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# Co-creation and Personalization as Incentive Mechanisms of Utilizing External Innovation Sources: Which Performs Better?

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**Abstract** Utilizing outside knowledge for innovation is an important task for companies in the competitive economy. Due to the rapid advance in the internet communication technology, the number and quality of innovation sourcing methods are increasing. We select co-creation, personalization and in-house R&D as the representative forms of innovation sourcing and suggest a game theory model that enables the comparative analysis between them. The decision and surplus outcome of the innovation mechanisms are compared under various settings of the input parameters of the model. The stakeholders voluntarily participate into all mechanisms when the product price is moderately high and the participation cost is low, while co-creation is the only feasible one when the product quality is niche. When the participation cost is relatively high, personalization outperforms co-creation.

**Keywords** Innovation sourcing; Co-creation; Personalization; Game theory; Simulation

## I. Introduction

In today's competitive economy, seeking outside knowledge and utilizing it in the production process is becoming an increasingly useful way for companies

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to complement their internal research and development (R&D) efforts (Leiponen and Helfat 2010). The toolbox for innovation sourcing has been reinforced with the seminal conceptualization of business practices such as user innovation (von Hippel 1976), open innovation (Chesbrough 2003) and crowdsourcing (Howe 2006). In addition to these representative forms of external innovation activities, companies carry out many others that are based on communicating information over the organizational boundaries (Lichtenthaler 2005, Huggins et al. 2012). Although the recent development of internet-based information systems is accelerating the growth in the number of innovation sourcing alternatives available to organizations (Yang and Han 2021), relatively little interest is given to the problem of choosing the most adequate type of activity for them. While the complexity of organizational environment and capability hinders a reasonable comparison of the relative effectiveness of innovation sourcing modes, analyzing their fundamental structure of economic rationale may provide a new approach to this problem. On this background, this study aims to conduct a comparative analysis of two specific mechanisms of utilizing external innovation sources: co-creation and personalization by game theory. We suggest a microeconomic model in which both involve an exchange of information between the producer firm and the consumers in their production process but differ in terms of the intensity of the communication and the incentive structures of participants. The performance levels of co-creation, personalization and in-house R&D as a benchmark are compared under various settings of exogenous parameters of the suggested model by conducting a numerical simulation that compares the social surplus and Nash equilibrium decision outcome.

## II. Literature Review

Many methods for organizations to procure useful knowledge and capabilities from outside entities have been suggested and found to be an effective complement of internal R&D in the vast existing literature. Companies can take advantage of the knowledge flows over the organizational boundaries with open innovation activities such as strategic alliance, contracts and knowledge spillovers (Gilsing et al. 2007; Hagedoorn and Zobel 2015; De Faria and Santos 2010), which can contribute to cost reduction and detection of market demands (van de Vrande et al. 2009).

Product and service users are another valuable source of innovative ideas. They capture the inconveniences and potential new features of the current products from their actual usage and come up with possible improvements and solutions (von Hippel 1986; Lüthje 2004). User innovation can bring effective solutions to organizations especially when the product is used by experts of a professional field or fascinated hobby players (Lüthje et al., 2005). Crowdsourcing expands the companies' innovation workforce into a subset of the gigantic general public who is capable of providing a solution (Afuah and Tucci 2012). It is greatly advantageous if the potential population of idea givers are large or the task is adequate for disassembly and distribution to a big group of workers (Olsen and Carmel 2013; Poetz and Schreier 2012).

We find the utilization of knowledge or information of external stakeholders to be a key commonality of the innovation concepts discussed above. This characteristic is also shared in a greater or less degree by other types of business practices. For example, co-creative production processes create value by the reciprocal interaction between the stakeholders encircling a value chain (Prahalad and Ramaswamy 2004). Personalization enables the consumers to submit their preferences over the configuration of products, leading to the maximization of utility (Franke et al. 2010; Wang et al. 2017). One important situation is that the emerging technologies, especially internet-based communication tools, are lowering the cost of exploring potential contributors of innovation and enhancing the quality of transmitted information (Chu 2013).

The existing literature has endeavored on investigating the advantages of individual innovation mechanisms and identifying the key conditions for the success of them. Innovation contests provide the applicants an extrinsic motivation in the form of prizes, which can effectively reinforce the intrinsic motivation of the inventors (Jeppesen and Lakhani 2010; Pellizzoni et al. 2015). Strategic alliances for open innovation cooperation heavily rely on the internal alignment of leadership, strategy and organizational structure (Slowinski and Sagal 2010). As companies are supplied with the increasing number of tools for innovation sourcing, the necessity for choosing the adequate innovation activity that fits the organizational environment and capabilities may arise (Afuah and Tucci 2012; Felin and Zenger 2014). In this context, we aim to contribute to the related literature in two directions. First, a comparative analysis of two utilization modes of external innovation source is conducted. Companies face many choice options for collaborating with external partners, but little academic interest has been given to the choice problem of innovation method. We select co-creation and personalization, which possess the characteristic of external innovation sourcing and are widely implemented in the economy, and compare their relative performance according to the business environment such as product price and participation cost. Also, the effect of uncertainty of product quality and profit-sharing phenomenon in co-creation on the result is discussed. Second, the preceding exploration on the relationship between environmental factors of organization and the fruitfulness of innovation activity is augmented by the microeconomic decision modeling approach of this study. Mathematical decision-making models such as optimization and game theory can be used as an alternative way to verify the theoretical and empirical studies of innovation (Baniak and Dubina 2012; Terwiesch and Xu 2008; Jiang et al. 2010; Natalicchio et al. 2017). We formulate co-creation and personalization into two distinct incentive mechanisms with different game-theoretic structures. The co-creators freely decide whether or not to participate in the co-creation process based on their microeconomic incentive structures. The typical type of personalization, in which the users create their own utility-maximizing product by participating in the production system, is modeled as the target of comparison. Also, the third game model of in-house R&D, where an innovative employee develops a product without intrinsic satisfaction, is suggested as a performance benchmark.

