

## Decision Model of Corporate R&D Behavior Based on Stimulus and Response Theory

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### Abstract

There is plenty of research about the influence factors of corporate Research and Development (R&D) behavior, but rarely is the define process of corporate R&D behavior explored. The external inducement of corporate R&D behavior is regarding government innovation policy and variation of market demand as external stimulus to corporate R&D behavior, based on Stimulus and Response Theory. Different enterprises may have different R&D behavior outputs that face the same stimulus input, caused by black-box of enterprise's internal state, which comprise two aspects of enterprise characteristics and industry characteristics. Then, an integrity and legible model was founded which describes the excitation process of corporate R&D behavior.

**Keywords:** Stimulus; Response; Corporate R&D Behavior; Model

### Theory of behavior

### Introduction

Technological innovation has played a key core in economic growth and international competition along with the acceleration of industrialization process [1,2]. Technological innovation has always been at the heart of economic and social development [3]. R&D activity is the source of enterprise competitiveness. Only by means of technological innovation, developing new products and production technology that possess the proprietary intellectual property rights, building own brands, can enterprise survival and development in the increasingly fierce international competition. Research and development (R&D) is an important part of enterprising technological innovation, and has always been a hot topic in researching about corporate R&D behavior.

Existing research explores the principal influencing factors of corporate R&D activities, including enterprise internal factors such as enterprise size, pattern of ownership, corporate governance structure, human capital of entrepreneur and so on; and industry factors such as market structure, technological level and industry categories. This also includes factors relevant to government, such as R&D subsidies, tax incentive, government procurement and patent protection. These studies have established solid foundation for us to understand corporate R&D behavior [4].

But we realize that this research mainly focused on some single factor, selected some samples, and analyzed the relation with the factor and corporate R&D activity (mostly are R&D input), thereby to judge the influence of the factor to corporate R&D activity. This research does not tell us how the corporate R&D behavior is stimulated and what is the mechanism of decision. There is not an integrity decision model of corporate R&D behavior combined with various factors. In fact, same as with any behavior, corporate R&D behavior is also a response to stimulus. We aim to construct an integrity decision model of corporate R&D behavior in this paper.

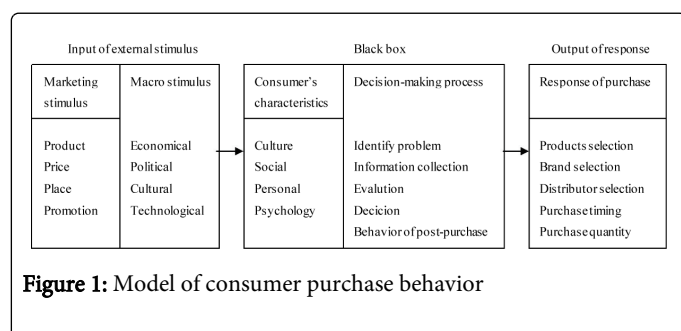
### Behavior

The concept of behavior is widely used, and there still is not a unified and precise definition of behavior. In Wikipedia, behavior is defined as the manner of action of mankind and other animals; it is a response to environment and other organisms or physical body. Behavior has significant meaning for how biology adapts to environment, which can be helpful to avoid the negative influence from external environment. Behavior is defined by one as the action of an organism change in the relation to the environment, it is an output of organism to environment [5]. Another believes that behavior is coordination and response organism faced internal or external stimulus [6]. In spite of disagreement on the definition of behavior, but they do all regard behavior as a method of acclimation to environment change.

Influence on human's behavior come from multiple aspects, and when various factors frequently interact, it is sophisticated. The influence factors can be divided internal and external. External factors mainly mean the objective social environment and natural environment, while internal factors mainly mean all kind of psychological and physiological factors. Kurt Lewin considered that human's behavior depends on the interaction of inner need and external environment. The individual will generate a kind of tension based on interior force field, while the external factors of surroundings work as a fuse. According to Lewin's point of view, internal factors are the fundamental and external factors are the conditional, and the results of the interaction causes an individual's behavior. He put forward the famous formula:  $B=F(P.E)$ , where B represents behavior, P represents the needs of the individual (inner psychological factors), and E represents the surroundings (external factors).

