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The Economics of Production Safety for Customized Product Using 3-D Printer based on Three-Dimensional Printing Industry Promotion Act

Sunho Yoon[a], Ahreum Hong[b], Junseok Hwang[a]

Abstract

『Three-Dimensional Printing Industry Promotion Act』 has been enacted in 2015 based on 『Product Liability Act』 in Korea. It is believed that Korea enacted 『Product Liability Act』 in 2002 to make easier for damage cost to be paid to users by reducing the burden of proof. The model used in this paper argues that the social cost of product damage for customized products is determined by sum of attention cost for user and the 3-D[1] service provider with the level of existed safety information, and expected damage costs. The equilibrium point can meet optimal point when the level of safety information is same as traditional products. Given six liability rule, the equilibrium point cannot meet social optimal point. So under the exemption in 『Three-Dimensional Printing Industry Promotion Act』, which is directly related to the customized product using three-dimensional printer, users and the 3-D service provider cannot be expected to minimize their costs.

[a] Technology Management, Economics, and Policy Program, College of Engineering, Seoul National University

[b] Graduate School of Technology Management, Kyung Hee University

[1] Three-dimensional Printing is hereinafter referred to as "3-D"

1. Introduction

In the modern industrial society, various products are produced, sold and consumed, resulting in damage to consumers or third parties due to safety defects of products. In recent years, the scale of the damage has been enlarged and the scope of the accident has become wider, and in particular, the damage to the body and life is increasing. Consumers' awareness of the safety of products is also increasing due to changes in social conditions such as the improvement of income levels. As a result of "Consumer Awareness Survey" of 400 ordinary citizens, the interest rate of product safety policy is rising from 38% to 51% in 2015 (Korean Agency for Technology and Standards, 2017).

Therefore, it has been regarded as an important policy issue for product safety to increase the products safety to prevent accidental risks, and to provide adequate compensation for damage after the accident. For these reasons, KATS(Korean Agency for Technology and Standards) require procedures to confirm that products satisfy the minimum safety criteria before market releasing, and conduct voluntary and involuntary recalls by monitoring the market for hazardous products (Korean Agency for Technology and Standards, 2014).

In addition, it provides policies and system supports to guarantee various types of product safety or utilize insurance as a means of distributing risk to accidents. Among them, it is the Product Liability Act that explains who will compensate the damages due to the defect of a product, which has been great interest in the United States. Recognizing the limitation of contractual liability to a manufacturer who does not have a direct contractual relationship with the consumer, Korea has been enforcing the Product Liability Law to protect the consumers (Kwon & Han, 2013).

As technology became more sophisticated and more difficult for consumers to understand the technology of products, the Strict Product Liability adopted California in the United States in 1963. This adoption influenced many researchers who analyze the Product Liability Law using economic analysis (Brown, 1973; Goldberg, 1974; Landes & Posner, 1985; Marino, 1988; Oi, 1973). But any of those explain customized product which is small quantity batch production (hereinafter referred to as “small production”)

in 3-D printer case.

These studies were conducted to analyze the economics of products liability when producer designed and produced the products. However, due to the development of 3-D technology, it is expected that the manufacturing method of industries will be changed. In particular, owners who own a three-dimensional printer will be able to use the online platform to accept and sell consumer ideas, parts and ornaments for hobbies and activities (Lee, 2016).

When consumers are expected to be able to purchase customized products in new production method, it is important to analyze the economics of 『Three-Dimensional Printing Industry Promotion Act』 based on economic analysis of 『Product Liability Law』in relation to future product liability.

This paper has five sections. Part 2 and 3 explain the "three-dimensional printing service business" and identify what will be changing and the reason for exemption in 『three-Dimensional Printing Industry Promotion Act』 and 『Product Liability Act』 in Korea. Part 4 analyzes economic of safety for a customized product using 3-D printer in the Act. In particular, we consider the liability rules in the 3-D service business through the social cost model that takes into consideration not only the level of attention but also the level of safety information for user[2]. Finally, Section V summarizes the discussion of this paper.

