functionalities decreases.

According to past literature, the complexity of the rhetorical figure correlates with the appreciation (McQuarrie and Mick, 1992). In the context of digital design, the product complexity is labeled on project website and can also be perceived by the description and illustration of the product design. According to relevance theory, message receivers are inclined to expect that the more messages processing, the more effect they will gain. Thus, consumers are more presumably willing to expend more cognitive effort to gain more effect, in the sense of more information, but also in the sense of more pleasure (Forceville, 2009; Sperber and Wilson, 1995; Tanaka, 1992; Van Mulken et al., 2010). However, when the product is too complex, on online peer-to-peer 3D printing platforms, the associated product description has a tendency to be more complex accordingly. According to Jones and colleagues (2004), information overload describes a state of an individual in which not all information and communication can be processed and leading to breakdown (Jones et al., 2004; Rogers and Agarwala-Rogers, 1975). In this perspective, when the product complexity is high, the description and illustration of the design also indicates the level of complexity. When consumers face with complex product commoditization, it is more likely for consumers to have more difficulties in processing and understanding the features and use values. When it comes to complexity specifically for 3D printing design, not many literatures have clearly defined the definition of complexity in 3D-printing industry (Baumann, 2017; Rodriguez-Toro et al., 2003). Most often, previous publications endowed the definition of complexity in an intuitive understanding way (Baumann, 2017). According to literature, the complexity can be evaluated by many different metrics and subjective matters including computational complexity, algorithm content, required time for manufacturing, requirement on hardware, required materials, object shape, and object

size (Baumann, 2017; Gell-Mann, 1995; Lipson, 2011). In another word, the complexity can be summarized as the technical difficulty of a 3D-printing design project to be turned into a physical item. Therefore, in this study, the complexity is measured by how difficult it is to turn a 3D printing design into a physical form of item. As a result, it is expected that:

H5a: Complexity moderates the relationship between product commoditization and the number of downloads. The positive relationship between product commoditization and the number of downloads is stronger when complexity is lower.

H5b: Complexity moderates the relationship between product commoditization and the number of likes. The negative relationship between product commoditization and the number of likes is stronger when complexity is lower.

As mentioned earlier, product innovativeness addresses and emphasizes on the uniqueness and newness of differentiated. In the context of online peer-to-peer 3D printing, the digital designs often express unique patterns, new aesthetic invention, and bold ideas or concepts. Due to its nature of strong expressing power, the project designs often embrace differences and strong visual impact, thus, they often require uncommon or rare raw materials. When the product complexity is high, together with the special needs for materials, it creates high difficulties to turn the design ideas and concepts into actual consumption goods. As mentioned earlier, an innovative design often captures rare elements and concepts. This is especially true when the product complexity is also high. From the economic perspective, when complexity also increases, the required materials are more expensive. Therefore, the cost surprises its use value. It indicates that the cost is considerably high.

Furthermore, as high uncertainty comes from unfamiliarity, when the product complexity is also high, the uncertainty risk increases the potential cost to consume the product. Kleinschmidt and Cooper (1991) suggest that highly innovative products are less

familiar to consumers which implies more risk, greater possibility of things go wrong, a less likelihood to be adopted by consumers, and a greater likelihood of financial failure (Kleinschmidt and Cooper, 1991). When it is innovative products which possess high product innovativeness, and when the product complexity is high as well, consumers have greater resistance to consumption and higher risks for financial failure.

As mentioned earlier, the complexity of messages correlates with appreciation (McQuarrie and Mick, 1992). Consumers are more presumably willing to expend more cognitive effort to gain more effect, in the sense of more information, but also in the sense of more pleasure (Forceville, 2009; Sperber and Wilson, 1995; Tanaka, 1992; Van Mulken et al., 2010). In the case of product innovativeness, products will be perceived as more innovative if they rate high on uniqueness and newness. With regards to digital design, a product is perceived more innovative when it is more complex. Thus, when the product complexity is high, the description and illustration of the design also indicates the level of complexity. When consumers face with complex product innovativeness, it is more likely for consumers to have higher level of expectation and appreciation. As a result, it is expected that:

H5c: Complexity moderates the relationship between product innovativeness and the number of downloads. The negative relationship between product innovativeness and the number of downloads is stronger when complexity is higher.

H5d: Complexity moderates the relationship between product innovativeness and the number of likes. The positive relationship between product innovativeness and the number of likes is stronger when complexity is higher.

CHAPTER 4

RESEARCH METHOD

4.1 Overall Research Design

In order to better access the nature of 3D-printing designs online, different steps have been implemented for data collection and empirical testing. Figure 4.1 illustrates all the steps in research design. First of all, a preliminary study including an online questionnaire with 90 participants was implemented to test the measurements of scale items which were later utilized for pretest and conceptual model testing. For preliminary study, a two-step data collection method was implemented. A secondary data including information of 150 projects on myminifactory.com was first collected. Then a survey was launched on Amazon Mechanical Turk. Second, a pretest was conducted prior to conceptual model testing, which included online questionnaires with 58 projects and 98 participants. The main purpose of the pretest was to test consumers' perceptions about the categories of design on myminifactory.com with regards to utilitarian values and hedonic values as well as to test consumers' perceptions about the category "Jewelry" and category "Spare-parts" to check if these two categories resembled hedonic and utilitarian values, respectively. For conceptual model testing, a secondary data collection from myminifactory.com was first conducted for further utilization and testing after primary data collection. In this step, all relative information of each project such as project photos, project title, the number of downloads, the number of likes, project created date and time, project parts, project part versions, material, and complexity were collected. The complexity level is listed by project uploaders which represents the technical difficulty to turn a 3D designed digital file

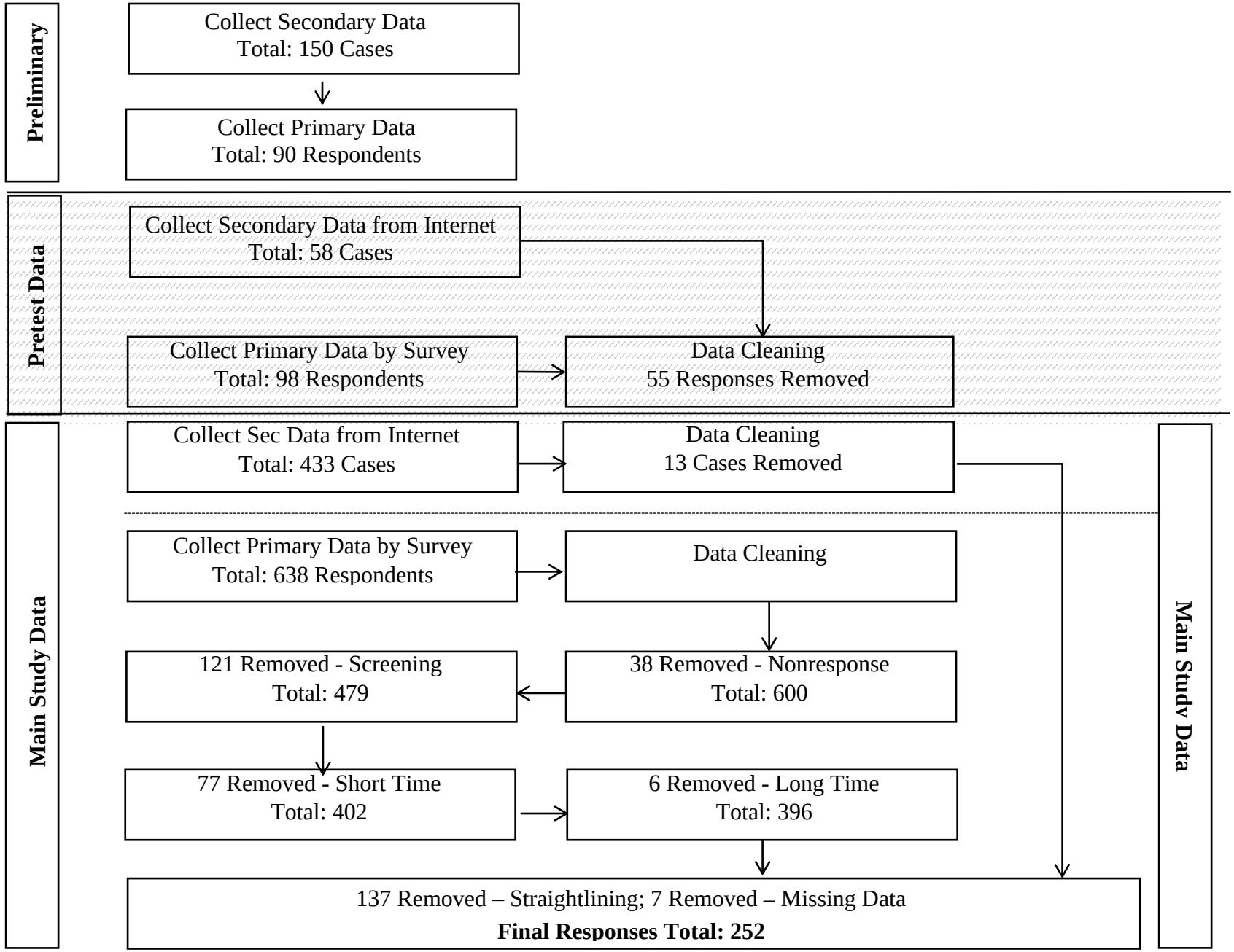


Figure 4.1 Research design steps.

into an actual object. In this way, the complexity takes how expensive the materials are, how comprehensive the concept of the design is, how hard it is to assemble, and how many pieces to assemble into consideration. After secondary data collection, an online survey was designed and conducted for primary data collection. The survey was distributed to 638 participants on Amazon Mechanical Turk. Each participant was displayed the title of project and the photos of the project. All other information about the projects were masked and not shown to participants to avoid information bias. Based on the project title and project photos, the participants were then asked questions to access their perceptions and understandings of the projects.

For preliminary study, pretest, and conceptual model testing, myminifactory.com was selected as secondary data source. As one of the fastest growing industry, there are some popular online 3D printing service websites as potential options. According to 3dprinting.com, Thingiverse, Pinshape, Cults3D, and myminifactory are the most popular online 3D printing service websites among all alternatives (3dprinting.com). Thingiverse.com has been a popular online 3D printing website for its innovative function of remix. A number of listed 3D printing design projects are remixed from other projects. This function, however, is problematic for this research as it is hard to identify and determine the originality. The majority of the projects on cults3d.com requires monetary contribution for peers to download. As this research was designed to study peer-to-peer consumption, only those projects with free download were considered. Moreover, the information about projects listed on pinshape.com only contains the number of likes, collects, views, comments, and design files. More information needed for analysis. On myminifactory.com, the majority of the projects are original (not remixed), free to

download, and with sufficient numbers of additional information listed. Therefore, myminifactory.com was selected as the context and data source for this research.

For the conceptual model testing, a total of 420 projects were used. To ensure an effective size of the sample, Cohen's d and effective size F were both tested. As Cohen's d = 1.58 and overall F = 1.03, it indicates a large effective size.

4.2 Preliminary Study

Prior to pretest and conceptual model testing, a preliminary study was first conducted, which included online questionnaires with 90 participants. The main purpose of this preliminary study is to test the measurements of different scale items. Modify the measurements of different scale items for pretest and conceptual model testing if needed.