## Theory of behavior decision

An example widely accepted by people, a theory of S-R applied in management, is consumer purchase model proposed by Philip Kotler. This model regards consumer's purchase as a process of stimulus and response. In this process, consumer will make all kinds of choices in the face of external stimulus from environmental and marketing. These choices are exactly the visible consumer purchase behaviors, including many types of selections such as product selection, brand selection, distributor selection, purchase timing, purchase quantity and so on, specifically can be summarized as 5W1H, that is "what, who, where, when, why and how". Obviously, purchase behaviors of different consumers vary greatly. Although they face the same external stimulus, the cause of differences in purchase behaviors comes from different personal characteristics. Kotler divided the personal factors of consumer into two types: consumer's characteristics and decision-making process. These factors are invisible, so called "Black box". That is to say, a specific and visible input of stimulus(external stimulus) can convert a visible output of response(behavior) though an invisible black box(internal state), as shown in Figure 1.



## Corporate R&D behavior

Just like individual's behavior, corporate behavior is also a response to surroundings. According to the involved fields, it can be divided into R&D behavior, marketing behavior, production behavior, financing behavior, human resource management behavior and so on. Based on the above definition of behavior, we can define corporate R&D behavior as the response to external stimulus in terms of R&D.

There are some similarities and differences between corporate R&D behavior and other kinds of behavior such as consumer purchase behavior. The similarity is that they all are a response to external stimulus, a kind of externalization, or visible activities. The difference is that they are two different kinds of activities. After all, the way of corporate R&D behavior is different than 5W1H of consumer purchase behavior as mentioned above. On the basis of existing research, we can describe corporate R&D behavior from the following aspects.

### R&D expenditure input

R&D expenditure input is the most important manner of corporate R&D behavior, and it was one of the R&D behaviors most studied by scholars. R&D expenditure refers to the amount of funds invested in corporate R&D activities. It also can reflect the intensity of R&D expenditure, which is generally measured by the ratio of R&D expenditure to corporate business income. The index is a good way to evaluate corporate R&D behavior.

### R&D personnel

Beside expenditure input, corporate R&D input also includes personnel input. R&D personnel input reflects the general state of staffs who participate in R&D activities in a corporation. Commonly, R&D personnel can be measured by the quantity of corporate R&D staffs or the ratio of quantity R&D staffs to quantity of all staffs. It can also be represented by R&D staff working full-time equivalent, and can even be measured by human capital of R&D staffs which calculated by education years [7].

### R&D mode

R&D mode shows how firms engage in R&D activities. There are many classification of corporate R&D mode. Nelson et al. [8] classified technology innovation as depth innovation and width innovation[8]; Clyde Eirikur Hull [9] classified it as internal innovation, cooperative innovation and external innovation[9]; Henderson et al. [10] classified it as fundamentally innovation, architectural innovation, incremental innovation and modular innovation; someone classified it as incremental innovation and radical innovation according to degree of technology change, and someone classified independent innovation as original innovation, integrated innovation and digestive absorption innovation [10].

We believe behavior is a response to environment; behavior only refers to the action itself and not to the results of the action. Similarly, corporate R&D behavior only refers to the action or way of action in the R&D field. It does not include the result or performance of R&D action, just like the two different concepts of student's learning behavior and learning outcome. It is very important to clarify the concept of R&D behavior. In fact, scholars launched lots of research on R&D performance, and some of them regarded R&D performance as R&D behavior [11].

Back to the classifications of R&D mode mentioned above, some of the classification are based on R&D results, such as depth innovation and width innovation, incremental innovation and radical innovation. According to our understanding of the concept of R&D behavior, they do not belong to the category of R&D behavior. We discuss the R&D mode mainly from the behavioral agent and behavioral manner.

From the aspect of behavior agent, the corporate R&D mode can be divided into independent R&D, cooperative R&D and commissioned R&D. Independent R&D means the corporate R&D activities are completely independent by itself; cooperative R&D means the corporate R&D activities are carried by enterprise and other institutions; commissioned R&D means the R&D activities are entrusted to other institutions and enterprise does not engage in R&D itself.