2. 3-D Service Business and Liability

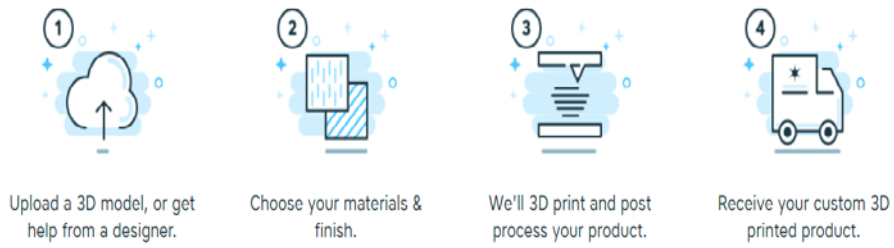
3-D technology is regarded as the core industry of the fourth industrial revolution,

[2] In 『Three-Dimensional Printing Industry Promotion Act』, "user" is defined as "a person to whom services are provided using such equipment, materials, software, or contents"

as normal products such as character goods, jewelry accessories, and automobiles, electronic devices as well as medical products such as teeth (Consumer, 2017). The global 3-D market has grown by 25% every year since 2010 and has grown from about 30 billion in 2012 to 250 billion in 2016 years in Korea (Kang, 2017). Therefore, in Korea, various plans are being developed to improve the industry promotion and competitiveness. One such effort was to enact 『Three-Dimensional Printing Industry Promotion Act』 in 2015 for providing policy support.

In general, a 3-D printer is widely recognized as an additive manufacturing method which means a technique of manufacturing an object by stacking various kinds of materials using a 3-D drawing. Legally, a “3-D printing” is defined as "creating 3-D shapes with electronic information for materializing 3-D forms" in Article 2 (1) of the 『Three-Dimensional Printing Industry Promotion Act』. And the act defines “3-D service business” as “business of providing 3-D services for users under supply contracts made with users (Article 2 (4) of the same Act).

An example of a 3-D service business is Shapeways, which began in 2007. Shapeways is a business model that carries out product production services that users do not have a three-dimensional printer. In addition to Shapeways, Thingiverse and 3D Hubs offer similar services.



<Figure 1 Shapeways process[3]>

Thus, the 3-D service business is making a change in the traditional industry as the end users can directly participate in the production process. This contributes to the opportunity of small production for the 3-D service business provider and the opportunity of purchase the customized product for the users. Also, Lee (2016) said the complexity of product and cost of the product are irrelevant, and it is instantly manufactured at the desired location that owns the 3-D printer.

The products produced through this 3-D technology still contain the risks that exist in traditionally manufactured product, and can have ambiguous liability due to the complexity of the technology and the various stakeholders (C. Kim, 2017). In addition, because of the technology-intensive manufacturing method, there is a burden of proving the cause and effect to users who suffer physical and property damage due to the lack of safety and durability inherent in the manufactured product.

3. Literature review

Product liability and exemption reasons

Because many technologies and materials are used for the advantages of the 3-D printers described in the previous chapter, there are risks inherent in the workplace, especially in the case of customized products, more safety measures must be provided, and discussions on these issues are continuing. In the case of the 3-D service business, the stakeholder can be the person who designed the drawings for 3-D printer product, the person who published the 3-D drawing on the Internet, the user whom the services are provided, and the person who provides the service. However, as Kim (2017) mentioned there is no guarantee that the above stakeholders are necessarily different person. The number of such cases shows that the 『Product Liability Act』 applied to existing

[3] Source : www.shapeways.com

products may or may not be applied to products manufactured through a 3-D printer.

In this regard, in this section will examine the liability of customized product covered by the『Three-Dimensional Printing Industry Promotion Act』and the reason for the exemption from the service provider, and compare it with the『Product Liability Act』in existing products.

Product liability and exemption under the『Product Liability Act』

Product liability defined as "A manufacturer shall compensate for damages to the life body or property of a person caused by a defect of a product(excluding damages inflicted only to the relevant product" in Article3 (1) of『Product Liability Act』, in Korea, which is a Strict liability rule or liability without fault rule.

Before the "Product Liability Act" was enacted, the user was liable to indemnity under the Civil Law liability or contract liability law if he suffered damage caused by a defective product. In 2002, however, the『Product Liability Act』was enacted in Korea, it is only necessary to insist on defects of the product without needing anything else. This can be said to reflect the legal request that makes it easier for damage cost to be paid to users by reducing the burden of proof (S. Kim, 2003).