## III. Research Method

In this study, a microeconomic decision model framework for comparing the performances of co-creation, personalization and in-house R&D is suggested and analyzed. This is conducted in three steps, each of which will be illustrated in the following subsections. First, the fundamental elements that compose the innovation sourcing mechanisms, namely the players, their roles and payoff structures, are defined. Second, the complete game theory model of the mechanisms consisting of serial strategy choices of the players and possible outcomes is suggested. Finally, the performance of the mechanisms, in terms of player participation and social surplus, is compared by deriving the Nash equilibria strategies of the players under different levels of the exogenous parameters. This is conducted by a numerical computer simulation.

### 1. The Underlying Model of Stakeholders

Table 1 displays how the players are modeled in co-creation, personalization and in-house R&D. There are three types of players – the manufacturer, the innovator, and the consumers. The manufacturer takes a role in all of the three mechanisms. We model its role to coordinate the entire innovation sourcing process with the innovator and the consumers into a simple decision of producing the product created as a result of each mechanism. If it chooses to produce, it earns the sales revenue from the consumers and expends the manufacturing cost. In co-creation and in-house R&D, it also pays the innovator wage to the innovator. The financial compensation for idea givers is becoming increasingly prevalent in several forms of co-creative activities such as crowdsourcing and innovation contests (Cappa et al. 2019). If the costs are projected to be larger than the sales revenue, the manufacturer decides not to produce and earns a zero profit.

**Table 1 The fundamental model of stakeholders in innovation sourcing mechanisms**

| Player | Innovation sourcing mechanism | | |
|---|---|---|---|
| | Co-creation | Personalization | In-house R&D |
| Manufacturer | Produces the co-created product<br>Profit = Sales revenue<br>– Manufacturing cost<br>– Innovator wage | Produces the personalized product<br>Profit = Sales revenue<br>– Manufacturing cost | Produces the R&D outcome product<br>Profit = Sales revenue<br>– Manufacturing cost<br>– Innovator wage |
| Innovator | Participate in co-creation<br>Profit = Innovator wage<br>– Participation cost<br>+ Intrinsic satisfaction | N/A | Carry out R&D<br><br>Profit = Innovator wage<br>– Participation cost |
| Consumers | Buy the co-created product<br><br>Utility =<br>Reservation price<br>– Product price<br>– Quality dissatisfaction | Participate in personalization and buy the outcome product<br>Utility =<br>Reservation price<br>– Product price<br>– Participation cost | Buy the R&D outcome product<br><br>Utility =<br>Reservation price<br>– Product price<br>– Quality dissatisfaction |

The innovator is the source of useful ideas for product design. In co-creation it is an external partner who is willing to communicate and cooperate with the manufacturer and is given the freedom of choice to participate in the innovation sourcing. On the other hand, in in-house R&D, it is an employee of the producer organization and is mandated to execute the product design task once the manufacturer decides to produce. When the innovation sourcing is carried out and the resulting product is delivered to the consumers, the innovator receives a wage from the manufacturer and pays a participation cost representing its effort. Also, in the case of co-creation, satisfaction is added to the inventor's profit, representing the sense of achievement from participating in the product development process and contributing to the innovation (Chu 2013; Cappa et al. 2019). The cost for mental effort and time of engaging in creative work is deducted from the payoff of innovators.

When a product is arranged for production by the strategy choices of other players, the consumers choose whether to buy it. We follow the consumer model of horizontal differentiation, which assumes that each consumer possesses its own value of reservation price and ideal product quality. It is adequate for describing markets with various tastes for the product such as fashion and hobby goods (Cremer and Thisse 1991; Böckem 1994). It pays the product price if it decides to purchase the product. In co-creation and in-house R&D, the quality of the product may differ from the consumer's most preferred one, and the dissatisfaction arising from a distance between those quality positions is subtracted from the utility. In personalization, the consumers carry out the additional role of innovator by themselves by personalizing the own product. They are assumed to have their ideal products at the expense of paying the participation cost. We assume a consumer distribution function that associates each value of product taste (horizontally differentiated product quality) to the number of consumers possessing it. The function shows how popular or niche a specific product's taste is.

## 2. Game Theory Models of Co-creation, Personalization and In-house R&D

Figure 1 shows the game trees that display the players, their strategy options, the order of decision-making, and the payoffs assigned to each possible outcome of each innovation sourcing mechanism. The manufacturer, innovator, and consumers are denoted by *M*, *I* and *C*, respectively.