The preliminary study was conducted in a two-step method. First of all, secondary data were collected from myminifactory.com. A total number of 150 projects were collected with 30 Spare-parts, 30 Jewelry, and 90 Home-office. The second step involved online survey on Amazon Mechanical Turk. A total of 90 participants were recruited with each answered few questions for randomly five projects. Each project was rated by 3 individual raters.

The measurement of scale items was first used in this preliminary. A minor modification for the measurements of pretest and main study had been implemented. The minor-modifications included the change of wording and grammar.

4.3 Pretest

4.3.1 Objectives

Prior to conceptual model testing, a pretest was conducted, which included online questionnaires with 58 cases and 98 participants. The main purpose of this quantitative data collection and testing are to:

a. Test consumers' perceptions about the categories of designs on myminifactory.com with regards to utilitarian values and hedonic values. As this research studies the different design orientations (utilitarian vs hedonic) and their effects on comparative advantages, it is crucial to confirm if there is a category effect. That is, if different categories have potential implication of specific design orientation.

b. Test consumers' perceptions about the category "Jewelry" and category "Spare-parts" to check if these two categories resemble hedonic and utilitarian values, respectively. In order to get an entire picture of different categories' roles, it is essential to investigate a comparably neutral category. Therefore, in addition to product orientation inclined categories, another category of designs that is mostly orientation-neutral has also been utilized to test perceived product orientation, which was "Office Product" category.

4.3.2 Sampling Procedure and Technique of Pretest

The pretest utilized Amazon Mechanical Turk for primary data collection. Amazon Mechanical Turk is known as a crowdsourcing website for both individuals and businesses to distribute as well as complete tasks. One of the many practical advantages of Amazon Mechanical Turk is the availability of prescreening for task requesters by defining "qualifications" prior to task distribution. This function has enabled requesters to set up constrains on who can see and complete specific tasks (Paolacci, Chandler, and Ipeirotis, 2010). The pretest is set to get an overall sense of the ecosystem of 3D-printing creatives sharing on online platforms (e.g., myminifactory.com). Therefore, for pretest, a convenience sampling method with qualifications has been utilized. All workers on

Amazon Mechanical Turk with the qualifications were selected based on their availability and willingness to participate.

The pretest study aims to get an overall image of how viewers of online 3D-printing designs interpret the orientations and product advantages of the designs with relation to the category. Therefore, prior to survey design, information of various 3D printing designs was needed in order to be rated by participants.

For pretest, 3D printing designs from three focal categories-- Spare-parts, Jewelry, and Home Office were randomly selected from myminifactory.com. In each of the categories, all projects can be sorted in many different methods on myminifactory.com, including sort by popularity, by date published, by views, and by magic. The default sorting method is by magic. To simulate a real-time web browsing experience, "sort by magic" method has been implemented. Another reason that "sort by magic" method has been chosen is that it displays the projects that were bubbling at the time when browsing. In total, 13 Spare-parts projects, 15 Jewelry projects, and 30 Home Office projects were tested.

According to statistics from myminifactory.com, there were more Home category projects than Spare-parts and Jewelry projects combined (myminifactory.com). Therefore, more Home Office projects have been selected and tested.

In the survey of pretest, a total of 98 participants were reached to answer the survey. After deleting unqualified responses (e.g., non-response, straightlining, speed-up through questions...), a total number of 43 responses were left for further data analysis. Each participant was randomly shown the photos of five different projects with project titles. The information of the projects such as the number of downloads and likes have been erased to minimize bias. Moreover, the participants were not shown any information

revealing projects' categories. After the photos and titles, series of questions addressing perceived utilitarian orientation, hedonic orientation, product commoditization, and product innovativeness were displayed. Each project was rated by three independent raters. The details of the survey questions in pretest are shown in Table 4.1.

Table 4.1 Scale Items of Pretest

Construct	Scale Item
Utilitarian Orientation (7-point scale; 1 = strongly disagree; 7 = strongly agree) (Adopted from Spangenberg et al., 1997.)	Please rate your agreement with the following statements about utilities. This product design is: 1.functional 2. practical 3. problem-solving 4. useful 5. beneficial 6. helpful
Hedonic Orientation (7-point scale; 1 = strongly disagree; 7 = strongly agree) (Adopted from Spangenberg et al., 1997.)	Please rate your agreement with the following statements about enjoyment. This product design is: 1. aesthetic 2. enjoyable 3. playful 4. fun 5. delightful
Product Commoditization (7-point scale; 1 = strongly disagree; 7 = strongly agree)	Please rate your agreement with the following statements about how this product can be possibly replaced by other products (i.e., how common this product is). 1. This product's functions are similar to its alternatives' functions. 2. It's easy to find substitutes for this product. 3. This product is similar to other products in the same category. 4. This product can be easily replaced by other products in the same category. 5. It is not costly to switch to another similar product.
Product Innovativeness (7-point scale; 1 = strongly disagree; 7 = strongly agree) (Adopted from Moorman, 1995)	Please rate your agreement with the following states about innovativeness. This product design is: 1. innovative 2. novel 3. unique 4. creative 5. interesting

4.3.3 Results of Pretest

The responses were collected within a one-week window. The descriptive statistics showed that there seemed to be differences between different categories in terms of utilitarian orientation and hedonic orientation as the means of utilitarian orientation and hedonic orientation differed vastly across different categories (Table 4.2). For utilitarian orientation, Spare-parts had much higher mean than that of Jewelry ($Mean_{spare\text{-}parts} = 5.92$, $Mean_{jewelry} = 3.68$). While for hedonic orientation, Jewelry had much higher mean than that of Spare-parts ($Mean_{jewelry} = 5.29$; $Mean_{spare\text{-}parts} = 3.43$).Therefore, it is crucial to test if these differences are significant. Thus, a One-Way ANOVA with Tukey test has been performed to study whether or not the selected categories can be representative of different orientations (Table 4.3). The results showed that the ratings of utilitarian orientation and hedonic orientation were significantly different between Spare-parts and Jewelry. For utilitarian orientation, Spare-parts had much higher mean than that of Jewelry (mean difference = |2.24|, $F = 14.38$, $p < .01$). While for hedonic orientation, Jewelry had much higher mean than that of Spare-parts (mean difference = |-1.86|, $F = 7.22$, $p < .01$). The mean of Home Office, on the other hand, was closer to Spare-parts when it was mostly rated on utilitarian orientation, whereas, it was closer to Jewelry when mostly rated on hedonic orientation. The results indicated that when rating utilitarian orientation, the means of Spare-parts and Jewelry were significantly different. The mean of Home Office was closer to the mean of Spare-parts and was significantly different from the mean of Jewelry. On the other hand, when rating hedonic orientation, the means of Spare-parts and Jewelry were significantly different. The mean of Home Office was closer to the mean of Jewelry and was significantly different from the mean of Spare-parts. This result implies that the

category of Spare-parts and Jewelry are significantly different in product orientation that the category of Spare-parts is more utilitarian-oriented while the category of Jewelry is more hedonic-oriented. The category of Home-office represents a mixed or neutral category which contains projects with different purposes and orientations. However, the result implies that when it is rated by utilitarian orientation, Home Office is still significantly different from the category of Jewelry. On the other hand, when it is rated by hedonic orientation, Home Office is significantly different from the category of Spare-parts.

Table 4.2 Descriptive Analysis Results of Pretest

Variables	Spare-parts		Jewelry		Home Office		Total	
	N	Mean	N	Mean	N	Mean	N	Mean
Utilitarian Orientation	13	5.92	15	3.68	30	5.19	58	4.96
Hedonic Orientation	13	3.43	15	5.29	30	4.53	58	4.48
Product Commoditization	13	5.05	15	4.72	30	5.24	58	5.06
Product Innovativeness	13	3.83	15	5.08	30	4.51	58	4.50

Table 4.3 Results of One-Way ANOVA Tukey Test for Pretest

Tukey HSD							
DV	**(I) S_or_J**	**(J) S_or_J**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**	
						Lower Bound	**Upper Bound**
Utilitarian Orientation	0	1	2.24*	.44	.00	1.19	3.29
		2	.73	.38	.15	-.20	1.65
	1	0	-2.24*	.44	.00	-3.29	-1.19
		2	-1.51*	.36	.00	-2.39	-.64
	2	0	-.73	.38	.15	-1.65	.20
		1	1.51*	.36	.00	.64	2.39
Hedonic Orientation	0	1	-1.86*	.49	.00	-3.05	-.68
		2	-1.11*	.43	.03	-2.14	-.07
	1	0	1.86*	.49	.00	.68	3.05
		2	.76	.41	.16	-.23	1.75
	2	0	1.11*	.43	.03	.07	2.14
		1	-.76	.41	.16	-1.75	.23

Note: 0 = Spare-parts; 1= Jewelry; 2 = Home Office.
The mean difference is significant at the 0.05 level. *

CHAPTER 5

CONCEPTUAL MODEL TESTING

In order to study the conceptual model, one empirical study with two stages of data collection has been implemented to test hypotheses. A secondary data collection from the Internet was conducted first for further utilization and testing. In stage one, secondary data have been collected from myminifactory.com. The purpose of stage one data collection is to collect the most relevant data and obtain a better understanding of the mechanism of myminifactory.com. In stage two, primary data collection was implemented. At this stage, a survey was distributed to 638 participants on Amazon Mechanical Turk. The survey has been designed over the Internet on Qualtrics.com. There are many survey collection methods in marketing and academic practices including in-person interviews, telephone interviews, mailed questionnaires, and online questionnaires. In this research, online questionnaire was selected due to its convenience, low cost, quick response time, and most importantly the ability to reach out to a great number of potential participants. The overall proposed conceptual model is displayed in Figure 2.1.

5.1 Stage One Data collection: Secondary Data from myminifactory.com

To test the proposed conceptual model, two-stage data collections were implemented on myminifactory.com and Amazon Mechanical Turk, respectively. For a representative secondary dataset, the first stage data collection included all available projects that were created and published in 2019 on myminifactory.com in the three pre-determined categories: Spare-parts, Jewelry, and Home Office. At this stage, as much information as

possible related to projects have been extracted and recorded. The information related to projects including: title, photos, number of photos, project creator, number of project creator's followers, number of project creator's previous objects, number of views, number of downloads, number of likes, number of comments, project description, if there is video, material, technical complexity, created date, material quantity, material quantity, object parts, part versions, tags text, and number of tags. The dataset only contains those projects are free to download. The ones that needed monetary supports were excluded from the data collection as they were not technically addressing the sharing mechanism which was the context of this study. Therefore, there were 433 projects (before cleaning) available in total. The secondary dataset contains previous information of these 433 projects. In order to proceed to next stage in data collection, the photo(s) and title of each project has been extracted by screenshot. All other information, such as description, the number of downloads, and the number of likes has been erased from the screenshot to minimize bias when these screenshots are used in the survey. To ensure the consistency of the dataset (for example, ten cases were collected few weeks later than the others may result in inconsistency of time and higher number of downloads sorely due to the extra length of time), all project information were collected within a two-day window.

In order to analyze with better quality and accuracy, projects that meet certain criteria have been deleted from the secondary dataset.

1. First of all, when a specific project had missing values on essential items, such as number of downloads (missing value, not 0) and number of likes (missing value, not 0), it was deleted. In the data cleaning process, there were 12 projects that were missing the number of downloads; thus, 12 cases were removed from the sample.

