

# TOWARD EVOLUTIONARY INNOVATION THEORY

**A.A. Seifoddin, M. H. Salimi, and M. M. Seyed Esfahani**

**Abstract:** *Innovations, commercialized by new or old established firms, located at the core of industrial renewal process. The innovation concept has suffered transformations, along with the evolution of the models that try to explain and understand the innovation process. The innovative process corresponds to all activities that generate technological changes and the dynamic interaction between them, not necessarily being novelties. Linier model, Chain-Linked Model and National Innovation Systems (NIS) Approach, are three models that have developed for innovation process. Innovation process can be viewed as evolutionary process. One can recognize some mechanism for innovation evolution. These are grouped into two classes; those that increase configurations variation and those that decrease it. Emergence of knowledge, knowledge flow and recombination are the mechanism to increase variation of configuration. Internal and external selections are the mechanism to selecting. Innovation operators are evolutionary operators that create new combinations of configuration and increase variation. This paper develops an evolutionary cycle in innovation process and extends evolutionary mechanisms of innovation.*

**Keywords:** *innovation, evolutionary theory of innovation, innovation presses, evolution, selection, fitness, variation, innovation-operators*

## 1. Introduction

Questions regarding the determinants of long-term growth and the possibility of influencing this growth via economic policy have returned to the centre of economic debate [1]. The process of industrial renewal is fundamental for economic growth and development. Innovations, commercialized by new or old established firms, are at the core of this process. If one wants to analyze the emergence and decline of different industries over time, the focal point should be on the commercialization of innovations in their entrepreneurial context, in line with Schumpeterian and evolutionary economics [2]. In many industries, competitive advantage depends on a firm's ability to foster innovation and turn first ideas into innovative processes or marketable products [3]. This explains the increasing importance of innovation theory and policy: the processes of technological progress are essential to the explanation of economic growth.

Knowledge, innovation and technological progress have been the core themes of research in macro and microeconomics, innovation processes and strategy. Schumpeter's [4] seminal book "Capitalism, Socialism and Democracy" is often credited with originating and stimulating interest, theoretical development and research on processes of creative destruction, involving new products, processes, markets, resources and organizations, and the role of the entrepreneur.

The destruction of a creative character refers to the dynamic mechanism connected to the continuous process of change in the capitalist development, where old and well-known products or processes are made obsolete and, thus, lose their value, as new innovations (re-combinations) are introduced in the market. In this way, innovations do for a time create a market situation of monopolistic character for the innovator who gains so-called Schumpeterian rents. Over time this monopoly situation is eroded both by other firms' imitation of these products and by firms that constantly bring forward new 'destroying' re-combinations to solve the same problem or feed the same market demand [5]. It is not only the introduction of new products, which is fundamental. Also, the ability to introduce something done in new ways has long been seen as a source of competitiveness. Firms build capabilities in an industry environment in competition with rivals. In the competitive process each of the firms employs its bundle of capabilities. A number of firms seek to generate primary competitive advantages by introducing new capabilities to the industry, for example, doing something faster, cheaper, higher quality,

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in the right time, etc. As a response other firms try to replicate these capabilities. Thus, the innovation vs. imitation relation constitutes the 'endogenous' force of industry evolution. This repeating death and renewal of firms and products leads to a constant cycle of innovation. To innovate is costly, uncertain and complex, yet, unavoidable for the firm to pursue if the firm wish to survive [6].

The innovation concept has suffered transformations, along with the evolution of the models that try to explain and understand the innovation process. It is now generally accepted that innovation is a complex process that involves not only the innovative firm but also a system of interactions and interdependencies among that firm and other organizations and institutions; and that the behavior of the agents is influenced by the institutional set up, by cultural and historical factors that are country specific. The great majority of this interactions and interdependencies are rooted in the normal channels of everyday economic activities (routine activities). So, the existing structure of economic relations and activities affects where and the manner that economic agents interact and innovate [7,8].

The great importance of innovation has led to a broad range of literature dealing with the wide field of innovation.[9,10] In the research on creativity, the individual is identified as the source of innovation, sometimes within a group of individuals.[11,12] The literature on entrepreneurship follows the individual through the process of innovation.[13-16] The identification of the stages in the process of innovation has been the aim of many studies in the literature on innovation.[17-10] There have also been many attempts to identify and structure, the success factors and barriers of individual and organization innovations. [20-22] Apart from a few exceptions,[17] most studies on the factors fostering and hindering innovation use static concepts [23,11]. Studies which take a closer look on the location of barriers in the process of innovation are limited to just a small part of this process or offer only a very broad concept[17] of barriers in the innovation process.

The paper is organized as follows. After a short review of literature background and evolutionary concepts related to innovation, an evolutionary concept of innovation shall extend. After that paper advances a new theoretical framework for evolutionary innovation by introducing evolutionary cycle in innovation process. Then paper classifies evolutionary innovation mechanisms into two groups; those that increase the variation of configurations and those that decrease variation by selecting. Subsequently it develops some new concepts for selection and variation such as innovation operators and finally delivers the conclusions.

## 2. Literature Background

### 2-1. Innovation

There are various definitions of innovation that appear in the literature. The purpose of this section is to compare some of the major definitions:

Joseph Schumpeter is often thought of as the first economist to draw attention to the importance of innovation. Schumpeterian definition is the distinction between inventions, and their commercialization as innovations through entrepreneurial activity. He defined, in the 1930s, five types of innovation (see [24]). Schumpeter [4] pointed out that "the fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers' goods, the new methods of production or transportation, the new markets, the new forms of industrial organization that capitalist enterprise creates".