In co-creation, the innovator makes its decision to participate in the cooperation with a manufacturer. If it chooses not to engage ( $t_I = DoNotParticipate$, when $t_I$ refers to the strategic choice of the innovator), the game ends instantly with payoffs $\pi_M = \pi_I = 0$ and $\pi_C = 0$ for all consumers. If otherwise ($t_I = Participate$), then a product with quality $x$ is generated by the co-creation. *x* stands for a position of consumer preference in the horizontal differentiation context. A higher value of *x* does not imply higher quality, and any value of *x* supplies the highest utility to the consumers whose position of ideal product coincides with it. It is assumed that *x* is an exogenously given number, reflecting the uncertainty in new product development. While a specific product field would have its unique set of possible quality positions, we use a normalized set of $\{0, 0.1, 0.2, \cdots, 1\}$ for the purpose of calculational convenience.

Then, the manufacturer decides whether it would produce the co-created offering or not. If no ($t_I = Participate$ and $t_M = DoNotProduce$), the game ends with $\pi_M = 0$ and $\pi_C = 0$ for all consumers, while the innovator's payoff is $\pi_I = q - e$. *q* is the sales quantity, e.g., the number of consumers that would have purchased the co-creation outcome if it was produced. We assume that $q$ is accurately estimated by a demand analysis process. The mental satisfaction of innovator from knowing that its invention is accepted by a certain number of consumers is described with $q$ in $\pi_I$. *e* stands for the effort cost for participating in the co-creation activity.

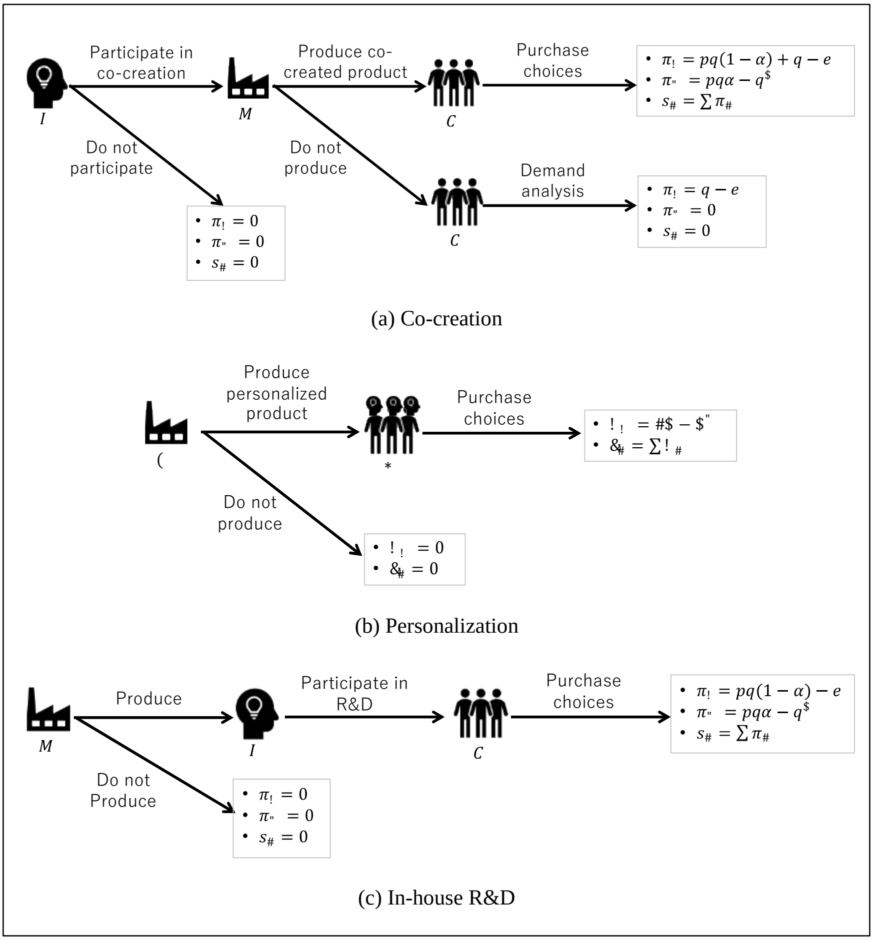


**Figure 1 The game trees of innovation sourcing mechanisms**

If the strategy to produce is chosen ($t_I = Participate$ and $t_M = Produce$), then the consumers face the co-created offering and choose to purchase it. The choice makes on the basis of the product quality *x*, price *p*, consumer preference $\theta$, and reservation price $r$, all of which take a value in $\{0, 0.1, 0.2, \cdots, 1\}$. To compare the two innovation sourcing mechanisms under various levels of price, we assume it to be a given number. Each consumer is endowed with a specific value of $\theta$ and $r$. $\theta$ represents a customer's most preferred position of quality. When it buys a product that satisfies $x = \theta$ its utility is maximized. If $x \neq \theta$, then a dissatisfaction that is proportional to the absolute distance $|x - \theta|$ is subtracted. The consumers estimate their payoff $\pi_C = r - |x - \theta| - p$, and buy the product if $\pi_C > 0$. Consumers with zero or negative projected payoff do not purchase and get $\pi_C = 0$. The sales quantity $q$ is computed by adding up the individual decision of consumers. For each value of $\theta \in \{0, 0.1, 0.2, \cdots, 1\}$, the number of consumers who have the same taste $\theta$ is given by the consumer distribution function $f$.