2. When there were misallocated designs which means the designs that have been misallocated to each of the categories, the projects were deleted. For example, if the design of a character miniature falls into the category of "Spare-parts" by

mistake, this project would be removed. There was one project that encountered this error, thus has been removed from the dataset.

Therefore, in total, there were 433 cases with 13 of those removed. In the final dataset, there were 420 cases available for further analysis.

At this stage, the objective of data collection is to obtain a better understanding of the mechanism of myminifactory.com. Therefore, descriptive analysis was performed (Table 5.1). Three categories together, the average number of downloads was 74.06 with standard deviation equals to 146.63. The average number of likes was 15.65 with standard deviation equals to 43.08. However, to better access the utilitarian and hedonic values of projects, examples of project descriptions using either hedonic or utilitarian signals were summarized in Table 2.1.

Table 5.1 Descriptive Analysis Results of Secondary Data

Descriptive Statistics	N	Mean	Std. Deviation
Complexity(1-5)	420	2.03	0.51
Downloads	420	74.06	146.63
Likes	420	15.65	43.08
Object_Parts	420	2.02	2.88
Part_versions	420	1.1	0.64

5.2 Stage Two Data collection: Primary Data from Amazon Mechanical Turk

Due to the advantages of online questionnaire that it is convenient, at low cost, has quick response time, and most importantly it enables researchers to reach out to a great number of potential participants, this research was designed to implement online questionnaire for

primary data collection. It is mentioned earlier that Amazon Mechanical Turk is known as a crowdsourcing website for both individuals and businesses to distribute as well as complete tasks. Many previous and recent literature in top-ranked journals utilized Amazon Mechanical Turk as the source to recruit independent raters (Chan and Parhankangas, 2017; Leung, Kim, and Tse, 2020; Melumad and Meyer, 2020; Rocklage and Fazio, 2020) and experiment participants (Liu and Ansari, 2020). Therefore, this methodology is a common practice for researchers to conduct. One of the many practical advantages of Amazon Mechanical Turk is the availability of prescreening for task requesters by defining "qualifications" prior to task distribution. This function has enabled requesters to set up constrains on who can see and complete specific tasks (Paolacci, Chandler, and Ipeirotis, 2010). As previously the pretest utilized the Amazon Mechanical Turk channel to reach out to potential participants, and there were overlapped questions in both pretest data collection and primary data collection, I have defined a qualification type that the respondents who have previously participated in pretest were excluded from the main study. According to statistics from myminifactory.com, the most active countries by downloads during Q1 2019 was the United States with a popularity of 25.9%, far beyond Germany's 7.2% which was the second most popular country (myminifactory, 2019). Since the users mostly come from the United States, to match the targeting demographics, the main study restrains the qualification type of respondent' location to be from the United States. Moreover, qualification type "HIT Approval Rate greater than 75%" has also been enabled. The maximum for the approval rate on Amazon Mechanical Turk is 99%. However, this number was not selected because most of these participants were too adapted to answer online questionnaire that they were almost elites in answering questionnaires. This crowd

of participants usually has techniques in answering and completing online surveys. This is not the appropriate demographic for this research. Approval rate with greater than 75% is moderately sufficient and is able to avoid the "elite" problem. Therefore, for primary data collection, a convenience sampling method with qualifications has been utilized. All workers on Amazon Mechanical Turk with the qualifications were selected based on their availability and willingness to participate.

An online survey was implemented to collect data. A total number of 252 responses have been utilized. The 252 participants were recruited from Amazon Mechanical Turk. The 252 participants have an average age of 36.68, with 151 males, 98 females, and one other gender. The majority of these participants have bachelor's degree and an income level of $45,000 - $59,999. The statistics of the demographics of the participants were shown in Table 5.2. In the survey, each participant was randomly shown the photos and titles of five projects from previous secondary data collection. For each project, only the design photos and project titles were displayed to participants. All other related information has been erased to minimize bias. Furthermore, the participants cannot see which category the project belongs to. After the screenshot of each project was shown, the participant was asked to answer series of questions to access participants' understandings and perceptions of the project. At the end of the survey, participants were asked demographic questions such as age, income, and education. Each project was rated by three independent raters.

Table 5.2 Descriptive Analysis of Participants' Demographics

Descriptive Statistics	N	Mean	Std. Deviation
Age	252	36.68	11.88
Descriptive Statistics	N		Frequency
Education	252		
Less than a high school diploma			0
High school degree or equivalent			67
Bachelor's degree			133
Master's degree			39
Doctorate degree			6
Other			7
Gender	252		
Male			151
Female			98
Other			1
Income	252		
< $15,000			26
$ 15,000 - $29,999			45
$ 30,000 - $44,999			49
$ 45,000 - $59,999			57
$ 60,000 - $74,999			35
$ 75,000 - $89,999			22
$ 90,000 and above			18

In the survey, the focal construct questions included utilitarian orientation, hedonic orientation, product commoditization, and product innovativeness. Each of the focal construct has several scale items and participants were asked to rate their agreement on each of the scale item (7-point scale: 1 = strongly disagree; 7 = strongly agree). There were seven focal variables including downloads, likes, utilitarian orientation, hedonic orientation, product commoditization, product innovativeness, and complexity. And there were five control variables in total including category, date, material, object parts, and part versions. As these variables were collected by different methods (secondary data and primary data), both secondary and coded variables were included. Table 5.3 displays details of examined constructs and the nature of the examined constructs.

Table 5.3 Examined Constructs

Variables	Nature of Variables	Measurement
Focal Variables		
Downloads	Secondary	The number of downloads of the project at the time of data collection.
Likes	Secondary	The number of likes of the project at the time of data collection.
Utilitarian Orientation	Coded	Independent raters were asked series of questions to rate project utilitarian orientations. Inter-rater reliability = .77.
Hedonic Orientation	Coded	Independent raters were asked series of questions to rate project hedonic orientations. Inter-rater reliability = .77.
Product Commoditization	Coded	Independent raters were asked series of questions to rate project commoditization. Inter-rater reliability = .31.
Product Innovativeness	Coded	Independent raters were asked series of questions to rate project innovativeness. Inter-rater reliability = .57.
Complexity	Secondary	The project complexity in terms of printing technique and difficulty. Very Easy = 1; Easy = 2; Medium = 3; Hard = 4; Very Hard = 5.
Control Variables		
Category	Secondary	Two dummy variables were created for three categories: Spare-parts, Jewelry, and Home Office.
Date	Secondary	The date when the project was published and available on myminifactory.com.
Material	Secondary	Two dummy variables were created for three categories: PLA, PETG, and Others.
Object Parts	Secondary	The number of parts designed and needed for the specific project.
Part Versions	Secondary	The number of different variations and choices of the project that the project creator uploaded.

5.2.1 Utilitarian Orientation

The scale items of utilitarian orientation were adapted from Spangenberg and colleagues (Spangenberg et al., 1997). The scale items have been modified to apply to the new context of 3D-printing designs. After adaption and justifications, respondents were asked to rate their agreement on whether the project design is 1) functional; 2) practical; 3) problem-solving; 4) useful; 5) beneficial; 6) helpful.

5.2.2 Hedonic Orientation

The scale items of hedonic orientation were adapted from Spangenberg and colleagues (Spangenberg et al., 1997). The scale items have been modified to apply to the new context of 3D-printing designs. After adaption and justifications, respondents were asked to rate their agreement on whether the project design is 1) aesthetic; 2) enjoyable; 3) playful; 4) fun; 5) delightful.

5.2.3 Product Commoditization

There are few academic papers tried to explain and investigate on commodity products. However, this research aims to refer commoditization to a result of the process of commoditizing. Therefore, commoditization is viewed as a specific feature or ability of a product to be considered as a commodity. In another word, in this research, commoditization is a feature that determines if a product can be easily compared to, replaced by, or switched to another product. Due to this originality, this construct is not adapted from other previous literature. Instead, I justified different concepts related to commoditization and created the scale items for product commoditization. Respondents have been asked to rate their agreement on the following statements 1) This product's functions are similar to its alternatives' functions; 2) It's easy to find substitutes for this

product; 3) This product is similar to other products in the same category; 4) This product can be easily replaced by other products in the same category; 5) It is not costly to switch to another similar product.

5.2.4 Product Innovativeness

The scale items of product innovativeness were adapted from Moorman (Moorman, 1995). The scale items have been modified to apply to the new context of 3D-printing designs. After adaption and justifications, respondents were asked to rate their agreement on whether the project design is 1) innovative; 2) novel; 3) unique; 4) creative; 5) interesting.

In the pretest, One-Way ANOVA with Tukey test was performed to study whether or not the selected categories can be representative of different orientations (Table 4.3). The results indicated that when rating utilitarian orientation, the means of Spare-parts and Jewelry were significantly different. The mean of Home Office was closer to the mean of Spare-parts and was significantly different from the mean of Jewelry. On the other hand, when rating hedonic orientation, the means of Spare-parts and Jewelry were significantly different. The mean of Home Office was closer to the mean of Jewelry and was significantly different from the mean of Spare-parts. In order to confirm the mechanism of the three selected categories, Spare-parts, Jewelry, and Home Office, a One-Way ANOVA with Tukey test was also performed in the main study (Table 5.4). The result of One-Way ANOVA with Tukey test of main study confirmed and agreed with the result of pretest.

Table 5.4 Results of One-Way ANOVA Tukey Test for Main Study

Tukey HSD							
DV	**(I) S_or_J**	**(J) S_or_J**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**	
						Lower Bound	**Upper Bound**
Utilitarian Orientation	0	1	1.79*	.12	.00	1.52	2.07
		2	-.01	.12	.99	-.28	.27
	1	0	-1.79*	.12	.00	-2.07	-1.52
		2	-1.80*	.14	.00	-2.13	-1.47
	2	0	.01	.12	.99	-.27	.28
		1	1.80*	.14	.00	1.47	2.13
Hedonic Orientation	0	1	-.68*	.15	.00	-1.03	-.33
		2	-.44*	.15	.10	-.79	-.09
	1	0	.68*	.15	.00	.33	1.03
		2	.24	.18	.38	-.19	.66
	2	0	.44*	.15	.10	.09	.79
		1	.24	.18	.38	-.66	.19

0 = Spare-parts; 1= Jewelry; 2 = Home Office.
The mean difference is significant at the 0.05 level. *

The result showed that the ratings of utilitarian orientation and hedonic orientation were significantly different between Spare-parts and Jewelry. For utilitarian orientation, Spare-parts had much higher mean than that of Jewelry (mean difference = |1.80|, F = 126.75, $p < .01$). While for hedonic orientation, Jewelry had much higher mean than that of Spare-parts (mean difference = |-.68|, F = 11.82, $p < .01$). The mean of Home Office, on the other hand, was closer to Spare-parts when it was mostly rated on utilitarian orientation, whereas, it was closer to Jewelry when mostly rated on hedonic orientation. The results between pretest and main study were consistent.