In other words, regardless of the existence of the fault of the manufacturer, if there is a defect of the product and the occurrence of the damage and the causal relationship there between, the manufacturer has the liability for damages (J. Kim, 2011). In article 2 (1) of『Product Liability Act』, "Product" is defined as "movables which are industrially manufactured or processed" and "defect" as "any of the following defects of a product with regard to manufacturing, design or indication or lack of safety ordinarily expected of a product". The liability for all deficiencies above is defined as the manufacturer under

the『Product Liability Act』. However, when the defect could not be identified by the scientific or technical knowledge at that time, the manufacturer can be exempted from any liability for damages (Article 4 (1) 2 in same Law).

Product liability and exemption under the『Three-Dimensional Printing Industry Promotion Act』

Article 17 of the『Three-Dimensional Printing Industry Promotion Act』enacted in December 2015 defines liability for products and reasons for the exemption. Basically, the 3-D service provider is obliged to compensate for damages in accordance with Article 3 of the "Product Liability Act" caused by defects in the product. This Act is related to the case of the additional exemption for 3-D cases.

In accordance with Article 17 (2) and (3) of the Act, the 3-D service provider has exempted by the damages caused by the 3-D drawings received from the user and the design or instruction and usage method received from the material and equipment manufacturer.

Unlike『Product Liability Act』, which is a Strict liability rule or liability without fault rule, it is necessary to establish a new exemption in consideration of the specificity of 3-D cases, and Lee (2016) evaluated this exemption as valid.

4. Economic Analysis of Customized Product

This research will analyze the『Three-Dimensional Printing Industry Promotion Act』in terms of "small production" products designed by the user, one of the cases among the various 3-D service businesses, using Brown (1973) method.

However, as described by Song (2005), there is a difference between law and

economics in that efficiency is regarded as an important criterion from the viewpoint of the existing legal system. In advance, also, it does not claim that the legal system should be changed, and it is merely a framework for how to think in terms of efficiency.

In the 『Product Liability Act』, as Lee (2016) explained, the criteria of the defect is that "lack of safety ordinarily expected of a product" as described above, so users' expectation of safety is considered as the legal standard of negligence. In addition, product liability is recognized if there is a defect from the design regardless of whether or not the manufacturer has violated the obligation to manufacture the product. In this respect, product liability in Korea is a strict liability rule or Liability without Fault Rule. In other words, the content of the user's expectation about the product, the content of the risk and the recognition of these are the criteria of the court's judgment.

In this regard, the 『Three-Dimensional Printing Industry Promotion Act』, which follows the 『Product Liability Act』, can be approached in a similar method to the previous study such as Brown (1973) did. However, the 3-D service business has different problems from the existing product accident.

In other words, the case of stakeholders can be more diverse and complex than the existing one as mentioned above, and manufacturers who do business in 3-D services provider will not be able to test products or understand the products since they produce products in various fields.

In this paper, we assume the service provider deal directly with the users and the user will use the customized products by themselves (clothes, accessories, etc.). Then, it is possible to analyze economics using the level of attention and the level of safety information.

Research Model

Brown (1973) assumed two people noncooperative game[4], and their goal is to minimize their expected private cost in his model[5]. As he assumed, 3-D printer service business for a customized product, as Shapeways do, are two people noncooperative game to minimize their expected private cost. So when users make 3-D drawings for themselves, their costs are related to 1) the level of attention (Y), such as knowledge of manual for the products or carefulness, and 2) the level of existed safety information[6] (Θ) which they can get for their customized product. For the service providers, the level of attention (X), for example safety training, is considered only. We assume when a user uploaded their 3-D drawing, the service provider understands the level of existed safety information from the products from their experience or company system.

To minimize their cost, the response functions[7] for two people, the service provider and user, are as following:

$$X^f(Y) = \text{Min } Cx(X,Y) = AxX + DLx(X,Y)(P(X,Y)),$$

$$Y^f(X) = \text{Min } Cy(X,Y) = \Theta AyY + DLy(X,Y)(P(X,Y))$$

Where Ax and Ay are the cost per unit of X and Y, D is damage cost. Lx(X,Y) and Ly(X,Y) denote liabilities of X and Y[8]. Also P(X,Y) is probability that an accident

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[4] Brown (1973) assumed in his paper that two people only communicate with each other in court after an accident, and all other transactions are assumed to be so expensive.