From the aspect of behavioral manner, the corporate R&D mode can be divided into original innovation, integrated innovation and imitative innovation. Original innovation refers enterprise pioneer to develop new products or to explore new processes. Imitative innovation refers enterprise absorb and re-innovate based on imitation of other innovations. For example, developing countries conduct localization reform to the new products or processes owned by developed countries combined with local context. There are disagreements about integrity innovation, we argue integrity is not original innovation nor imitation innovation, rather similar to the cross-over study in scientific research. That is to say creatively apply

the new product, knowledge or process of other industry or field to own industry or field, thereby to achieve a kind of new combination.

Of course, more about the classification of R&D mode is still broad and needs further clarification. For instance, cooperative R&D can be further subdivided according to the cooperation partner or cooperation way. According to the cooperation partner (whom enterprise cooperate with), is the partner universities, research institutions or enterprises? Furthermore, if cooperate with enterprises, what kind of enterprise would it be? Suppliers, distributors or same industry companies? According to the cooperation way, it is contract, strategic alliances or technology transfer, etc. These all belong to the category of corporate R&D behavior, and need to further study.

### Orientation of corporate R&D

Orientation refers to the research field of enterprise mainly engaged in R&D activities. The research fields are different between different enterprises. According to the general classification method, science and technology can be divided into basic research, applied research and trial development. Sometimes it can also be divided into product innovation and process innovation.

It need to be pointed out, corporate R&D behavior involves a wide range of content, not only the several main behavior mentioned above. It is hard to list all of them in this paper, but it does not prevent us from building the theory model of corporate R&D behavior.

### Decision model of corporate R&D behavior

As mentioned above, corporate R&D behavior is a kind of specific and visible response to adapt to the environment. We have already analyzed the connotation of corporate R&D behavior, now we will try to establish a theory model to describe the decision process of corporate R&D behavior.

#### External stimulus

Corporate R&D behavior is a response to external stimulus, and the external stimulus can be divided into two categories, government innovation policy and market demand change.

First is government innovation policy. Innovation has significantly positive external effects, so governments will issue a series of policies to encourage and promote enterprise innovation. Innovation policy elaborated in World War II. Innovation policy has emerged gradually as a policy distinct from both science and industry policies. After decades of development, the notion of innovation policy has become very fashionable, and innovation policy has been implemented as an important policy tools in most countries in the world.

Government innovation policy mainly includes some policy tools such as financial subsidy, tax incentive, government procurement, and patent protection. Different policy tools have different orientation and function, but all of these tools are

aimed to inspire the enthusiasm of enterprise innovation through the appropriate way to supporting innovators, removing obstacles and forming innovative environment. Government innovation policy can promote enterprise to engage in innovation, so we can regard innovation policy as a 'pushing force' (Note: Corporate R&D activities are not completely equal to innovation. But R&D is a very important content of innovation, so in this article, we are not strictly distinguishing between the two concepts).

Secondly is the change of market demand. The key factor of enterprise's success is the ability to satisfy the customer's demand. Especially nowadays, where customer demands are diversified, personalized and rapidly changing, only if the enterprises engage in R&D activities can they improve their ability to satisfy the customer demand. Change of customer demand is the driving force of corporate R&D activities, and can play a role as pulling and guidance to corporate R&D. So, we can regard change of market demand as a 'pulling force'.

Under the interaction of the pushing force from government innovation policy and the pulling force from change of market demand, the external stimulus induce corporate R&D behavior.

### Black box

External stimulus induces corporate R&D behavior, but different enterprises tend to show different behaviors that face the same external stimulus, just like purchase behaviors of difference consumers varied greatly as we mentioned above. That is to say, the same input will convert to different output, and the reason is implicit in the "Black box", which reflects different enterprise's internal states.

What is the black box? According to existing research, we can divide the enterprise's internal states into two categories. One is the enterprise's own characteristics, and the other is industry characteristics.