5.2.5 Complexity and Control Variables

5.2.5.1 Complexity. On myminifactory.com, in the technical information section of each of the project, complexity is listed as one important feature of the project design. The complexity was rated from very easy, easy, medium, hard, to very hard. Very easy represents the lowest level of difficulty to turn the project design into an actual object whereas very hard represents the highest level of difficulty to implement the project design. Not many literatures have clearly defined the definition of complexity in 3D-printing industry (Baumann, 2017; Rodriguez-Toro et al., 2003). Most often, previous publications endowed the definition of complexity in an intuitive understanding way (Baumann, 2017). According to literature, the complexity can be evaluated by many different metrics and subjective matters including computational complexity, algorithm content, required time for manufacturing, requirement on hardware, required materials, object shape, and object size (Baumann, 2017; Gell-Mann, 1995; Lipson, 2011). In another word, the complexity can be summarized as the technical difficulty of a 3D-printing design project to be turned into a physical item. According to Allen and colleagues, technical complexity was defined

as the perceived degree of complexity due to technical nature of the design (Allen, Chandrasekaran, and Basuroy, 2018). Also, Radjou and Prabhu once discussed that the more complex the design, the costlier it is to build (Allen, Chandrasekaran, and Basuroy, 2018; Radjou and Prabhu, 2015). Therefore, in this study, the complexity is also measured by the way myminifactory.com does. The complexity ranges from 1 = very easy, 2 = easy, 3 = medium, 4 = hard, to 5 = very hard. The more the complexity is, the more difficult and costlier for individuals to print out the physical item through 3D printing. The descriptive analysis in Table 5.1 shows that on average the projects have a complexity level of easy (Mean = 2.03; SD = 0.51).

5.2.5.2 Control Variable: Category and Material. As mentioned earlier, the secondary data were collected from three categories on myminifactory.com including Spare-parts, Jewelry, and Home Office. On myminifactory.com, under technical information, project creators usually list the materials that are needed for printing the items. Therefore, the material information has been recorded. Three categories of material have been coded with PLA, PETG, and others.

5.2.5.3 Control Variable: Date. As mentioned earlier, all projects that published within the year of 2019 have been collected and recorded. The specific date has also been recorded for further analysis.

5.2.5.4 Control Variable: Object Parts and Part Versions. On myminifactory.com, project creators upload 3D designs of items for others to download, share, or even monetary support. Most often, the printed objects require different pieces or functional parts to be assembled. In this case, project creators upload the 3D designs of different parts that are needed. Thus, the number of the functional parts that are needed is

represented by “Object Parts”. According to Table 5.1, the number of Object Parts ranges from one to 46 with an average number of 2.02 (Mean = 2.02; SD = 2.88). In addition to the fundamental object parts, project creators sometimes offer different options and variations to the functional parts. For example, a necklace can have different variations including the pendant with one heart, the pendant with double hearts, or the pendant with a round-shaped tree. In this circumstance, the project creator has offered three different versions. In this way, the variable Part-versions records how many different variations of the design have been provided by the project creator. According to Table 5.1, the number of Parts_versions ranges from one to nine with an average number of 1.1 (Mean = 1.1; SD = 0.64).

5.2.6 Data Cleaning

To optimize the quality of responses, a rigorous data cleaning procedure was implemented. First of all, there were total 638 participants reached to answer the survey. Each of the participants answered questions of five randomly selected projects. In return, each participant received $1 dollar for completing the survey. However, if a participant did not complete the survey, no payment would be in effect. Even though there were 638 participants opened the survey, only 600 of those have completed the questionnaire and received the payment. Among the 600 participants, many had disqualified answers and their responses had been removed from the sample.

1. There were screening questions across the survey. For each of the project, one screening question was asked twice. If the answers of the screening question were different, then this participant’s response was disqualified and was removed from sample. By using this criteria, 121 responses were removed.

2. When a specific respondent speeded through the survey, then this response was determined to be removed from the sample. After many times of previews, the average time spent on the survey is around seven minutes. Also, the average

time of all respondents completing the survey was 6.56 minutes. With a standard deviation of the length of completing the survey of 0.82 minutes, responses with less than three minutes were outliers. Therefore, if a respondent answered the survey in less than 2.5 minutes, it is a sign that the respondent was not paying enough attention to the survey, therefore the response is disqualified and is removed from the sample. By using this criteria, 77 responses were removed from the sample.

3. When a specific respondent finished the survey in a considerably long time, then this response was determined to be removed from the sample. After many times of previews, the average time spent on the survey is around seven minutes. Also, the average time of all respondents completing the survey was 6.56 minutes. With a standard deviation of the length of completing the survey of 0.82 minutes, responses with over 30 minutes were outliers. If a respondent finished the survey in more than 30 minutes, it is a sign that the respondent is not paying enough attention to the survey, therefore the response is disqualified and is removed from the sample. By using this criteria, six responses were removed from the sample.

4. Respondents who were "straightliners" had been removed from sample. In the survey, many respondents engaged in "straightlining" behavior. The "straightlining" has many different patterns. First of all, for each project, there were 32 individual seven-point questions for respondents to answer. Therefore, when a respondent gave six identical ratings in a row, it was viewed as "straightlining" behavior. Secondly, when a same pattern of answers appeared three times in a row, it was viewed as "straightlining" behavior. By using this criteria, 137 responses were removed from the sample.

After data cleaning, there were 259 responses left for analysis. However, 96% of the sample only had three independent raters' ratings. 4% of the sample were rated by four independent raters. Another seven responses were removed to avoid the missing value problem for the majority projects.

5.2.7 Combined Dataset

The dataset of main study consists of both secondary dataset and primary dataset. Table 5.3 shows examined constructs from both dataset and how they were measured. The focal variables including downloads, likes, and complexity obtained from secondary dataset. On the other hand, utilitarian orientation, hedonic orientation, product commoditization, and

product innovativeness obtained from primary dataset. In addition to focal variables, there were another five control variables obtained from secondary dataset. Therefore, the dataset for main study integrates the two-dataset obtained from secondary data collection and primary data collection.

5.2.8 Measurement Model, Convergent Validity, and Discriminant Validity

In order to assess if constructs were adapted and measured appropriately, SPSS AMOS was utilized to conduct confirmatory factor analysis (Albright and Park, 2009). According to Table 5.5 of measure, confirmatory factor analysis and convergent validity, the Cronbach's alpha of utilitarian orientation, hedonic orientation, product commoditization, and product innovativeness respectively were .98, .97, .92, and .95. As all of the four indices exceeded .90, it indicated that the scale items of each measure fit with each other. Fit indices for measurement model were : $\chi 2 = 671.80$, d.f. = 183, $p < .01$; Tucker-Lewis Index TLI = .95; Comparative Fit Index CFI = .95; Incremental Fit Index IFI = .95; Standardized Root Mean Square Residual SRMR = .06; Root Mean Square Error of Approximation RMSEA = .08. According to Hu and Bentler (Hu and Bentler, 1999), SRMR of this model is considered to be low, and RMSEA is at the cut-off point. Also, all Average Variance Extracted (AVE) exceeded .50 ($AVE_{UO} = .87$; $AVE_{HO} = .85$; $AVE_{PC} = .69$; $AVE_{PI} = .79$). These are evidence show that the model has satisfactory reliability and convergent validity of each construct (Fornell and Larcker, 1981). Moreover, according to Table 5.5, the square root of the AVEs were greater than the correlation coefficients between the paired items. This circumstance indicates satisfactory discriminant validity (Fornell and Larcker, 1981).

Table 5.5 Measure, Confirmatory Factor Analysis and Convergent Validity

Fit indices for measurement model: $\chi 2 = 671.79$, d.f. = 183, $p < .01$; TLI = .95; CFI = .95; IFI = .95; SRMR = .06; RMSEA = .08

Construct	Scale Item	SFL	α	CR	AVE
Downloads	The number of downloads of the project at the time of data collection.	n/a	n/a	n/a	n/a
Likes	The number of likes of the project at the time of data collection.	n/a	n/a	n/a	n/a
Utilitarian Orientation	Please rate your agreement with the following statements about utilities.		.98	.98	.87
(7-point scale;	This product design is:				
1 = strongly disagree;	1. functional	.91			
7 = strongly agree)	2. practical	.92			
	3. problem-solving	.93			
	4. useful	.95			
(Adopted from Spangenberg	5. beneficial	.93			
et al., 1997.)	6. helpful	.96			
Hedonic Orientation	Please rate your agreement with the following statements about enjoyment.		.97	.97	.85
(7-point scale;	This product design is:				
1 = strongly disagree;	1. aesthetic	.86			
7 = strongly agree)	2. enjoyable	.92			
	3. playful	.93			
(Adopted from Spangenberg	4. fun	.95			
et al., 1997.)	5. delightful	.94			
Product Commoditization	Please rate your agreement with the following statements about how this product can be possibly replaced by other products (i.e.,		.92	.93	.69
(7-point scale;	how common this product is).				
1 = strongly disagree;	1. This product's functions are similar to its alternatives' functions.	.78			
7 = strongly agree)	2. It's easy to find substitutes for this product.	.88			
	3. This product is similar to other products in the same category.	.83			
	4. This product can be easily replaced by other products in the same category.	.92			
	5. It is not costly to switch to another similar product.	.74			
Product Innovativeness	Please rate your agreement with the following states about innovativeness.		.95	.95	.79
(7-point scale;	This product design is:				
1 = strongly disagree;	1. innovative	.86			
7 = strongly agree)	2. novel	.87			
	3. unique	.90			
(Adopted from Moorman,	4. creative	.91			
1995)	5. interesting	.90			
Complexity	The project complexity in terms of printing technique and difficulty. Very Easy = 1; Easy = 2; Medium = 3; Hard = 4; Very Hard = 5.	n/a	n/a	n/a	n/a
Control Variables					
Category	Two dummy variables were created for three categories: Spare-parts, Jewelry, and Home Office.	n/a	n/a	n/a	n/a
Date	The date when the project was published and available on myminifactory.com.	n/a	n/a	n/a	n/a
Material	Two dummy variables were created for three categories: PLA, PETG, and Others.	n/a	n/a	n/a	n/a
Object Parts	The number of parts designed and needed for the specific project.	n/a	n/a	n/a	n/a
Part Versions	The number of different variations and choices of the project that the project creator uploaded.	n/a	n/a	n/a	n/a

5.2.9 Common Method Bias

In this research, two techniques have been employed to test and address the issue of common method bias. First of all, Harman's single-factor method was used to test the multi-item constucts including utilitarian orientation, hedonic orientation, product commoditization, and product innovativeness. All scale items have been loaded to one single factor. The single factor model showed the following model fit: $\chi 2 = 614.01$, d.f. = 189, $p < .01$; Tucker-Lewis Index TLI = .34; Comparative Fit Index CFI = .41; Incremental Fit Index IFI = .41; Root Mean Square Error of Approximation RMSEA = .28. Compared with the CFA result of measurement result, the single factor model however had a much worse fit, this indicates that the model does not suffer from common method bias. Second, exploratory factor analysis on the multi-item constucts including utilitarian orientation, hedonic orientation, product commoditization, and product innovativeness has been implemented. The three components loaded 8.72, 5.10, and 3.23, respectively. A total of 82% variances explained by the constructs, the first factor explained 41% of the variance, no dominant effect was assumed as the first factor explained no more than 50% of the variances explained by the constructs (Tehseen, Ramayah, and Sajilan, 2017; Podsakoff et al., 2003; Podsakoff and William, 1985). This is not a sign of common method bias. Therefore, it can be concluded that the common method bias was not a concern of the model in this empirical study.