[5] Using the X and Y as "accident avoidance", and P(X,Y) as "probability that an accident will be avoided", Brown (1973) establish Social Cost model as following :

Cs(X,Y) = WxX + WyY + A(1-P(X,Y)), when Wx, Wy, A are the cost of X, Y, and damage.

[6] Assume level of existed safety information(Θ) is the safety information and criteria requested by government for traditional products. ($0 < \Theta \leq 1$)

[7] Brown (1973) used response functions as to show "what response a person would choose, given the choice of the opponent".

[8] When $Lx(X,Y) \geq 0, Ly(X,Y) \geq 0,$ and $Lx(X,Y) + Ly(X,Y) = 1,$ Brown (1973) explained six liability rules as following : (when (X^*, Y^*) *is a legal standard of negligence*)

will occur.

Assume social optimum point is same as a legal standard of negligence which means ordinarily expected of a product (As 『Product Liability Act』Article 2 (2)). Then, the social optimum is the point that minimizing social cost, which is

$$\text{Min } Cs(X,Y) = AxX + \Theta AyY + DL(X,Y)(P(X,Y))$$

When, attention costs ($AxX + \Theta AyY$) and the damage costs ($DL(X,Y)P(X,Y)$). when if assume social optimal values of X and Y are X^{Ω}, Y^{Ω}, we can say X^{Ω}, Y^{Ω} are expected to be same as X^{*}, Y^{*} in Brown model.

Figure 2 shows if the level of existed safety information(Θ) is 1, which means that the user has made the 3-D drawing as the same safety level as the traditional product, then there is only one optimal point as Brown (1973) mentioned.

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1) No liability : The user has all the product liability
   $Lx(X,Y) = 0$, $Ly(X,Y) = 1$

2) Strict liability : The service provider has all the product liability
   $Lx(X,Y) = 1$, $Ly(X,Y) = 0$

3) Negligence rule : The user is liable unless the service provider is found negligent

   $Lx(X,Y) = \begin{cases} 0 \\ 1 \end{cases}$, $Ly(X,Y) = \begin{cases} 1, & if \;\; X \geq X^{*} \\ 0, & if \;\; X < X^{*} \end{cases}$

4) Strict Liability with contributory negligence : The service provider is liable unless the user is found negligent

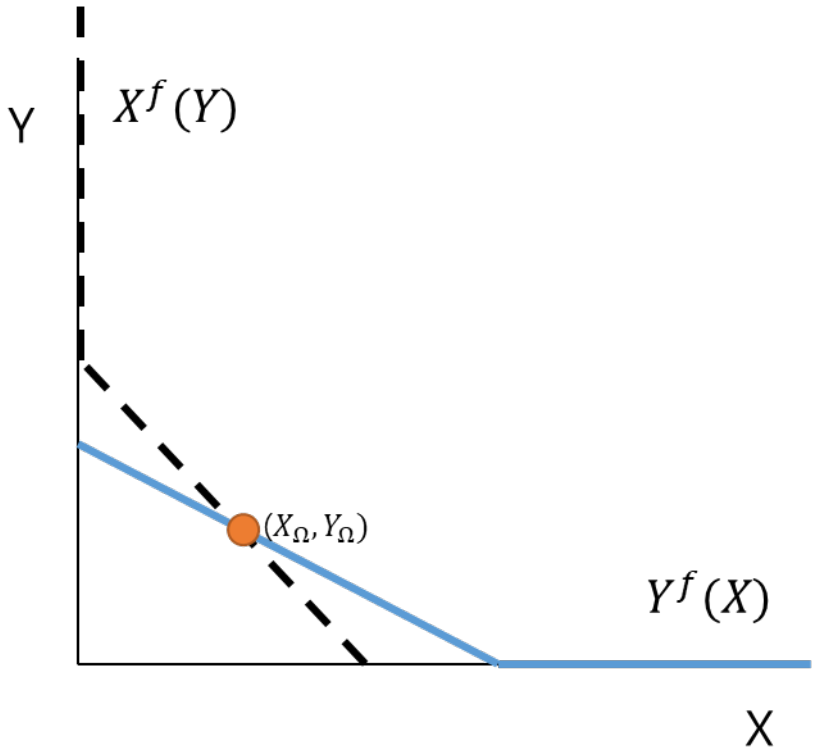
   $Lx(X,Y) = \begin{cases} 1 \\ 0 \end{cases}$, $Ly(X,Y) = \begin{cases} 0, & if \;\; Y \geq Y^{*} \\ 1, & if \;\; Y < Y^{*} \end{cases}$