### Enterprise's own characteristics

Discrepancy of enterprise's own characteristics will cause different corporate R&D behavior when enterprises face the same external stimulus. The enterprise's own characteristics include various factors such as firm size, firm life, pattern of ownership, corporate governance, human capital, geographical position, and so on.

#### (1) Firm size

There are many factors that influence corporate R&D behavior, and firm size is one of the factors that scholars focus on the most. Schumpeter [12] creatively explored the influence of firm size on R&D activities, and raised the famous judgment that firm size can promote R&D. Since then, the research efforts have continued on the relationship of firm size and R&D behavior, creating a series of theoretical and empirical research literatures, but no consensus about the influence of firm size to R&D behavior [13].

For instance, Villard [14] found that the proportion of enterprise engaged in R&D will increase along with the firm size; Scherer [15], Soete [16] believed there was an inverse U-shaped relationship between firm size and R&D activities; but Bound et al. [17], Pavitt et al. [18] draw the opposite conclusion; that there was a U-shaped relationship between firm size and intensity of R&D expenditure.

#### (2) Corporate governance

R&D activity has characteristics such as high risk, high investment and long time period, it is relevant with the company's decision-making mechanism influenced by corporate governance structure. In a company, interest appeal varies greatly between different stakeholders, such as owner and operator, big shareholders and small shareholders, so their attitude towards corporate R&D activities may vary. In addition, scholars also pay close attention to other issues related to

corporate governance: ownership concentration, operator shareholding, external institutional investors, and so on.

Jensen and Meckling [19] argued that it is helpful to get more support from operators on technology innovation, through implementing stock ownership incentives to operators. Shaker et al., [20] found a significant inverse U-shaped relationship between board size and innovation. While, Baysinger et al., [21], Shaker [22] found the negative correlation between the proportion of outside director and enterprise's R&D investment, Feng and wen [23] discovered the inverse U-shaped relationship between ownership concentration and enterprise's R&D investment, and also discovered the negative correlation between proportion of state-owned shareholding and enterprise's R&D investment. Wen and Feng [24] discussed the influence of different types of institutional investors to enterprise's R&D investment, and found the different impact of Qualified Foreign Institutional Investors(QFII), insurance capital, and securities investment funds. Shu and chen [25] found that shareholding of institutional investors and operators have a positive influence to enterprise's R&D investment.

### (3) Pattern of ownership

China is in the process of economic transition, enterprises have various patterns of ownership, and Chinese scholars research the relationship between patterns of ownership and corporate R&D behavior combined with Chinese practical situations. Zhou and Luo [26] discovered that private enterprise of a large size is more innovative, but it does not adapt to state-owned enterprises. An et al., [27] pointed that foreign firms' R&D intensity is the highest, while state-owned and collective-owned enterprise is the lowest. Wu held a systematic research on the issue, first finding that state-owned property rights have no significant positive influence on innovation, then found that the state-owned property rights have significant positive influence on R&D personnel. Furthermore a comprehensive evaluation of the discrepancy on R&D expenditure, innovation efficiency and productivity efficiency between different ownership enterprises included foreign company, private company, and state-owned company. It was discovered that when R&D expenditure of private company is highest, foreign company and state-owned company have no significant difference [28-30](Note: This article only focused on corporate R&D behavior, we believe that innovation efficiency is the result of innovation activity, not belongs to the category of R&D behavior. So, we only consider the influence of ownership forms to R&D investment. In fact, scholars have carried out lots of researches about the influence factors of innovation performance, this article does not involve the content).

Lin et al., [31] draw the analogous conclusion. Some other scholars draw different conclusions, Li and song [32] pointed out that R&D intensity of state-owned firm is greater than private firm.

### Industry characteristics

Different industries have different characteristics, such as the degree of market competition, technological level of industry and industry type. These factors can also affect corporate R&D behavior. We put them as belonging to the category of "black box" because they can induce different corporate R&D behavior when enterprises face same external stimulus.

### (1) Market structure

The hypothesis that monopoly power is helpful to enterprise innovation activities first proposed by Schumpeter promoted this kind of research. Since then, it has been the most important problem attracting scholars concentration.

