

# Hyper-cycle Self-organizing Evolution of Industrial Innovation

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**Abstract** Industrial innovation is the process of the formation and promotion of industrial competitive advantage. Using biological evolution theory and self-organization theory, this paper reveals the dynamic evolutionary law of industrial innovation. It also points out that industrial innovation is a hyper-cycle evolutionary process, which is evolved from industrial formation innovation, industrial organization innovation to industrial structure innovation. Induced by S&T innovation, the synergetic function produced by product innovation, technological innovation and market innovation, promotes the development of industrial formation innovation, industrial organization innovation and industrial structure innovation. Such an evolution demonstrates a higher cycle level and stronger self-organizing ability.

**Key words** industrial Innovation, self-organization evolution, hyper-cycle

## 1 Introduction

It is a new field of innovation theory that uses biological evolution theory and self-organization principles and methods to research the dynamic evolutionary law of innovation. As Nelson and Winter (1982) have pointed out evolution theory has the most important applications to research on industrial changes<sup>[1]</sup>. Chris Freeman and Luc Soete (1997) have discussed that evolutionary point of view is the most important, when studying on technological changes<sup>[2]</sup>. John Ziman (2000) illuminated that the industrial technological innovation can be considered as a co-evolution ecosystem<sup>[3]</sup>.

Evolution theory has wide applications in industrial innovation. It lays theoretical and methodological basis for the developing countries to achieve success of industrial innovation, so that catch up with developed industries and upgrade competitive advantage in the field of knowledge innovation. From the perspective of industrial evolution, this paper use Hyper-cycle theory to research industrial innovation evolution. It will not only enrich the academic research results, but also has important realistic significance on constituting industrial policy and improving international competitiveness.

The remainder of this paper is structured as follows. Section 2 analyzes the premise of hyper-cycle evolution. We introduce the three basic forms of industrial innovation and draw an analogy between biological evolution system and industrial innovation evolution in section 3. Section 4 reveals the hyper-cycle evolutionary mechanism of the industrial innovation. We analyze the industrial innovation of Japan's Electron Industry as a case in section 5. Finally, we summarize our main findings and conclude the study.

## 2 The Premise of Hyper-cycle Structure

Hyper-cycle theory is a principle of natural self-organization, which is advanced by M • Eigen (1979). According to the level of evolution, there are three levels which are reaction cycle, catalytic cycle and hyper-cycle<sup>[4]</sup>. Hyper-cycle, a specific mechanism of the origin of life, can explain evolutionary process of the system structure. Selective Evolutionary theory is the guiding principle of hyper-cycle, and is also the premise of hyper-cycle structure. When we use Hyper-cycle theory to study on industrial innovation evolution, it should accord with Selective Evolutionary theory first, that is, it should illuminate the elements of selectivity and evolution, and necessary conditions of engendering Darwin Behavior.

### 2.1 Metabolism

The metabolism of industrial innovation evolution is on the basis of opposites and uniformity, which is assimilation and catabolism. This contradiction is the source of evolution. Industrial system constantly obtains innovative resources from outside, such as personnel, products, money, technology, information, and combines them by the inside operating mechanism. After various internal circulations, digestion and absorption, they turn to production factors. This process is assimilation. On the contrary, industries can create new products by consuming materials. Products and technologies can improve through product innovation, industrial innovation, and market innovation etc. Then industrial

competitive advantages will be enhanced. The process is called catabolism. Assimilation and catabolism is mutual condition. One can not do without the other. Otherwise conversion will stop, and the industry dies simultaneously.

## 2.2 Self-replication

The molecular structure in competition needs a kind of internal capacity to guide its own synthesis. This self-catalyze is necessary for any self-selection mechanism. It will lose stability, when there is a single copy which is beneficial to mutation. Therefore, self-replication capacity is a necessary condition to accumulate and preserve information for system. With the development of an enterprise or industry, innovation is self-replicating. Their technology and capacity of personnel constantly improve through self-accumulation. There are traces of original innovation as well as reproduction and self-replication. It upgrades spiral and turns to a new self, thereby achieve the success of industrial innovation.

## 2.3 Variation

Variation in physics always associated with self-replication, but it is also necessary for evolution. Variation means new information emerging. It is likely to form mutation which is suitable for survival. However, when it evolves fastest, mutation rate has a certain threshold value which can not exceed, except that all the accumulated information is lost in the course of evolution. In process of industrial innovation, there are many changes such as economic policy, technology, and supply channels of raw material, enterprises strategies competitive situation, and users' needs. Any change is likely to affect success or failure of innovation, so that a qualitative change would happen in industrial innovation.