It was mentioned earlier that the exploratory factor analysis on the multi-item constucts including utilitarian orientation, hedonic orientation, product commoditization, and product innovativeness was implemented. There were only three components emerged. This result does not agree with the model design including four multi-item constructs. To

assess the inconsistency, the rotated component matrix has been conducted (Table 5.6). The results showed that the model encountered the issue of cross-loading with the variable hedonic orientation and product innovativeness loaded together. In the designed conceptual model, there were four components. However, the rotated component matrix deducted the number of components from four to three. This issue indicates that there is a need for model modification and revision.

Table 5.6 Rotated Component Matrix

Designed Construct		Rotated Component Matrix	Component			Rotation Sums of Squared Loading		
		Please rate your agreement on the following statements:	Factor	Factor	Factor	Total	% Variance	Cumulative %
		(7-point scale: 1 = strongly disagree; 7 = strongly agree)	1	2	3			
1	Utilitarian Orientation	The project design is functional.	.07	.91	.15	5.66	26.93	62.46
1	Utilitarian Orientation	The project design is practical.	.08	.91	.15	↑	↑	↑
1	Utilitarian Orientation	The project design is problem-solving.	.05	.94	.11	↑	↑	↑
1	Utilitarian Orientation	The project design is useful.	.09	.94	.15	↑	↑	↑
1	Utilitarian Orientation	The project design is beneficial.	.13	.92	.13	↑	↑	↑
1	Utilitarian Orientation	The project design is helpful.	.10	.94	.12	↑	↑	↑
2	Product Commoditization	This product's functions are similar to its alternatives' functions.	.13	.31	.77	4.00	18.71	81.17
2	Product Commoditization	It's easy to find substitutes for this product.	.08	.06	.89	↑	↑	↑
2	Product Commoditization	This product is similar to other products in the same category.	.10	.23	.83	↑	↑	↑
2	Product Commoditization	This product can be easily replaced by other products in the same category.	.07	.10	.91	↑	↑	↑
2	Product Commoditization	It is not costly to switch to another similar product.	.08	.07	.80	↑	↑	↑
3	Hedonic Orientation	The project design is aesthetic.	.83	.00	.23	7.46	35.53	35.32
3	Hedonic Orientation	The project design is enjoyable.	.88	.00	.23	↑	↑	↑
3	Hedonic Orientation	The project design is playful.	.87	-.12	.24	↑	↑	↑
3	Hedonic Orientation	The project design is fun.	.89	-.08	.22	↑	↑	↑
3	Hedonic Orientation	The project design is delightful.	.89	-.02	.22	↑	↑	↑
4	Product Innovativeness	The project design is innovative	.77	.40	-.12	↑	↑	↑
4	Product Innovativeness	The project design is novel.	.81	.25	-.07	↑	↑	↑
4	Product Innovativeness	The project design is unique.	.86	.18	-.09	↑	↑	↑
4	Product Innovativeness	The project design is creative.	.89	.12	-.05	↑	↑	↑
4	Product Innovativeness	The project design is interesting.	.87	.21	.01	↑	↑	↑

Extraction Method: Principal Component Analysis with Varimax.
Note: All factor loadings that are higher than .50 are highlighted.

5.2.10 Inter-rater Reliability

In order to ensure the quality and reliability of the data, reliability tests were performed. First of all, the reliability of each measurement scale items was implemented. To access the data quality and reliability, the inter-rater reliability test of participant evaluations on utilitarian orientation, hedonic orientation, product commoditization, and product innovativeness was calculated. As shown in Table 5.3 examined constructs, the Cronbach's alpha of utilitarian orientation, hedonic orientation, product commoditization, and product innovativeness respectively was .77, .77, .31, and .57. The average intra-class correlation coefficient was .61. As the inter-rater reliability of utilitarian orientation and hedonic orientation exceeded .70, it indicated a good level of reliability. The inter-rater reliability of innovativeness was .57 reflected a moderate level of reliability. However, the inter-rater reliability of product commoditization was .31 which did not exceed .50 was considered at low level of reliability. As the average intra-class correlation was .61, it showed a moderate level of reliability (Chan and Parhankangas, 2017).

CHAPTER 6

ANALYSIS AND RESULTS

Given the nature of the conceptual model, the main study consists of several regression equations with multiple dependent variables and different sets independent variables. For example, in the first half of the conceptual model, independent variables are utilitarian orientation and hedonic orientation whereas dependent variables are the mediators, product commoditization and product innovativeness, respectively. On the second half of the conceptual model, both the number of downloads and the number of likes are introduced and served as dependent variables. Considering the nature of the model, the error terms in the separate equations have a potentiality to be correlated across the different equations (Srivastava and Giles, 1987; Zellner, 1963; Zhang, Wu, and Cui, 2015). In such a case, seemingly unrelated regression (SUR) was conducted to do estimation for the conceptual model (Srivastava and Giles, 1987; Zellner, 1962; Zellner, 1963; Zhang, Wu, and Cui, 2015). Seemingly unrelated regression (SUR) is a generalization or simplification of linear regression model. The estimation of the conceptual model can be approached by ordinary least squares (OLS), with the method of running different equations in a "one-by-one" fashion. However, seemingly unrelated regression (SUR) offers a more convenient and efficient alternative as seemingly unrelated regression (SUR) treats error terms across different equations (Srivastava and Giles, 1987; Zellner, 1962; Zellner, 1963; Zhang, Wu, and Cui, 2015). According to Zellner's method, the seemingly unrelated regression (SUR) is suitable to estimate multiple equations with accounting for heteroskedasticity and contemporaneous correlation in the errors across a set of equations (Khan et al., 2014;

Zellner, 1962; Zellner, 1963). In this study, the conceptual model contains several sets of independent variables, mediators, and dependent variables. It is not realistic to expect the different equations not sharing correlated error terms. In the survey design, all photos of projects shared and evaluated by participants were previously extracted from the source of secondary data collection, where is the same source of the two dependent variables. Hence, in this study, it is also unrealistic to expect that there are no common factors influence the errors of the various separate equations. Therefore, seemingly unrelated regression (SUR) was applied in this study by considering utilitarian orientation and hedonic orientation as independent variables, product commoditization and product innovativeness as mediators, and the number of downloads and the number of likes as the outcomes of interest. As there are moderation effect to be evaluated, parts of the variables have been mean-centered before moderation effect. This study followed a stepwise approach to implement the estimation for the equations.

$$PC = c_1 + \beta_1 (UO) + \beta_2 (HO) + CV + \varepsilon_1 \quad (1)$$

$$PI = c_2 + \beta_3 (UO) + \beta_4 (HO) + CV + \varepsilon_2 \quad (2)$$

$$DL = c_3 + \beta_5 (UO) + \beta_6 (HO) + \beta_7 (PC) + \beta_8 (PI) + \beta_9 (CPL) + \beta_{10} (PC \times CPL) + \beta_{11} (PI \times CPL) + CV + \varepsilon_3 \quad (3)$$

$$LK = c_4 + \beta_{12} (UO) + \beta_{13} (HO) + \beta_{14} (PC) + \beta_{15} (PI) + \beta_{16} (CPL) + \beta_{17} (PC \times CPL) + \beta_{18} (PI \times CPL) + CV + \varepsilon_4 \quad (4)$$

Where c = constant, UO = Utilitarian Orientation, HO = Hedonic Orientation,

PC = Product Commoditization, PI = Product Innovativeness, DL = Downloads, LK = Likes, CPL = Complexity, CV = Control Variables (including: Category, Date, Material, Object Parts, and Part Versions), ε = error term.

6.1 Results

First of all, the correlation matrix with descriptive analysis of focal variables is displayed in Table 6.1. The results of Seemingly Unrelated Regression (SUR) are shown in Table 6.2.

Table 6.1 Correlation Matrix

	Mean	SD	1	2	3	4	5	6	7	8	9
1. Downloads	74.06	146.63	(n/a)								
2. Likes	16.80	46.78	.78**	(n/a)							
3. Object Parts	2.02	2.88	.09	.08	(n/a)						
4. Part Versions	1.10	.64	-.02	-.02	.02	(n/a)					
5. Utilitarian	5.12	1.21	-.04	.01	.07	.04	(.93)				
6. Hedonic	4.65	1.25	.19**	.17**	.02	.03	.09	(.92)			
7. Commoditization	5.00	.84	.03	.08	-.05	.06	.31**	.30**	(.84)		
8. Innovativeness	4.74	1.04	.15**	.12*	.05	-.01	.30**	.76**	.11*	(.89)	
9. Complexity	2.03	.51	.19**	.11*	.31**	.09	-.01	.08	-.03	.08	(n/a)

Note. N = 420. * $p < .05$; ** $p < .01$. Diagonal values in the parentheses are values of square root of AVEs.

Table 6.2 Results of Seemingly Unrelated Regression

	Model 1				Model 2				Model 3			
	PC		PI		DL		LK		DL		LK	
Intercept		5.35**		4.56**		48.73		1.55		47.87		1.58
Main Effects												
Utilitarian Orientation	H1a	.37**	H1b	.31**		-.04		-.01		-.05		-.01
Hedonic Orientation	H1a	.21**	H2b	.72**		.16†		.18*		.13		.16†
Product Commoditization					H3a	.01	H3b	.06		.04		.09
Product Innovativeness					H4a	.03	H4b	-.03		.05		-.02
Complexity						.17**		.10†		.17**		.10†
Moderation Effects												
Product Commoditization × Complexity									H5a	-.04	H5b	-.05
Product Innovativeness × Complexity									H5c	.13*	H5d	.08
Control Variables												
Category_1		-.28**		.13**		-.01		.09		-.01		.10
Category_2		-.05		.20**		.04		.10		.04		.10
Date		.01		.01		.04		.04		.04		.04
Material_PETG		.02		.01		.05		.09†		.04		.09
Material_PLA		.01		.01		.01		.01		.01		.01
Object Parts		-.09*		.04		.05		.06		.04		.06
Part Versions		.02		-.05†		-.04		-.04		-.02		-.03
System Weighted R^2			.45				.04				.04	

PC = Product Commoditization; PI = Product Innovativeness; DL = Downloads; LK = Likes.

† $p < .10$ (two-tailed).

* $p < .05$ (two-tailed).

** $p < .01$ (two-tailed).

6.1.1 Utilitarian Orientation

H1 states that utilitarian product orientation is positively related to product commoditization whereas is negatively related to product innovativeness. According to the results of seemingly unrelated regression (SUR) in Table 6.2, utilitarian product orientation is positively related to both product commoditization and product innovativeness (product commoditization: b = .37, $p < .01$ (two-tailed); product innovativeness: b = .31, $p < .01$ (two-tailed)). The result indicates that H1 is partially supported with H1a (utilitarian product orientation is positively related to product commoditization) is supported but H1b (utilitarian product orientation is negatively related to product innovativeness) is not supported.

6.1.2 Hedonic Orientation

H2 states that hedonic product orientation is negatively related to product commoditization whereas is positively related to product innovativeness. According to the results of seemingly unrelated regression (SUR) in Table 6.2, hedonic product orientation is positively related to both product commoditization and product innovativeness (product commoditization: b = .21, $p < .01$ (two-tailed); product innovativeness: b = .72, $p < .01$ (two-tailed)). The result indicates that H2 is partially supported with H2a (hedonic product orientation is negatively related to product commoditization) is not supported but H1b (hedonic product orientation is positively related to product innovativeness) is supported.