Scholars have launched systematic research on the relationship between market structure and corporate R&D behavior. Many scholars identified the degree of market competition by industry market concentration, and studied the effect of monopoly on corporate R&D behavior. An inverted U-shaped relationship has been found between market concentration(measured by four firm concentration), intensity of R&D personnel [33], and intensity of R&D expenditure [34]. Kamien et al. [35] discovered that market concentration has a slight positive influence on enterprise innovation activity; Geroski [36] found evidence against the hypothesis that enhancing competition will weaken entrepreneurship [33,34,35,36].

### (2) Technological level of industry

Technological level exists differently in different industries; technological level of some new technology industries is high, and it is low in some traditional industries. The technological level of industry will affect the corporate R&D behavior. Cohen et al., [37] argued that about 50% of the discrepancy of enterprise's R&D expenditure intensity can be contributed to industry technological disparity. Globerman [38] found that in high technological opportunities industry, market concentration has a significant negative influence on the intensity of R&D personnel; in low technological opportunities industry, market concentration has no significant positive effect on the intensity of R&D personnel. An et al. [27] found intensity of R&D expenditure in medical manufacturing industry is 10.25%, far higher than 0.25% in oil processing and coking industry. Discrepancy of technical characteristics and market characteristics between different industries lead to the endogenous difference in corporate R&D behavior. Zhang et al. [39] discovered that in high technological opportunities industry, enterprise was more inclined to independent innovation; and in traditional industry, enterprise was more inclined to technology import or imitation innovation. In fact, there are many external factors which influence corporate R&D behavior, besides the factors mentioned above. It is hard to list all of them in this article, but it does not prevent us to build the theory model of corporate R&D behavior.

### Decision model of corporate R&D behavior

We have already analyzed corporate R&D behavior, the external factors and internal factors, now we can build the decision model of corporate R&D behavior, as shown in Figure 2.

Figure 2 shows clearly the excitation process of corporate R&D behavior, the external stimulus from government innovation policy and change of market demands induce corporate R&D behavior. This reflects a decision process from input of stimulus to output of behavior. Just as mentioned above, the description about external stimulus, black box and corporate R&D behavior may not be complete, and some factors may not be mentioned, but the mechanism of "Stimulus-Response" illustrated by the model is still appropriate. The model can help us completely understand the excitation process and influence factors in all steps.

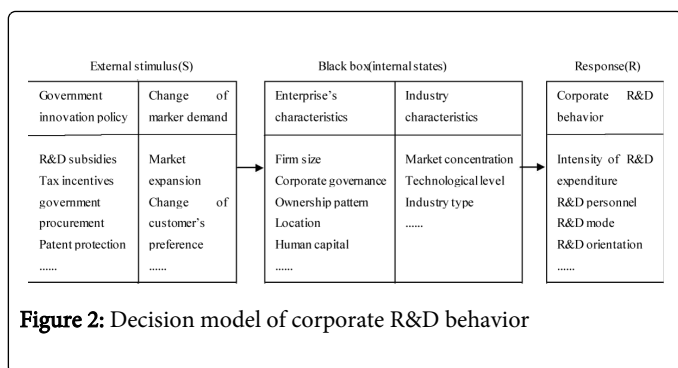


Figure 2: Decision model of corporate R&D behavior

## Conclusion

Innovation is the source of enterprise competition. Scholars have done plenty of research about the influence factors on corporate R&D behavior, but rarely do they explore the excitation process of corporate R&D behavior from a holistic perspective. We analyzed the connotation of corporate R&D behavior based on theory of behavior. We classified the influence factors of corporate R&D behavior from two aspects, which are external and internal. Under the interaction of the pushing force from government innovation policy and the pulling force from change of market demand, the external stimulus induces corporate R&D behavior. Different enterprises may have different R&D behavior outputs yet face the same stimulus input, caused by black-box of enterprise's internal state. This comprises the two aspects of enterprise characteristics and industry characteristics. An integrity and legible model was developed which describe the excitation process of corporate R&D behavior.

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