$$f = \begin{cases} 4\theta & 0 \le \theta \le 0.5, \quad 0 \le r \le 1 \\ -4\theta + 4 & 0.5 < \theta \le 1, \quad 0 \le r \le 1 \\ 0 & elsewhere \end{cases}$$

We suppose that the consumer distribution is symmetric about $\theta = 0.5$, $\theta = 0.5$ is the most popular taste for product and $\theta = 0{,}1$ is the least popular. The linear function is chosen for the simpleness of modeling and numerical calculation. The coefficient of the linear term and the constant term are set to 4 by considering the continuous function version of the suggested model. If $\theta$ and $r$ can take a real number value in interval $[0{,}0.1]$ and the consumer population is supposed to be 1, $a = 4$ is derived from $\iint f(\theta, r)\, drd\theta = 1$. In this study, the total population is $\sum_{(\theta,r)} f(\theta, r) = 110$. Also, $f$ does not depend on the values of $r$, which means that the number of consumers is identical for all values of $r$ when $\theta$ is fixed. The sales quantity $q = \sum_{(\theta,r)\in\{(\theta,r)|\pi_C > 0\}} f(\theta, r)$ is the sum of the number of consumers with positive payoff.

The computation of $q$ concludes the payoff of each player when both innovator and manufacturer choose to participate in co-creation. The manufacturer earns $\pi_M = pq\alpha - q^2$, consisted of its share of sales revenue $pq$ and manufacturing cost $q^2$. It pays the innovator a wage of $pq(1 - \alpha)$, which is proportionate to the sales revenue, as the compensation for participating in co-creation. $\alpha$ stands for the ratio of the manufacturer's share of the sales revenue. Reversely, $1 - \alpha$ is the ratio of the innovator's share. The innovator's payoff is $\pi_I = pq(1 - \alpha) + q - e$, when $e$ is the effort cost of participation into the innovation activity. The consumer surplus $s_C = \sum \pi_C$ is the sum of consumer utility, and the social surplus is calculated as $s = \pi_M + \pi_I + s_C$.

The decision model of the personalization mechanism differs from co-creation in several aspects. First, there is no separate innovator, and consumers carry out the role themselves. They appraise the product price $p$ and the effort cost $e$ needed for participating in the personalization activity and choose to participate if they do not exceed the reservation price $r$. In this case, they design their most preferred product by themselves using the personalization service ($x = \theta$ for all customers), and the consumer payoff is $\pi_C = r - p - e$. If $r - p - e$ is anticipated to be zero or negative, the consumer does not perform personalization and $\pi_C = 0$.

Then given the estimated consumer demand, the manufacturer decision-makes whether to provide the personalization service to the customers. Strategy not to operate ($t_M = DoNotProduce$) leads to a zero payoff for everyone ($\pi_M = 0$ and $\pi_C = 0$ for all consumers). Consumers can buy a personalized product if the producer produces ($t_M = Produce$). The surpluses become $\pi_M = pq - q^2$ , $s_C = \sum \pi_C$ and $s = \pi_M + s_C$ , when the manufacturer's decision is made to operate the personalization system.

In in-house R&D, the innovator is a separate entity as it is in co-creation but does not possess the freedom of choosing a strategy regarding the product development. If the manufacturer decides to launch a product ($t_M = Produce$), it engages in the product design by paying the mental cost $e$ and earning the wage $pq(1-\alpha)$, but without the intrinsic satisfaction $q$ of inventing. The purchase choice of consumers and the sale quantity are determined in the same manner of co-creation. The surpluses are $\pi_M = pq\alpha - q^2$, $\pi_I = pq(1-\alpha) - e$, $s_C = \sum \pi_C$ and $s = \pi_M + \pi_I + s_C$. In the case, the projected value of $\pi_M$ is negative, the producer chooses not to produce ($t_M = DoNotProduce$), and everyone earns a zero profit ($\pi_M = \pi_I = 0$ and $\pi_C = 0$ for all consumers). The following equations summarize the game trees explained so far.

Co-creation mechanism

Consumer payoff:

$$\pi_C = \begin{cases} r - |x-\theta| - p & if \;\; s_I = Participate, s_M = Produce, \\ & \text{and } r - |x-\theta| - p > 0 \\ 0 & otherwise \end{cases}$$

Manufacturer profit:

$$\pi_M = \begin{cases} pq\alpha - q^2 & if \;\; s_I = Participate \;\; and \;\; s_M = Produce \\ 0 & otherwise \end{cases}$$

Innovator profit:

$$\pi_I = \begin{cases} pq(1-\alpha) + q - e & if s_I = Participate \text{ and } s_M = Produce \\ q - e & if s_I = Participate \text{ and } s_M = DoNotProduce \\ 0 & otherwise \end{cases}$$

Personalization mechanism

Consumer payoff:

$$\pi_C = \begin{cases} r - p - e & if \;\; s_M = Produce \;\; and \;\; r - p - e > 0 \\ 0 & otherwise \end{cases}$$

Manufacturer profit:

$$\pi_M = \begin{cases} pq - q^2 & if \;\; s_M = Produce \\ 0 & otherwise \end{cases}$$

<u>In-house R&D mechanism</u>
Consumer payoff:

$$\pi_C = \begin{cases} r - |x-\theta| - p & if \;\; s_M = Produce \;\; and \;\; r - |x-\theta| - p > 0 \\ 0 & otherwise \end{cases}$$