5) Negligence rule with contributory negligence : The service provider is liable if he is negligent and the user is not. The user is liable otherwise.

   $Lx(X,Y) = \begin{cases} 1 \\ 0 \end{cases}$, $Ly(X,Y) = \begin{cases} 0, & if \;\; X < X^{*} \;\; and \;\; Y \geq Y^{*} \\ & 1, \; otherwiser \end{cases}$

6) Strict Liability with dual contributory negligence : The user is liable if he is negligent and the service provider is not. The service provider is liable otherwise.

   $Lx(X,Y) = \begin{cases} 0 \\ 1 \end{cases}$, $Ly(X,Y) = \begin{cases} 1, & if \;\; Y < Y^{*} \;\; and \;\; X \geq X^{*} \\ & 0, \; otherwiser \end{cases}$



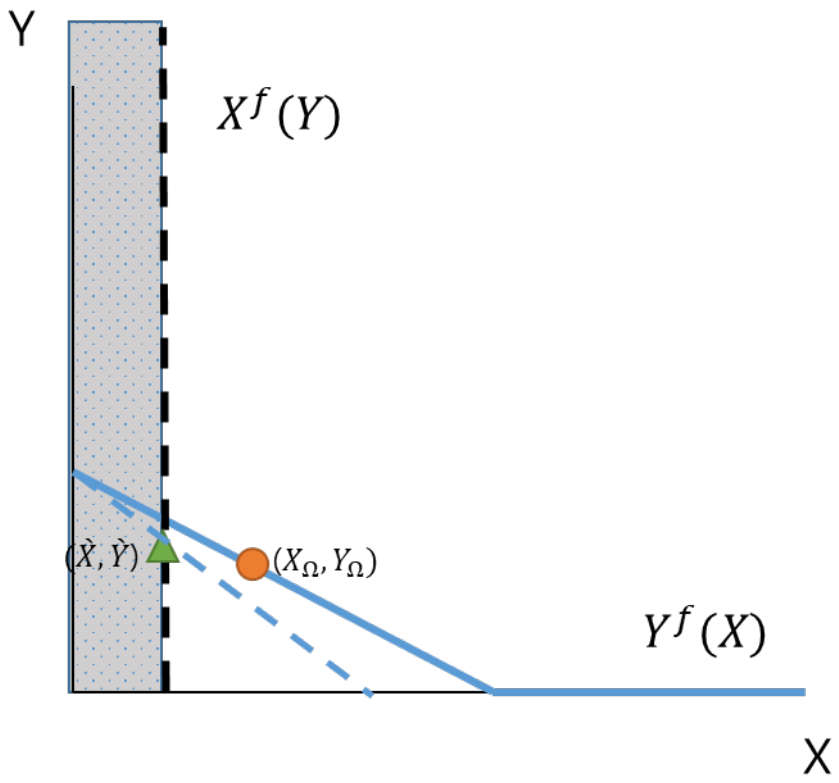
<Figure 2 cost of the service provider and user(Θ =1)>

Under the Six Various Liability Rules

Consider the rule of six liability rules explained above,

1) No Liability :

The service provider only pays the costs of the level of attention (AxX). To minimize his cost, he will choose X=0 or just minimum X as his reputation. See figure 3 (dotted line is when Θ has a value between 0 and 1, and shaded area explains the service provider liability).



<Figure 3 No Liability>

2) Strict Liability :

The user only pays the costs of the level of attention (AyY). To minimize his cost, he will choose Y=0 or just minimum Y as his safety. See figure 4.