6.1.3 Product Commoditization

H3 states that product commoditization is positively related to the number of downloads whereas is negatively related to the number of likes. According to the results of seemingly unrelated regression (SUR) in Table 6.2, product commoditization is not significantly

related to both the number of downloads and the number of likes (the number of downloads: b = .01, $p > .05$ (two-tailed); the number of likes: b = .06, $p > .05$ (two-tailed)). The result indicates that H3 is not supported.

6.1.4 Product Innovativeness

H4 states that product innovativeness is negatively related to the number of downloads whereas is positively related to the number of likes. According to the results of seemingly unrelated regression (SUR) in Table 6.2, product innovativeness is not significantly related to both the number of downloads and the number of likes (the number of downloads: b = .03, $p > .10$ (two-tailed); the number of likes: b = -.01, $p > .10$ (two-tailed)). The result indicates that H4 is not supported.

6.1.5 Complexity

H5a proposes that complexity moderates the relationship between product commoditization and the number of downloads. The positive relationship between product commoditization and the number of downloads is stronger when complexity is lower. According to the result of seeming unrelated regression (SUR) in Table 6.2, the interaction between complexity and product commoditization was not significantly associated with the number of downloads (b = -.04, $p > .10$ (two-tailed)). Therefore, H5a is not supported.

H5b hypothesizes that complexity moderates the relationship between product commoditization and the number of likes. The negative relationship between product commoditization and the number of likes is stronger when complexity is lower. According to the result of seeming unrelated regression (SUR) in Table 6.2, the interaction between complexity and product commoditization was not significantly associated with the number of likes (b = -.05, p > .10 (two-tailed)). Therefore, H5b is not supported.

H5c proposes that complexity moderates the relationship between product innovativeness and the number of downloads. The negative relationship between product innovativeness and the number of downloads is stronger when complexity is higher. According to the result of seeming unrelated regression (SUR) in Table 6.2, the interaction between complexity and product innovativeness was positively associated with the number of downloads (b = .13, $p < .05$ (two-tailed)). However, as the hypothesis proposed that the relationship between product innovativeness and the number of downloads was negative, therefore, H5c is not supported as it is in opposite direction. Yet, the result is significant and suggests that complexity positively moderates the relationship between product innovativeness and the number of downloads.

H5d hypothesizes that complexity moderates the relationship between product innovativeness and the number of likes. The positive relationship between product innovativeness and the number of likes is stronger when complexity is higher. According to the result of seeming unrelated regression (SUR) in Table 6.2, the interaction between complexity and product innovativeness was not significantly associated with the number of likes (b =.08, p > .10 (two-tailed)). Therefore, H5d is not supported. A summary of the results of all hypothesis is displayed in Table 6.3.

Table 6.3 Summary of Results

Hypothesis	**Model 1**	**Model 2**	**Model 3**
H1a: Utilitarian Orientation (+) →product commoditization	Supported		
H1b: Utilitarian Orientation (-) →product innovativeness	Not supported (opposite direction)		
H2a: Hedonic Orientation (-) →product commoditization	Not supported (opposite direction)		
H2b: Hedonic Orientation (+) →product innovativeness	Supported		
H3a: Product commoditization (+) →downloads		n.s.	
H3b: Product commoditization (-) →likes		n.s.	
H4a: Product innovativeness (-) downloads		n.s.	
H4b: Product innovativeness (+) likes		n.s.	
H5a: Complexity (-) moderates [product commoditization and downloads (+)]			n.s.
H5b: Complexity (-) moderates [product commoditization and likes (-)]			n.s.
H5c: Complexity (+) moderates [product innovativeness and downloads (-)]			Not supported (opposite direction)
H5d: Complexity (+) moderates [product innovativeness and likes (+)]			n.s.

Note: n.s. = not significant

As there was one moderation effect of complexity was significant, a simple slope analysis was implemented. A modification of complexity has been made that high level of complexity has been set to one standard deviation above the mean whereas the low level of complexity has been set to one standard deviation below the mean (Aiken and West, 1991; Schmitz, Lee and Lilien, 2014; Zhang, Wu, and Cui, 2015). When complexity level is high, product innovativeness has positive effects on the number of downloads (b = .26, t = 3.82, $p < .01$). However, when complexity level is low, the effect is not significant (b = .02, t = .25, $p > .05$). The moderation result figure is presented in Figure 6.1.

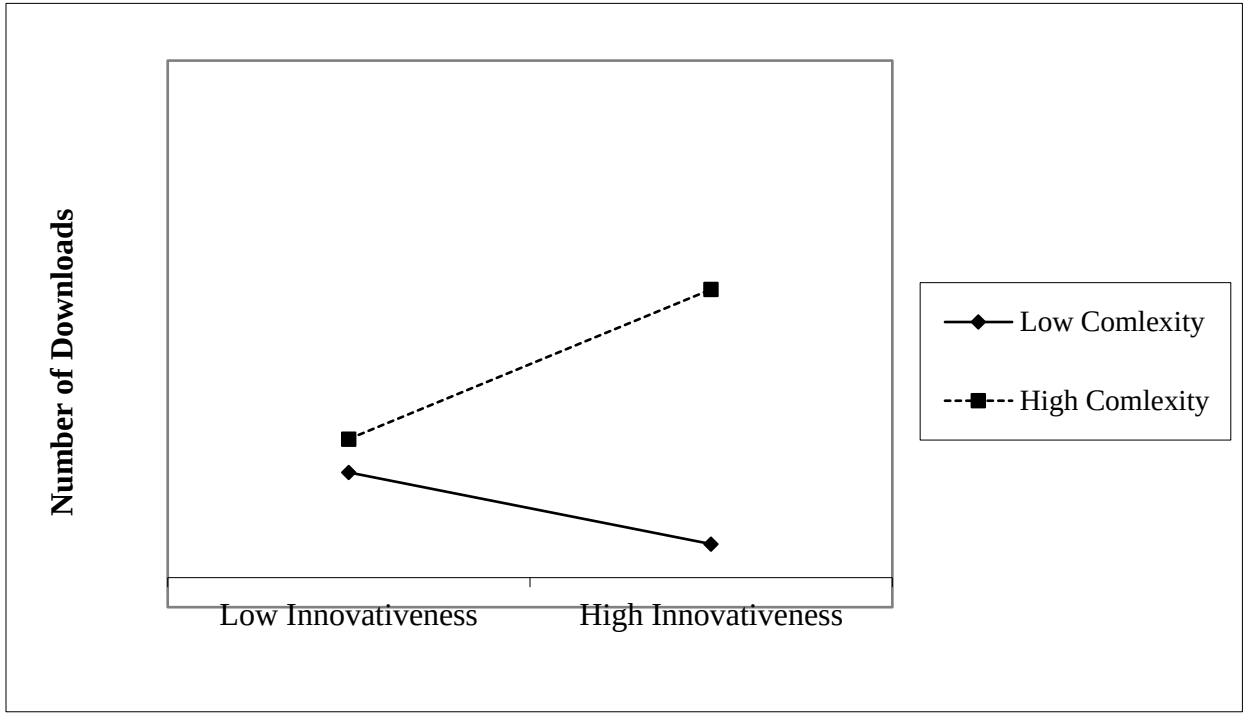


Figure 6.1 Moderation effect figure.

6.1.6 Mediation Effects of Product Commoditization and Product Innovativeness

In the conceptual model, product commoditization and product innovativeness were designed to serve as mediators. The mediation effects are as following: 1) product commoditization mediates the relationship between utilitarian orientation and the number of downloads; 2) product commoditization mediates the relationship between hedonic orientation and the number of downloads; 3) product commoditization mediates the relationship between utilitarian orientation and the number of likes; 4) product commoditization mediates the relationship between hedonic orientation and the number of likes; 5) product innovativeness mediates the relationship between utilitarian orientation and the number of downloads; 6) product innovativeness mediates the relationship between hedonic orientation and the number of downloads; 7) product innovativeness mediates the relationship between utilitarian orientation and the number of likes; 8) product innovativeness mediates the relationship between hedonic orientation and the number of likes. To test the mediation effect of product commoditization and product innovativeness, the Process regression of mediation effect has been implemented (Hayes, 2017). As there two product orientations, two mediators, and two outcomes of interest, there are eight (2 × 2 × 2) mediations. All of these 8 mediations have been tested (UO = Utilitarian Orientation; HO = Hedonic Orientation; PC = Product Commoditization; PI = Product Innovativeness; DL = Number of Downloads; LK = Number of Likes).

For mediation 1) UO → PC → DL: There was no significant result.

For mediation 2) HO → PC → DL: The direct effect of hedonic orientation on downloads was positive and significant (Effect = 21.14, SE = 6.09, CI = (9.17, 33.11)). However, the indirect effect of hedonic orientation on downloads through product commoditization was

not significant as its confidence level included zero (Effect = - .58, SE =2.76, CI = (- 6.30, 4.51)).

For mediation 3) UO → PC → LK: There was no significant result.

For mediation 4) HO → PC → LK: The direct effect of hedonic orientation on likes was positive and significant (Effect = 5.44, SE = 1.79, CI = (1.92, 8.96)). However, the indirect effect of hedonic orientation on likes through product commoditization was not significant as its confidence level included zero (Effect = .59, SE = .79, CI = (- .88, 2.23)).

For mediation 5) UO → PI → DL: The indirect effect of utilitarian orientation on downloads through product innovativeness was significant (Effect = 10.57, SE = 4.46, CI = (2.57, 20.06)). However, the direct effect of utilitarian orientation on downloads was not significant as its confidence level included zero (Effect = -6.14, SE = 8.31, CI = (-22.48, 10.21)).

For mediation 6) HO → PI → DL: The direct effect of hedonic orientation on downloads was positive and significant (Effect = 18.63, SE = 9.17, CI = (.61, 36.65)). However, the indirect effect of hedonic orientation on downloads through product innovativeness was not significant as its confidence level included zero (Effect = 1.93, SE = 6.05, CI = (-9.67, 14.14)).

For mediation 7) UO → PI → LK: There was no significant result.

For mediation 8) HO → PI → LK: The direct effect of hedonic orientation on likes was positive and significant (Effect = 7.20, SE = 2.70, CI = (1.90, 12.51)). However, the indirect effect of hedonic orientation on likes through product innovativeness was not significant as its confidence level included zero (Effect = -1.17, SE = 2.46, CI = (-6.26, 3.27)).

The mediation analysis indicated that only one of the 8 indirect mediations was significant.

Therefore, it should be concluded that product commoditization and product innovativeness are not successful mediators in the conceptual model. It also indicates a modification of the conceptual model is needed.