Manufacturer profit:

$$\pi_M = \begin{cases} pq\alpha - q^2 & if \;\; s_M = Produce \\ 0 & otherwise \end{cases}$$

Innovator profit:

$$\pi_I = \begin{cases} pq(1-\alpha) - e & if \;\; s_M = Produce \\ 0 & otherwise \end{cases}$$

## 3. Numerical Simulation for Comparison between Mechanisms

Figure 2 shows the process of the numerical simulation of the game theory model suggested in the previous subsection. The decision-making of the players depends on the values of the exogenous parameters *p*, *e*, *x*, and $\alpha$. We use the set $\{0, 0.1, 0.2, \cdots, 1\}$ as the range of possible values of these parameters. Then, for each of the possible combination $(p, e, \alpha, x)$ of the exogenous parameters, the Nash equilibrium strategy and its consequent surpluses of the three innovation sourcing mechanisms is calculated by the backward reduction in game theory. Then, the individual and social surpluses, and player strategies of the models are compared. The calculation is carried out by MATLAB software.

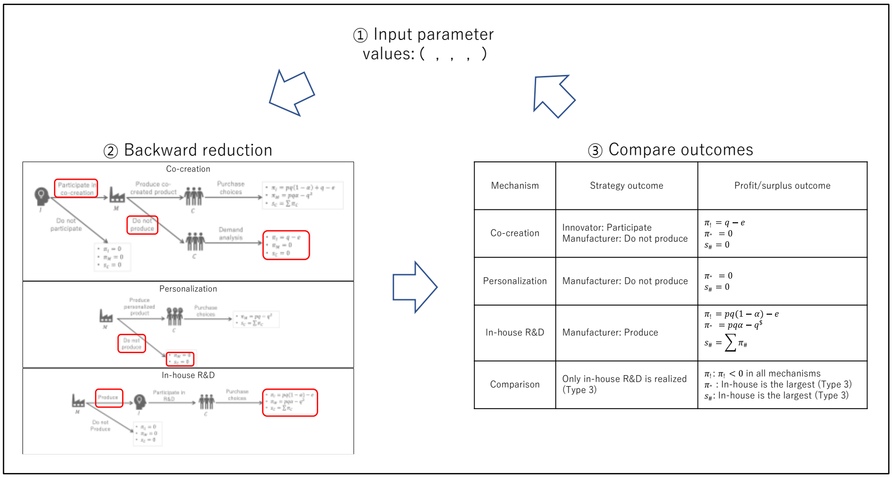


**Figure 2 The structure of the numerical simulation**

# IV. Results

Figure 3 shows the player's decision outcome corresponding to the combination of exogenous parameter values. The figure's horizontal axis marks the value of price $p$, and the vertical axis denotes the manufacturer-innovator profit sharing ratio $\alpha$. In each subfigure, the value of $p$ and $\alpha$ is fixed according to the corresponding axes, and the combination of remaining parameters $(e, x)$, consists of the coordinate plane. Therefore, a point in Figure 3 denotes a specific combination of the parameters. For example, in the subfigure located where the lines of $p = 0.5$ and $\alpha = 0.5$ intersect, the points are representing $(p, \alpha, e, x) = (0.5, 0.5, e, x)$ . For each parameter combination, the Nash equilibrium strategy of manufacturer and innovator is calculated and categorized into the following types, with a focus on whether the players choose to participate in innovation sourcing and thus the outcome product is delivered to the consumers.

Decision outcome types

Type 1: Co-creation only.
Type 2: Personalization only.
Type 3: In-house R&D only.
Type 4: Co-creation and personalization.
Type 5: Personalization and in-house R&D.
Type 6: Co-creation and in-house R&D.
Type 7: All mechanisms.

Each type refers to the mechanisms that are realized by the decision-making of the manufacturer and innovator. For instance, type 1 means that under the given parameter values, the innovator and manufacturer decide to participate in co-creation, but the manufacturer does not choose to conduct personalization and in-house R&D. As shown in Figure 3, five out of the seven outcome categories, namely type 2, 3, 5, 6 and 7, are observed.

Figures 4 to 6 show the comparison of values of social surplus, consumer surplus and manufacturer profit, respectively. The coordinate structure of each figure and its subfigures are identical to that of Figure 3. The color displayed on the coordinate points presents which of co-creation, personalization and in-house R&D performs the largest non-zero surplus or profit, according to the following categories.