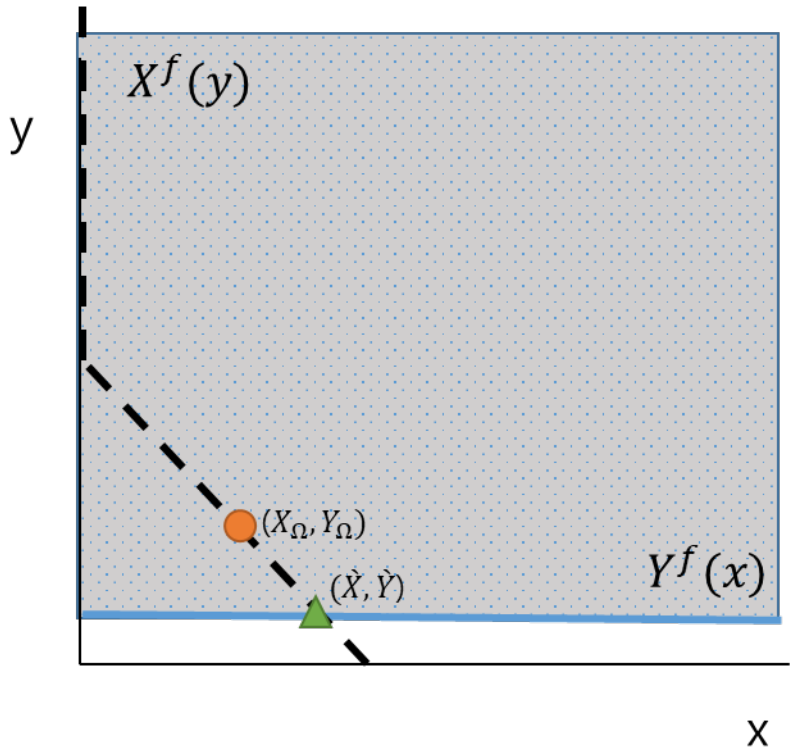


Figure 4 Strict Liability

3) Negligence Rule and Negligence rule with Contributory Negligence

This can be major result in this paper. Since the exemptions of “defect in any of the 3-D drawings provided by the relevant user” in 『Three-Dimensional Printing Industry Promotion Act』, Strict liability rule or liability without fault rule can transfer to these liability rules for the customized product by 3-D printer. See figure 5.