## 2.4 Dynamic Differential Equation of Industrial Innovation Evolution

We suppose that  $i$  is a enterprise which can self-replicate.  $x_i$  stands for its growing rate.  $\dot{x} = dx/dt$  refers to the changing coefficient of the enterprise.  $A_i Q_i x_i$  stands for spontaneous metabolism, that is, assimilation.  $D_i x_i$  is spontaneous catabolism. Spontaneity means the two reactions have positive appetency.  $A_i$  contains all the matter and energy for innovation. Quality gene  $Q$  describes variation.  $Q_i$  refers to the rate of correct replication.  $w_{ik}$  is a parameter which stands for the contribution.  $\sum_{k \neq i} w_{ik} x_k$  is the total contribution.  $\Phi_i$  is the individual flow, which represents the success or failure of innovation. And then we can get the dynamic differential equation that describes the process of industrial innovation evolution. As shown in Equation 1.

$$\dot{x} = (A_i Q_i - D_i) x_i + \sum_{k \neq i} w_{ik} x_k + \Phi_i \quad (1)$$

## 3 The Basic Forms of Industrial Innovation

Chris Freeman, founder of Industrial Innovation Theory, has pointed out innovation is a systemic concept, including technical innovation, product innovation, technological innovation, management innovation (including organizational innovation) and market innovation. We think that industrial innovation is a kind of systemic innovation, which contains knowledge innovation, technology innovation, market innovation and organizational innovation etc. Knowledge innovation is originator, while technology innovation is core. It is a process of changing industrial state, including change industrial form and structure. Therefore, the process of industrial innovation is that of enhancing industrial competitive advantage. There are three basic forms of industrial innovation, namely industrial formation innovation, industrial organization innovation and industrial structure innovation.

### 3.1 Industrial Formation Innovation

Industrial formation innovation refers to innovation of a single industry, that is, the formation process of a new industry. It can be described as follows. Enterprises, industrial basic elements, have initially established division system by mutual cooperation. Then they integrate various resources develop from scratch, eventually offer products or service independently. The process of industrial formation innovation is just the course of improving competitive advantage, that is, the formation process of a new industry through knowledge innovation, technological innovation, and technological innovation.

For example, cassette recorder was invented by Philip Co. of Holland in 1970. In 1975 Sony Co. made the video recorder first. Then Panasonic Co. carried out market innovation to improve quality, reduce product capacity, cut production cost and price. As a result, market ratio of Panasonic Co. was higher than that of Sony Co. It is product innovation, technical innovation and market innovation that realize the process of industrial formation innovation.

### 3.2 Industrial Organization Innovation

Industrial organization innovation is the fundamental changes in organizational structure. Compared with technological innovation, technological imitation costs much lower and has less risk, so the achievements in technological innovation can be easily imitated. In order to maintain sustainable competitiveness, an industry must have organization innovation. When it comes to Handicraft Industry, Large-scale Machine Production is industrial organization innovation. So is the emergence of monopoly industries. Since market competes fiercely, the original form of industrial organization has been some new changes, such as previously the original individual enterprises expand through mergers and acquisitions. Now many small and medium enterprises through innovative network concentrate in the same area to achieve industrial-scale expansion and industrial organization innovation has also realized. Scott and Storper (1992) pointed out the world becomes obvious economic mosaic in a form because of industrial agglomeration, which created the main wealth of world<sup>[5]</sup>. Such as in middle of 1990s, the amount of 380 industrial agglomeration areas in the United States gave birth to 60% output. Not only there is car industrial agglomeration of 20th century in Detroit, but also there is Silicon Valley which appears in 1960s, solids in 1980s, considered as the classic industrial agglomeration. Today, industrial agglomeration has competitive advantage and plays an important role on the development of economy.

### 3.3 Industrial Structure Innovation

Industrial structure innovation refers to the structure changes of traditional industrial system, that is to say, industrial border becomes fuzzy, industrial structure turns flexible, and new industrial system is gradually taking shape, which is called the emergence of industrial convergence. Schumpeter (1990) said that innovation is similar to Biological Mutation Theory<sup>[6]</sup>. That is to reform the economic structure continuously, to destroy the old and create new structures, to mutate a kind of "creative destruction". Therefore, Industrial structure innovation can be considered as evolution of industrial structure.

Since 1990s, with the development of information and the extensive application of Internet, it pushes forward to the convergence of publishing, television, music, advertisement and education etc. According to the analysis, in recent years the contribution rate of IT industry to economy in the United States is over 35%. At present, through industrial convergence, information technique is used in every aspect of manufacturing industry and has revolutionary function.

## 4 Hyper-cycle Structure of Industrial Innovation

The three basic forms of industrial innovation are just like the three level cycle of evolution. So we can use Hyper-cycle theory to research the dynamic evolution law of industry innovation.

### 4.1 Reaction Cycle: Industrial Formation Innovation

Industrial formation innovation is on the basis of knowledge innovation, technological invention and so on. Industry is a new one. There is no competitor in the market, so it has absolute advantage. Through product innovation, products are enriched and unit costs become lower. Productivity is improved too. Through technological innovation, processes and production equipment are updated, and production methods are reformed. So productivity is also improved and competitive advantage is enhanced. Through market innovation, many new markets emerge. It realizes commercialization, extends product life cycle, and accesses to more lasting innovation profits, thereby enhances industrial competitiveness.