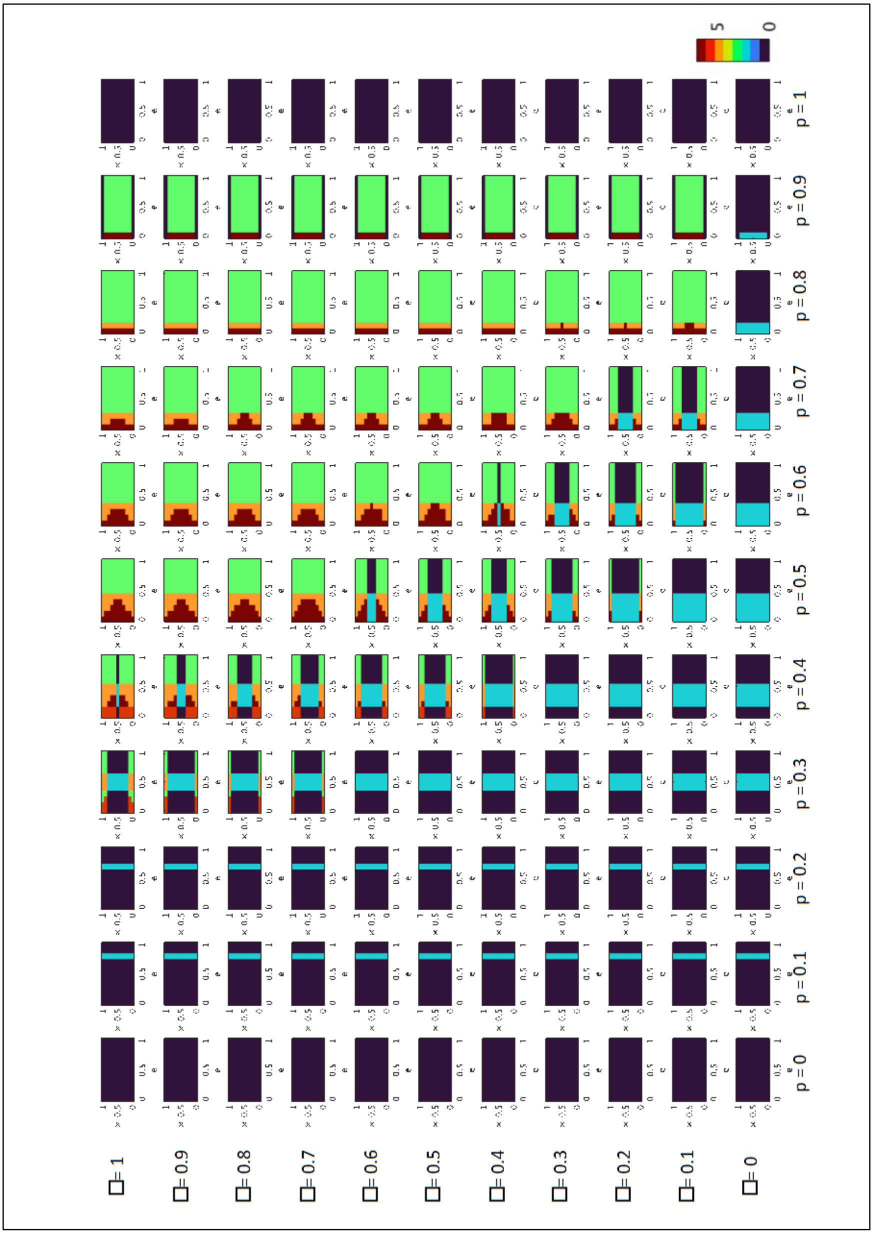


**Figure 3 The comparison of decision outcome**
**(Axis legend: Outside horizontal - p; outside vertical - α; small horizontal = e; small vertical – x. Color legend: Light blue - type 2; light green - type 3; orange - type 5; red - type 6; dark red - type 7; navy - no type.)**

**Figure 4 The comparison of social surplus**
**(Axis legend: Outside horizontal - p; outside vertical - α; small horizontal = e; small vertical – x. Color legend: Blue - type 1; light blue - type 2; navy - no type.)**