6.1.7 Post-hoc Study

A *post hoc* study was conducted to check different assumptions and to determine if a new model would fit better than the existing model. As the result of seemingly unrelated regression of the conceptual model showed that utilitarian orientation and hedonic orientation both had significant positive effect on product commoditization and product innovativeness (UO→PC:.37, $p < .01$; HO→PC:.21, $p < .01$; UO→PI:.31, $p < .01$; HO→PI:.72, $p < .01$), it was necessary and interesting to check if there are any significantly stronger positive effect. Therefore, two t-tests were implemented to examine relative coefficient strength. Due to the assumption that control variables should have no effects on dependent variable in this test, all control variables were discarded. The result did not yield any significant output for the relationship between product orientation and product commoditization ($t_{PC} = .30$, $p_{PC} > .10$). This result indicated that there was no significant difference between utilitarian orientation and hedonic orientation with respect to their effects on product commoditization. However, the t-test result showed that utilitarian orientation and hedonic orientation had different strength of effects on product innovativeness ($t_{PI} = -9.11$, $p_{PI} < .01$). The result indicated that despite the fact both utilitarian orientation and hedonic orientation positively related to product innovativeness, hedonic orientation had much stronger positive effect on product innovativeness than utilitarian orientation. The t-test finding suggests that both utilitarian orientation and

hedonic orientation positively affects product innovativeness, but hedonic orientation has a much stronger effect on product innovativeness.

Moreover, as mentioned earlier, product commoditization and product innovativeness in the conceptual model suffered from low inter-rater reliability. In Table 5.3, it shows that the inter-rater reliability of product commoditization and product innovativeness respectively were .31 and .57. According to Table 5.6, the scale items of product innovativeness have loaded on hedonic orientation. Therefore, the two constucts--product commoditization and product innovativeness are not appropriate to be examined in the conceptual model. Hence, to eliminate the side-effect of low inter-rater reliability and cross-loading, a new model without these two constructs is proposed in Figure 6.2.

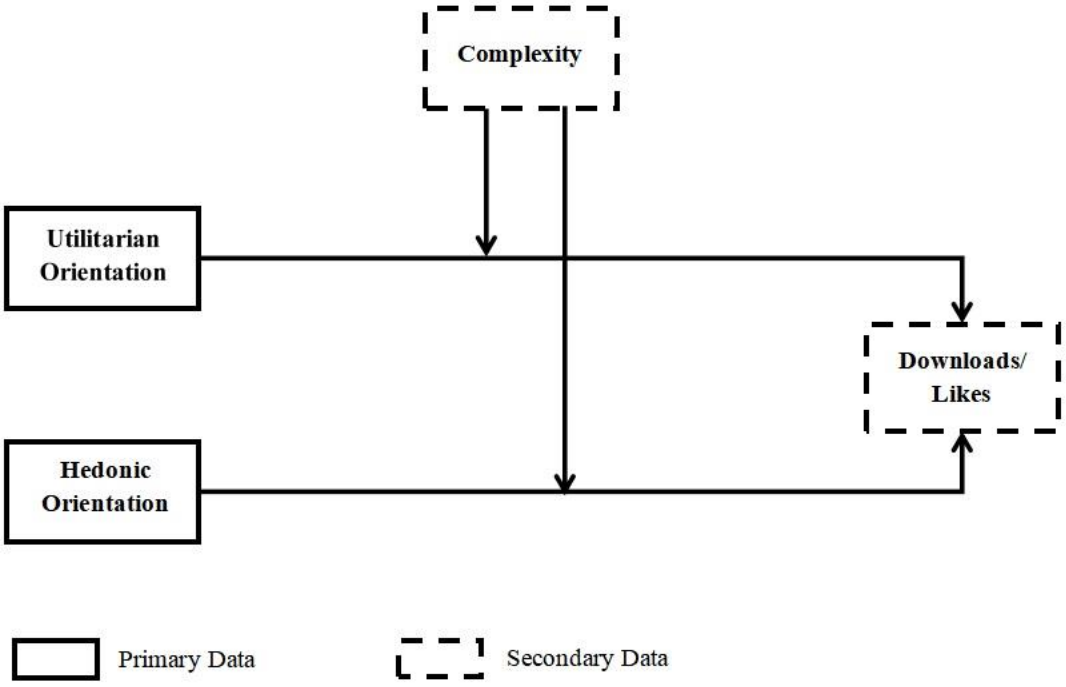


Figure 6.2 Revised conceptual model.

In the new proposed conceptual model, independent variables are still utilitarian orientation and hedonic orientation. By removing product commoditization and product innovativeness, the new revised model no longer has mediators. Instead, the new model is proposed to test the direct effect of utilitarian orientation and hedonic orientation on the number of downloads and likes. Most importantly, it is proposed to test the moderation effect of complexity. Following the revised conceptual model, a seemingly unrelated regression (SUR) has been implemented. The result of the seemingly unrelated regression (SUR) for the new model is displayed in Table 6.4.

Table 6.4 Results of Seemingly Unrelated Regression for Revised Model

	Model 1		**Model 2**	
	DL	**LK**	**DL**	**LK**
Intercept	48.45	2.86	45.28	2.22
Main Effects				
Utilitarian Orientation	-.03	.01	-.01	.01
Hedonic Orientation	.18**	.17**	.16**	.16*
Complexity	.17**	.09†	.21**	.12*
Moderation Effects				
Utilitarian Orientation × Complexity			-.10*	-.09†
Hedonic Orientation × Complexity			.14**	.09†
Control Variables				
Category_1	-.01	.07	-.01	.07
Category_2	.05	.09	.04	.09
Date	.04	.04	.04	.04
Material_PETG	.05	.09†	.04	.09†
Material_PLA	.01	.01	.01	.01
Object Parts	.04	.05	.04	.05
Part Versions	-.04	-.03	-.02	-.02
System Weighted R^2	.04		.06	

DL = Downloads; LK = Likes.
† $p < .10$ (two-tailed).
* $p < .05$ (two-tailed).
** $p < .01$ (two-tailed).

The result shows that the direct effect of hedonic orientation on the number of downloads and likes are both positive and significant (HO→DL:.18, $p < .01$; HO→LK:.17, $p < .01$). Moreover, utilitarian orientation is not significantly related to the number of downloads and likes. Complexity is positively related to the number of downloads and likes (CO→DL:.17, $p < .05$; CO→LK:.09, $p < .10$). However, when utilitarian orientation interacts with complexity, the interaction has negative effect on the dependent variables (UO×CO→DL: -.10, $p < .05$; UO×CO→LK: -.09, $p < .10$). This outcome could imply that complexity has opposite effect on adoption depending on different product orientation in 3D-printing design context.

CHAPTER 7

DISCUSSION

With the emerging use of the Internet, online businesses, peer-to-peer sharing, crowdsourcing, and sharing intellectual inputs are getting more attention and have the potential to be significant convention in both marketing practice and academia. 3D printing or additive manufacturing has also gained momentum in recent years. As a combination of technology, collaboration, and peer-to-peer sharing, online platforms such as myminifactory.com which devoting to serve as community for users to share 3D-printing designs are comparably new promising phenomenon and are diamonds in the rough. While the personalized and fabricated 3D-printing industry is still in early stages, it is feasible to expect that the needs will be increasing in years (Clark, Çallı, and Çallı, 2014). This research is one of the pioneers in marketing and new product development academics to explore this new phenomenon by examining the 3D-printing design collaboration in peer-to-peer sharing context. In this dissertation, I examined the roles and effects of product design orientations, product advantages, and complexity on sharing outcomes in 3D-printing design practices. This study found that both utilitarian and hedonic orientation have significant positive effect on product commoditization and product innovativeness.

7.1 Theoretical Implications

This study makes several theoretical contributions. First of all, this research contributes by defining the concept of product commoditization and constructing the measurements of product commoditization. Previous literature has neglected the mechanism of

commoditization in different context. There is none unified definition for commoditization in the past. In fact, most often, the term "commoditization" has been interchangeably used with the term "commodity". In the context of online 3D printing platforms, the shared product is digital design of 3D printing product. It is neither an actual product nor a commodity. Therefore, this research defined "commoditization" in the context of online 3D printing. There are few academic papers tried to explain and investigate on commodity products. However, this research aims to refer commoditization to a result of the process of commoditizing. Therefore, commoditization is viewed as a specific feature or ability of a product to be considered as a commodity. In another word, in this research, commoditization is a feature that determines if a product can be easily compared to, replaced by, or switched to another product. In this dissertation, product commoditization has been measured by five scale items including that the similarity of specific product's functions to alternatives' functions, the easiness to find substitutes for specific product, the similarity between the specific product and other products in the same category, the easiness for the specific product to be replaced by other products in the same category, and the switch cost of switching to another similar product. In the dissertation, the Cronbach's alpha between these five scale items is .92 which indicates appropriate measurement. These scale items have the potential to define and evaluate the new term "commoditization" in the future. However, unfortunately that in the main study, the inter-rater reliability on commoditization did not yield a satisfactory response with the inter-rater reliability equals .31. More investigations and exploration should be implemented to this new concept.

This research contributes to theory by extending product orientation theory to the new online collaborative platforms and the new context of online 3D printing. Adopted

from product orientation theory, this research distinguishes utilitarian goods from hedonic goods, utilitarian values from hedonic values, utilitarian motivation from hedonic motivation in the context of 3D printing industry in peer-to-peer consumption. This research dedicates to distinguish utilitarian product orientation from hedonic product orientation in consumers' perception in 3D printing design industry. Hence, this research adopts utilitarian and hedonic product orientation theory and extends it to 3D printing context in peer-to-peer consumption.

Despite a variety of previous literature have examined the role and effects of utilitarian values and hedonic values, the result of this result contradicts the findings from previous literature. In this research, the results indicate that utilitarian orientation has no significant effects on consumption and adoption (represented by downloads and likes). Researchers' efforts have been devoted to exploring different values and motivations. Li and colleagues have looked into online customer journeys with respects to utilitarian and hedonic purchases (Li et al., 2020). They found that utilitarian purchases are more likely to be engaged in third-party review websites, search engines, and deal sites than hedonic purchases (Li et al., 2020). Similarly, Shang and colleagues have revealed that people have higher purchase intention for utilitarian products than hedonic products when they are required to complete a purchase decision task during an online shopping festival. They explained this result as that when people need to make a purchasing decision efficiently in a short amount of time with various product promotions and time restrictions (e.g., during online shopping festivals), people are more likely to choose a product which is easy to be justified (Shang, Jin, and Qiu, 2020). So, Oh, and Min studied home-sharing services by using Airbnb (So, Oh, and Min, 2018). The result of their empirical study indicates that both enjoyment (represent hedonic orientation) and home benefits (represents utilitarian orientation) significantly explained consumers' intentions to Airbnb choice (So, Oh, and Min, 2018). Lee and Kim's study also indicates that both hedonic and utilitarian values significantly

influenced customer satisfaction (Lee and Kim, 2018). Mi and colleagues have investigated the effect of utilitarian values of reference group on low-carbon consumption intention and found that utilitarian influence of reference groups is the most important motivation for low-carbon consumption intention (Mi et al., 2019). These previous literatures suggest that utilitarian motivation and values positively affect product adoption, product consumption, and purchase intention. However, the result of our empirical study contradicts the findings of previous literature. The contradictory result suggests that on online 3D printing collaborative platforms, the designs of different 3D printing items possess different features than regular products.