Industry formation innovation is the process of a single industrial innovation, equaled to a reaction cycle. For example, enterprises that make the same product are corresponding to mutants. Product innovation, technological innovation, and market innovation are similar to enzyme for replication. After reaction cycle, it generates new technologies, new processes, and new markets, emerging more enterprises. Finally it forms a new industry. As shown in Figure 1. Here, E stands for Enterprise.

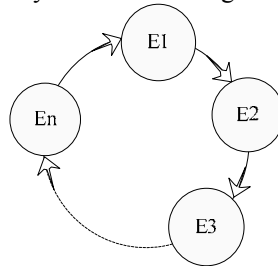


Figure 1 Reaction Cycle: Industrial Formation Innovation

#### 4.2 Catalytic Cycle: Industrial Organization Innovation

Enterprises that have the same products cluster in the same area, sharing infrastructure and services, labor pool and technology spillovers. Thus these enterprises save transportation costs, management costs, and transaction costs. Previously there is competitive relationship among enterprises of the same industry, but now in condition of industrial agglomeration, cooperative relation comes into being. At last it achieves industrial organization innovation. Industrial agglomeration has advantages of combining resources. By industrial agglomeration, it provides new business or services, and good environment for innovation. Thereby innovative cooperation is strengthened between users and producers. It will help to improve productivity, enhance competitive advantage. Industrial agglomeration is a form of organizational innovation. It is as well as a new space theory of industrial organization. It is that mutant has variation in the system. So catalytic cycle is formed in the industry, which is industrial organization innovation. As shown in Figure 2. Here, IA stands for Industrial Agglomeration.

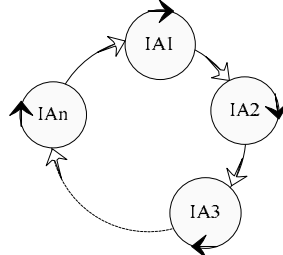


Figure 2 Catalytic Cycle: Industrial Organization Innovation

#### 4.3 Hyper-cycle: Industrial Structure Innovation

With the emergence of industrial convergence, the original Industrial Classification system is broken by operational convergence and technology convergence. The borders in technology, business and market are disappeared. A new integrated industrial system forms. Industry convergence will be conducive to integrate resources and avoid repeated construction. It promotes economy optimized, industrial structure adjusted and industry value chain formed. Industry convergence can increase the overall economic benefits, so as to enhance industrial competitiveness. Industry convergence will create a new highly competitive form and realize the evolution of industrial structure. This constitutes a hyper-cycle structure. As shown in Figure 3. Here, IC stands for Industrial Convergence.

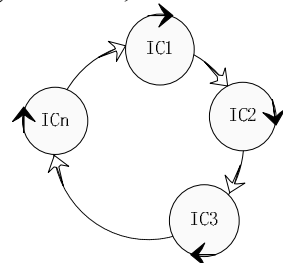


Figure 3 Hyper-cycle: Industrial Structure Innovation

### 5 Empirical Analysis: Industrial Innovation of Japan's Electron Industry

After War II, Japan's electron industry develops fast. In 1966, Japan's industries, universities and research departments innovated together, first developed the integrated circuit technique into color television. But the wireless company of the United States couldn't sale the color television of solid model until 1973. Middle of 1970s, Japan's color television occupied half of the production quota of world and exports the three quarters of world.

In 1970s Japan successfully makes use of the electronics technique that the United States used for public product, home appliances and car etc. It is industrial convergence that helps Japan access to the market advantage. Table 1 describes the development of Japan's electron industry.

**Table 1 the Development of Japan's Electron Industry**

year	Production value ( thousand billion yen )	period	increasing ratio per year ( % )
1950	0.02	/	/
1960	3.40	1950~60s	38
1970	9.00	1960~70s	21
1980	24.20	1970~80s	10

Japan has stronger spirit of absorption, digestion and innovation. Though Japan's electronic technique mostly introduces from the United States, Japan's own technique level has overstepped the United States through technical innovation, and organizational innovation etc. It has strong competition ability in the world market. The development of Japan's electron industry is the process of industrial innovation.

## 6 Conclusions

Industrial innovation is a hyper-cycle evolutionary process. It is from industrial formation innovation, industrial organization innovation to industrial structure innovation. Industrial formation innovation refers to innovation of a single industry, equaled to a reaction cycle. Industrial organization innovation is the fundamental changes in organizational structure, which is the catalytic cycle basis on industrial formation innovation. Industrial structure innovation refers to industrial border turns fuzzy, industrial structure becomes flexible, and new industrial system is gradually taking shape. It's hyper-cycle. Induced by S&T innovation, the synergetic function produced by product innovation, technological innovation and market innovation, promotes industrial formation innovation, organization innovation and structure innovation. Cycle level is higher, and self-organizing is much stronger. In order to enhance national and regional industrial competitiveness, we should strengthen S&T innovation, and promote industrial formation conversion, industrial agglomeration and industrial convergence.

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