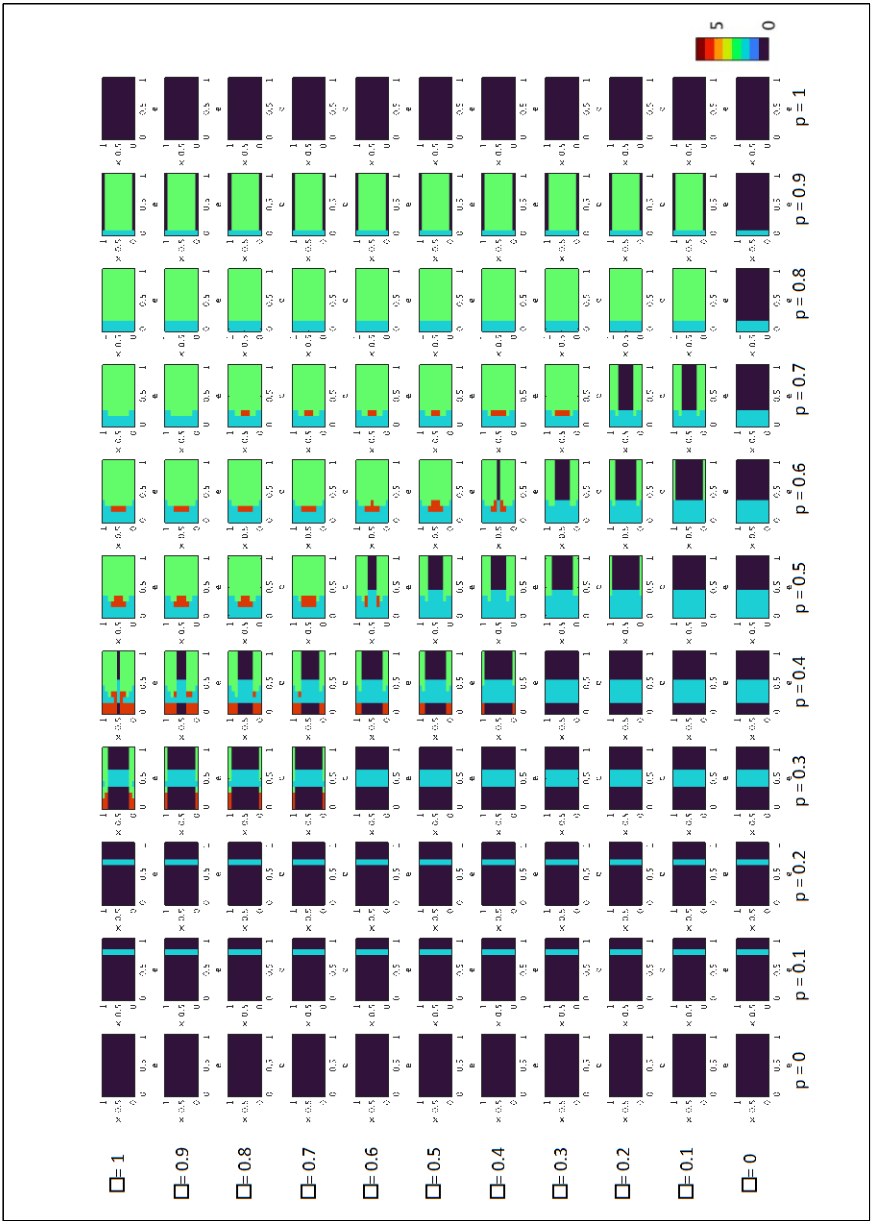

**Figure 5 The comparison of consumer surplus**
**(Axis legend: Outside horizontal - p; outside vertical - α; small horizontal = e; small vertical – x. Color legend: Light blue - type 1; light green - type 2; red - type 6; navy - no type.)**

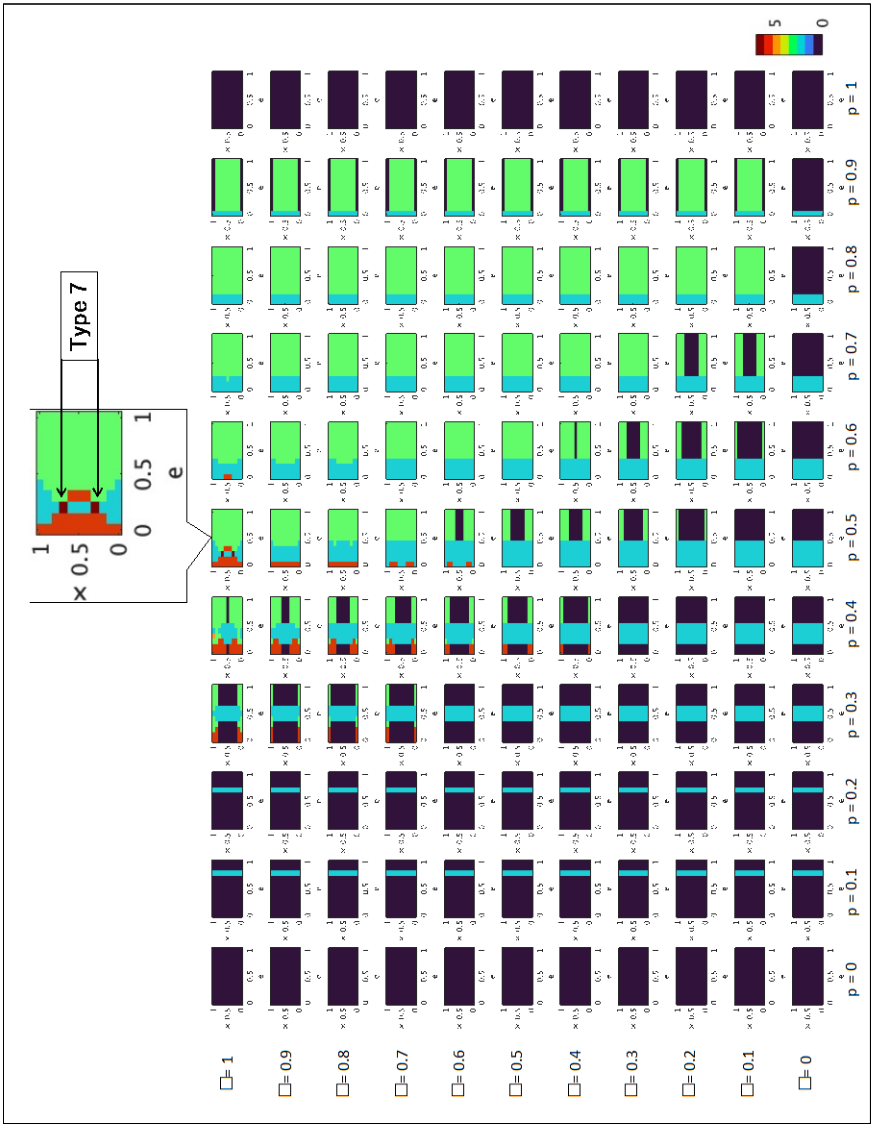


**Figure 6 The comparison of manufacturer profit**
**(Axis legend: Outside horizontal - p; outside vertical - α; small horizontal = e; small vertical – x. Color legend: Light blue - type 2; light green - type 3; orange - type 5; red - type 6; dark red - type 7; navy - no type. The locations of type 7 outcomes are displayed in the enlarged subfigure.)**

Profit/surplus outcome types

Type 1: Co-creation surplus/profit is positive and the largest.