This research contributes to the theory by introducing digital and intangible products into the theory. Past research on peer-to-peer consumption often bases theoretical assumption on tangible products. A significant debate over the differentiation of "ownership" and "access" of tangible products in sharing has been entangling peer-to-peer consumption. As the mainstream of peer-to-peer consumption research primarily restricts to access-based consumption, most of the previous literature lies in the "sharing of physical goods" scenario. For example, access-based car-rental and car sharing are often studied by researchers (Bardhi and Eckhardt, 2012; Botsman and Rogers, 2010). This research, however, proposes to focus on the online peer-to-peer consumption platform with the sharing digital 3D printing design files. There is no previous work has evaluated and conducted in this context. In contradistinction to prior streams and debates, this research distinguishes the sharing of digital 3D printing design files from both access-based consumption and ownership-based consumption. Unlike the tangible products are transferred or temporarily accessed, the digital file will not expire nor needs to be returned to the owner once being downloaded. Besides, the recipient peers have the possession of

digital files once shared, yet the copyright still belongs to the creator. This mechanism has made the peer-to-peer consumption for digital 3D printing design files a particular case.

Combining the theory of product orientations and the adoption in peer-to-peer sharing, this research sheds light on revealing how product characteristics (orientations) affect adoption in non-physical products such as intellectual properties, crowd-sourced ideas, and product designs. As the result shows that product innovativeness has significant positive effect on both downloads and likes, it indicates that the features of innovativeness, novelty, and unique are expected to be essentially important in the adoption of intellectual products (e.g., 3D-printing designs). On the other hand, contrary to common consumer products, product utilitarian is somehow not found to be significant for 3D-printing designs online. This aspects implies that digital intellectual products such as 3D-printing designs may have different patterns between product attributes (e.g., product orientation) and product adoption in the peer-to-peer sharing context. Therefore, this concept has a potential to be new theoretical gap and needs to be further investigated.

Third, this study contributes by introducing and examining the effect of complexity into the new peer-to-peer consumption sector in the context of 3D printing. Also, this research contributes by contradicting the findings of previous literature. Referring to the adoption of technology, complexity was defined as a function of the number of activities that have to be performed to adopt and to use a technology weighted with the difficulty of these activities (Willke, 1991; Batz, Peters, and Janssen, 1999). Not many literatures have clearly defined the definition of complexity in 3D-printing industry (Baumann, 2017; Rodriguez-Toro et al., 2003). Most often, previous publications endowed the definition of complexity in an intuitive understanding way (Baumann, 2017). In terms of technology

adoption, previous literature suggest that when the complexity of the technology is higher, there is a higher chance of abandonment of adoption and a slower rate of adoption (Aldunate and Nussbaum, 2013; Batz, Peters, and Janssen, 1999). In this research, the effect of complexity has been investigated. As the result shows, complexity has a positive effect on the number of downloads which suggests that when the technical complexity of a 3D-printing project is higher, more likely people will engage in adoption by downloading. This result contradicts previous literature findings and theories. Moreover, when complexity serves as a moderator, it also interacts with product innovativeness and have positive effect on the number of downloads. All of these findings contribute to the existing theories by opposing them.

7.2 Managerial Implications

In the age of personal fabrication, consumers often look for more flexible sources of products, customized products, and novel ideas rather than traditional channels. Peers such as individuals, entrepreneurs, and groups, in response, often upload their own ideas, designs, products online for others to use with or without monetary exchange for return. This research provided peers including entrepreneurs, individuals, and groups with managerial implications of how to effectively capture consumers' needs and address their designs for better product adoption. First, this research provided guidelines on differentiating designs by product orientations. On online 3D printing sharing platforms, consumers will look at the demonstrations, photos, and descriptions of designs first. The nature and orientation of the product should match the way how the design is addressed. This research emphasized on the pairing mechanism between utilitarian/ hedonic product

orientation with different design categories. The result has shown that there is a significant difference on product orientation between different categories on myminifactory.com. For example, the designs fall into the category of Spare-parts are found to be more utilitarian-oriented than the ones fall into the category of Jewelry. On the other hand, the designs fall into the category of Jewelry are found to be more hedonic-oriented than the ones fall into the category of Spare-parts. This phenomenon asserts that most of the designs within one category usually possess a core value. Therefore, it is suggested that practitioners using online peer-to-peer sharing and crowdsouring platforms such as 3D-printing collaboration communities should identify and position products accordingly.

Moreover, this research emphasized on the importance of complexity on product adoption (download or like). In traditional way, product complexity or technical complexity discourages adoption. However, the findings of this study contradicts the traditional philosophy and suggests that for intellectual product (e.g., creative ideas and designs) or product in new technology segment (e.g., 3D-printing designs), the complexity is not always bad thing for adoption. On the contrary, designs and products which have the core values of creativity and innovativeness may be more appreciated when they are complex. Thus, this research suggests practitioners to worry less about the disadvantage of complexity in customers' adoption if the product is intellectual product (e.g., creative ideas and designs) or product in new technology segment (e.g., 3D-printing designs). Instead, emphasizing on the complexity builds up the concept of originality and innovativeness thus may promote customers' adoption.

CHAPTER 8

LIMITATIONS AND FUTURE RESEARCH OPPORTUNITIES

This research tries to explore the mechanism of 3D printing product consumption in peer-to-peer consumption. Due to the lack of literature of 3D printing in peer-to-peer consumption under personal fabrication, there is limited previous studies and evidence to borrow and learn from. Therefore, concepts and knowledge concluded in this research may need to be further confirmed by future research.

As mentioned earlier, not many literatures have clearly defined the definition of complexity in 3D-printing industry (Baumann, 2017; Rodriguez-Toro et al., 2003). According to previous literature, the complexity can be evaluated by many different metrics and subjective matters including computational complexity, algorithm content, required time for manufacturing, requirement on hardware, required materials, object shape, and object size (Baumann, 2017; Gell-Mann, 1995; Lipson, 2011). Therefore, besides the technical complexity introduced in the main study, other types of complexity can also be important construct to investigate. For example, technical complexity represents how difficult or comprehensive it is to print and assemble the printed object, then project complexity could represent how difficult or comprehensive for other peers to understand a specific product's idea and functionality. This type of project complexity could also be measured by different methods, such as the way the project is expressed (by video or by text), how explicit the description is (the length of the description, the format of the description, and if keywords are highlighted), and how dedicated the creator is (e.g., how many updates).

Second, the two mediators product commoditization and product innovativeness in the conceptual model suffered from low inter-rater reliability. Hence, to eliminate the side-effect of low inter-rater reliability, a new model without these two constructs is proposed in Figure 6.2. In the new proposed conceptual model, Following the revised conceptual model, a seemingly unrelated regression (SUR) has been implemented. The result of the seemingly unrelated regression (SUR) for the new model is displayed in Table 15. The result shows that the direct effect of hedonic orientation on the number of downloads and likes are both positive and significant. Moreover, utilitarian orientation is not significantly related to the number of downloads and likes. Complexity is positively related to the number of downloads and likes. However, when utilitarian orientation interacts with complexity, the interaction has negative effect on the dependent variables. This outcome could imply that complexity has opposite effect on adoption depending on different product orientation in 3D-printing design context. More investigations and studies should be conducted in this regard.

Moreover, this research primarily focuses on two product orientation: utilitarian and hedonic product orientation. As utilitarian and hedonic orientations are not mutually exclusive and they are continuum, it is possible for another category—mixed-indulgence plays differently comparing to the two tested orientations. Mixed indulgence, on the other hand, can be further distinguished by utilitarian products plus hedonic values and hedonic products plus utilitarian functions added on. Therefore, it is recommended for future research to test the mechanism of mixed-indulgence products in addition to utilitarian products and hedonic products.

As mentioned earlier, despite recent flourish of peer-to-peer consumption in both academia and practitioner crowd, the definition of "peer-to-peer consumption" has not reached to a precise consensus. Many scholars have dedicated their efforts to define the peer-to-peer consumption (Bardhi and Eckhardt, 2012; Dellaert, 2019; Kumar et al., 2018; Ranchordás, 2015). With the contribution of digital facilities, there is a surge of new forms of sharing and new platforms for sharing emerging alongside (Grassmuck, 2012). Classical instances of peer-to-peer consumption in the new digital age include physical goods sharing using digital platforms (e.g., Zipcar), services sharing by using mobile apps (e.g., Uber and Lyft), peer-to-peer file sharing (e.g., The Pirate Bay and BitTorrent), peer-to-peer financing or microfinancing (e.g., Kiva), and content sharing (e.g., YouTube) (Hamari et al., 2016). All of the instances emerged from the interaction between peer-to-peer consumption and technological development share similarities but also have blurred boundaries between each other. A significant debate over the differentiation of "ownership" and "access" in sharing has been entangling peer-to-peer consumption. As Snare (1972) defined, ownership endorses a special relationship between an object and its belonged person named "owning". Hence this object is considered as a "personal property" or a "possession" (Bardhi and Eckhardt, 2012; Snare, 1972). Moreover, this type of special relationship entitles the belonged person as "owner". Recent research has also focused on commercial transactions in the peer-to-peer consumption (Frenken and Schor, 2017; Narasimhan et al., 2018; Sundararajan, 2016; Zervas et al., 2017). On the other hand, Bardhi and Eckhardt have pointed out that instead of acquiring the ownership of certain objects, consumers sometimes prefer exchanging for temporary access of a certain object or experience (Bardhi and Eckhardt, 2012). Unlike the long-term ownership, temporary

access only guarantees for a short-term right to. Past research suggests the temporal or long-term utilization without ownership is referred to as access (Chen, 2009; Holbrook and Hirschman, 1982; Pine and Gilmore, 1999). Like its nonunified definition, whether the activity of "transferring ownership" resembles peer-to-peer consumption remains debated and unsolved. The mainstream of literature in peer-to-peer sharing and collaborative consumption field follows the peer-to-peer market notion of "transactions that maybe market-mediated in which no transfer of ownership takes place" and excludes the transfer of ownership as collaborative consumption (Bardhi and Eckhardt, 2012; Belk, 2014; Borsman and Rogers, 2010; Bucher et al., 2016; Lamberton and Rose, 2012). Under this stream of research, peer-to-peer consumption primarily involves the activities only permit temporary access such as sharing, lending, and returning among peers. However, there is still previous work that does not exclude the transfer of ownership or possession under this circumstance (Belk, 2014; Perren and Kozinets, 2018). Therefore, there are many different types of "sharing" or "consumption". Types of "consumption" can be categorized by the ownership, such as long-time ownership, temporary access, or ownership transfer. For example, Airbnb should represent temporary access of ownership which entitles users a temporary right to occupy and use. Peer-to-peer file sharing including 3D-printing file sharing could be the example of long-time ownership and ownership transfer depending on the license. Therefore, future research can investigate on the different consumption or adoption pattern in different category of "sharing".

Last, this research studied peer-to-peer consumption in the context of 3D-printing in peer-to-peer consumption. As mentioned earlier, including 3D-printing design sharing, there are many different peer-to-peer sharing formats. For example, the co-riding services

by Uber, car-rental services by Enterprise, and home-rental services by Airbnb are all examples of peer-to-peer sharing in peer-to-peer consumption. However, although they are all peer-to-peer sharing, they are still different. Another way to categorize them could be by the selectivity prior to utilization. For example, when consumers are using Uber to request a ride-sharing service, it is not possible for consumers to do filtering, matching, and selection. They will only be assigned a Uber driver. On the other hand, when it is the case of 3D-printing design sharing, users are able to look for different design projects by simply browsing, searching, filtering, matching, and making selections. Therefore, even though they are both peer-to-peer sharing activities, they are different on the ability to make selection. In this way, the adoption pattern may be different when the option is different. It is recommended to be a future research opportunity to investigate the different types of peer-to-peer consumption.

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