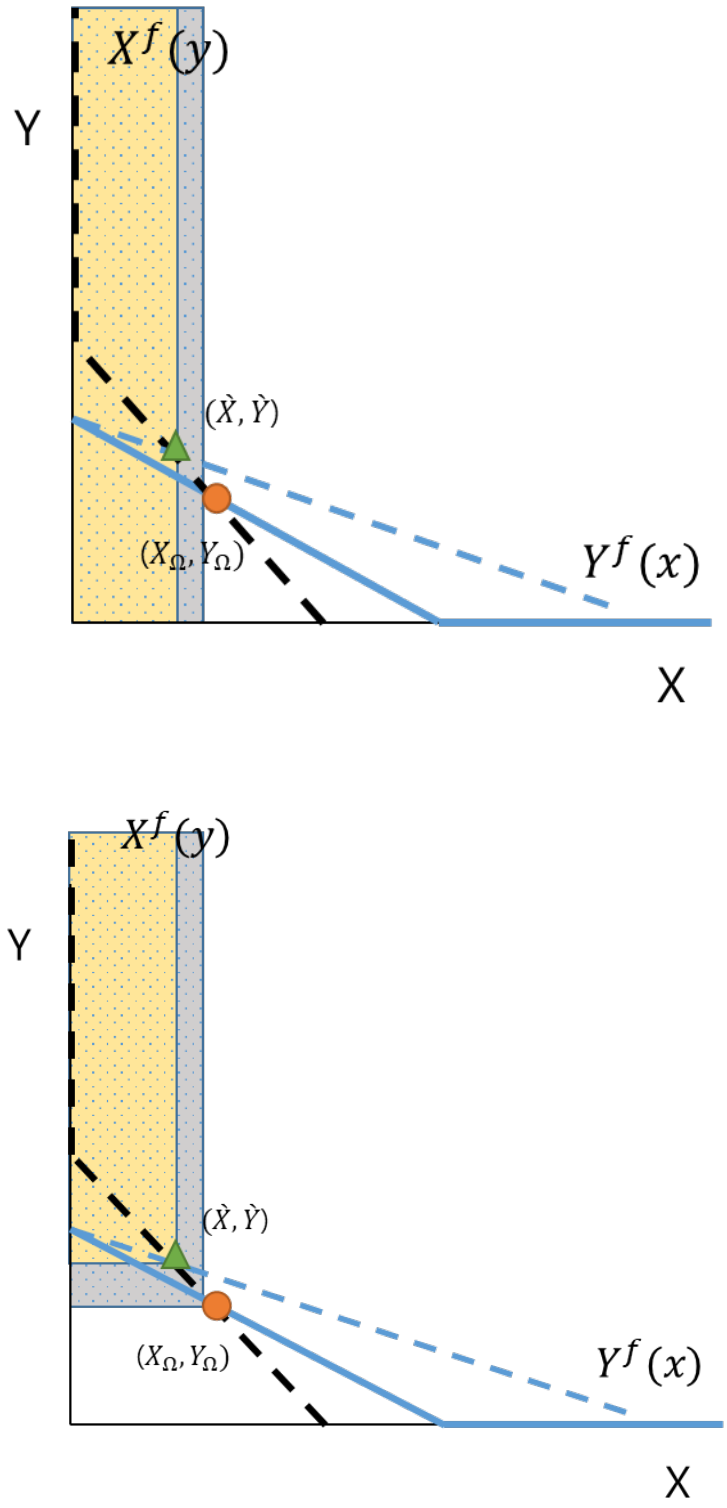


Figure 5 Negligence Rule and Negligence rule with Contributory Negligence

4) Strict Liability with Contributory Negligence and with dual Contributory Negligence

For Strict Liability with Contributory Negligence and with dual Contributory Negligence rule, the result can be made by exchanging the roles of X and Y in the previous result.

Above results show 1) the equilibrium point of no liability and strict liability rule are not same as optimal point, which is same as the result of Brown (1973), and 2) for other four rules, the equilibrium point cannot meet optimal point which is social optimum point, identical to the negligence standard point. Within the six frameworks, there is no preferred choice to meet optimal point.

In other words, the 3-D service business is still used as a criterion for determining the product liability. For the customized products assumed described in this paper, however, the users are obliged to pay attention to the design so that they can follow the negligence rule rather than the Strict liability rule or liability without fault rule as other products, which is not socially optimum.

5. Conclusion

To analyze economic of customized product using 3-D printer, we described the 3-D technology that provides a new service business, and identify the product characteristics of the technology and the corresponding specific service business (customized product business) along with the contents of the 『Three-Dimensional Printing Industry Promotion Act』.

The key argument of this paper, the discussion in Chapter IV, is that the customized product using 3-D service approaches the social cost minimization based on the level of existed safety information from the related government department or traditional manufacturer. In other words, if the negligence standard is identical to the

optimal point for social cost, there should be some safety information giver to raise the level of safety information to achieve user cost optimization.

Also, it was believed that when a strict liability rule or liability without fault rule are applied to producers, they would consider not only their expected full cost, also level of consumer attention to minimizing damage cost, which can minimize total social cost. In the customized product in this paper, however, under negligence rule, they don't have any duty to provide their existed safety information or improve their technic to reduce the probability of the accident.

There are many limitations in this paper. 1) It does not include other types of liability rules, such as relative negligence, which means the user or the service provider takes all product liability. 2) It specifies one service business that users make 3-D drawing themselves, from many other cases. 3) Following Brown (1973) assumption that "cost of damage is fixed value". 4) research-model assumption that the service provider can understand the level of the user's attention and safety information through the 3-D drawing they uploaded.

Among the various types of the service business that can occur through 3-D technology, the customized product (small production) service business may not be large in market size and it is difficult to find Korea's law case in the customized product in the past. However, it seems desirable to examine efficiency issues as well as product liability for an emerging manufacturing method. This paper is expected to contribute to the research on the 3-D service industry.

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