Type 2: Personalization surplus/profit is positive and the largest.

Type 3: In-house R&D surplus/profit is positive and the largest.

Type 4: Co-creation and personalization mark the same surplus/profit, which is positive and larger than in-house R&D.

Type 5: Personalization and in-house R&D mark the same surplus/profit, which is positive and larger than co-creation.

Type 6: Co-creation and in-house R&D mark the same surplus/profit, which is positive and larger than personalization.

Type 7: Co-creation, personalization and in-house R&D mark the same surplus/profit, which is positive.

Figure 4 shows that types 1 and 2 appear as the result of social surplus calculation. In figure 5, the observed consumer surplus types are 2,3 and 6. And in figure 6, there are types 2, 3, 5, 6 and 7.

## V. Discussion

In our suggested model, the parameters of the product price, product quality, profit-sharing ratio, and participation cost affect the decision choice of the players on participating in the innovation sourcing mechanisms. Table 2 summarizes the key outcomes of the numerical simulation.

In Figure 3, there is an area where all players choose to participate in and thus realize the innovation activity (Type 7, marked with dark red). It is mainly located in moderately high levels of price ($p$ = 0.5~ 0.7) and manufacturer's profit-sharing ratio ($\alpha$ = 0.5~1), but low levels of participating cost ($e$ = 0~0.2). This range of parameters can be regarded as being a "favorable" condition for the realization of innovation sourcing methods through the voluntary participation of stakeholders. Another important feature regarding the strategy choice of players is that personalization is the only feasible mechanism (Type 2, light blue) in a vast spectrum of low price ($p$ = 0.1~0.5) and profit-sharing ratio ($\alpha$ = 0~0.5). With this level of the parameter value, the co-creative manufacturer cannot anticipate a positive profit because of its low share of the sales revenue ($pq\alpha$) and high production cost ($q^2$). Since the personalization provider does not spend the innovator wage, it can bear a higher production cost, and it leads to the superiority of the mechanism over co-creation and in-house R&D. On the other hand, co-creation and in-house R&D induces the manufacturer and innovator in the area of Type 6 (red) outcome, where the product quality ($x$ = 0~0.1 and 0.9~1) is located far away from the point of population concentration (0.5). The consumers with niche taste are in small number, but they provide enough incentive for the co-creative manufacturer to produce. The number of buyers in the personalization case is even smaller because of the participation cost; therefore, the production decision is discarded.

When the innovation sourcing mechanisms are compared to each other upon the social surplus, the parameter space is divided into Type 1 and 2 areas. The domination of personalization over co-creation and in-house R&D (Type 2, light blue in Figure 4) can be explained by the utility structure. The user-innovators acquire a product perfectly fitting to their preference if they choose to participate. This leads to a higher consumer surplus and sales quantity when the participation cost is relatively lower. On the other hand, co-creation possesses a different source of social surplus. If the innovator player decides to participate in co-creation, it gains intrinsic satisfaction from participating in the product development process, regardless of the manufacturer's production decision. Because of this payoff component, the social surplus of co-creation is positive even though the manufacturer renounces to produce due to the low price (Type 1, blue in Figure 4, $p$ = 0~0.3).

The area colored with a certain color in Figure 3 demonstrates the relative extent of realization probability of the outcome type corresponding to the color. A large area is colored with light green, orange, and dark red (Type 3, 5, and 6 outcomes, respectively), meaning that the manufacturer in the in-house R&D mechanism chooses to participate in the mechanism and produce the result innovation under a large set of exogenous parameter settings. Also, the mechanism realizes a larger consumer surplus and manufacturer profit than the others, as it can be seen in the light green areas (Type 3) in Figures 5 and 6. But at the same time, the social surplus of in-house R&D becomes smaller than co-creation and personalization in Figure 4. In the in-house R&D mechanism, the innovation worker is mandated to participate if the manufacturer decides to produce, even when its anticipated profit is not positive due to the participation cost. This causes more chances of mechanism realization that leads to higher consumer and manufacturer surplus, but it is not enough to cover the loss of innovator surplus. The personalization mechanism is realized in the second vastest area of exogenous variables including Type 2 outcome (light blue), and the co-creation mechanism induces the player participation only when the product price is relatively low (red and dark red, Type 6 and 7).

## VI. Conclusion

The fast revolution of computer and internet technologies is giving birth to emerging modes for companies to source innovative ideas from outside of the organizational boundary. Comparing the relative effectiveness between the various forms of external innovation sourcing considering the market and organizational environment may be helpful for firms. From this viewpoint, we aim to contribute to the related literature by suggesting a game theory framework for comparing the performance of several innovation sourcing mechanisms and analyzing it by a numerical simulation. There is a range of parameters - product price, product quality, manufacturer-innovator profit sharing ratio, innovation participation cost - where all mechanisms are realized by the voluntary decision of stakeholders. Co-creation displays a higher social surplus than personalization when the participation cost is relatively lower, and the quality of the generated product is in the niche segment of consumers. The suggested decision model simplifies the co-creation and personalization processes in reality to a great extent, making it difficult to compare the results with those of empirical studies. Therefore an extension toward more complicated settings is necessary.

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