Edquist [25] defined that Innovations are new creations of economic significance normally carried out by firms (or sometimes individuals). They may be brand new, but are more often new combinations of existing elements. It is a matter of what is produced by firms and how.

Other authors such as Yosty peter [26], Quinn [27] know that innovation is successful implementation of creative idea in organization (for the first time). Rogers [28] believes that innovation is only regarded to have occurred if it has been implemented or commercialized in some way. The creation of abstract knowledge, or the invention of new products or processes, is not normally considered innovation until it has been productively incorporated into the enterprise's activities.

Some researchers regard innovation as only those ideas that are radical or totally new to the world. For example, Grupp [29] averred that "innovation occurs only in the first company to complete industrial R&D which culminates in the launch of the first product onto the markets.

Other researchers adopt a broader view of innovation. For example, Van de Ven et al. [30] defined innovation as "the process of developing and implementing a new idea. The idea may be a recombination of old ideas, a scheme that challenges the present order, a formula or a unique approach that is perceived as new by the individuals involved." Similarly, Pennings and Harianto [31] suggested, "Innovation represents the adoption of a new idea, process, product or service, developed internally or acquired from the external environment." The perspective that an idea is an innovation as long as the people involved view it as new, is also shared by other researchers (e.g., Li and Atuahene-Gima [32]; Nord and Tucker [33]; Zaltman, Duncan and Holbek [17]).

Andreas W.O. Böhringer, [34] improved Slappendel, C. [35], Hauschildt, J. [36], Kieser, A.; Kubicek, H. [37], King, N. [19] and Kimberly, J. [38] definition's of Innovation and define innovation as a process that implies a change of the status quo. This process covers the emergence of that change until its implementation and use. It aims at a direct or indirect economic success for the relevant organization and results in products, services, objects and processes that are new to the organization and its relevant environment.

#### 2-1-1. Taxonomies of Innovations

The first taxonomy return to Schumpeter who recognizes five types of innovation [24].

1. Introduction of a new product or a qualitative change in an existing product,
2. Process innovation new to an industry,
3. The opening of a new market,
4. Development of new sources of supply for raw materials or other inputs,
5. Changes in industrial organization.

Sethi, Smith, and Park [39], Song and Parry [40], Song and Xie [41] stress on product innovation and the degree of product newness to the developing firm and the marketplace.

The Oslo Manual, produced by the OECD [24], aims to set a benchmark for innovation surveys and research for its members, concentrate on the first two Schumpeter categories, which it claims are relatively easier to define and measure. Thom, N. [42] categorize innovation into process-, social- and product-innovations.

Another taxonomy is the degree of novelty of innovations. Mensch [43], Abernathy & Clark [44], Utterback [45] distinction between:

1. Continuous small incremental changes,
2. Discontinuous radical innovations.

Edquist and Riddell [46] add “Massive shifts in some pervasive ‘general purpose technology’ (GPT)”, sometimes called ‘techno-economic paradigms’ to above list.

Tushman, M., O’Reilly, Ch. [47] has called this evolutionary vs. revolutionary innovations on the level of technology life cycles, instead of incremental and radical innovations.

Daft, R. [48], West, M.A.; Farr, J.L.[49] and Damanpour [9] differentiation between administrative and technical innovations.

Freeman & Perez [50], which defines innovations according to their socio-economic effects and patterns of diffusion. They divide innovation in two types:

1. Competence enhancing innovations,
2. Competence destroying innovations,

This approach takes the point of departure in a partial critic of basic Schumpeterian distinctions between incremental and radical innovations, since these arguably overemphasize the technical novelty and radicalness of innovations and wrongfully ignore the competitive implications of different types of innovation for firms' competencies.

Authors within this tradition introduce a multi-faceted view of innovations that is particularly useful for innovation studies, since it essentially integrates different aspects of firm competencies into taxonomy of different types of innovations (Abernathy & Clark [44], Tushman & Anderson [51], Teece [52], Henderson & Clark [53], Phillips [54]).

Cardinal [55] does not find much difference between incremental and radical innovation with regard to uncertainty, an important variable. Damanpour [9] finds that types of innovation are not highly effective

moderators of the determinant-innovation relation. Van de Ven [56] also rejects a differentiation between types of innovation; since an innovation always includes aspects of different types.

## 2-2. Innovation Process

Innovation should be understood as a process. The innovative process corresponds to all activities that generate technological changes and the dynamic interaction between them, not necessarily being novelties. The concepts of different authors describing the process of innovation do not differ fundamentally. Wolfe [10] has analyzed different models of the stages of the innovation process and summarized them into a ten-stage process of innovation:

1. Idea conception,
2. Awareness (decision making unit becomes aware of innovations existence),
3. Matching (problem or opportunity is matched to the innovation),
4. Appraisal (costs and benefits are appraised),
5. Persuasion (sources of support and/or opposition attempt to influence the process),
6. Adoption decision (decision is made to adopt or to reject the innovation),
7. Implementation (innovation is implemented...),
8. Confirmation (... reviewed and confirmed or reversed),
9. Reutilization (innovation becomes organizational routine),
10. Infusion (innovation is applied to its fullest potential).

Since the acceptance of the concept of innovation process, there have developed some models for innovation process. These models can be characterized in three categories:

✓ **Linear model:** Since the World War II the linear model was the generally accepted model. In this model, innovations are considered to be the result of a linear process made up of different stages that take place in a sequential, hierarchical and one-way order. Innovation process sequences from idea conception and basic research to diffusion stages namely new technology is assumed to start with basic research and move through applied research, invention, commercial market testing, and ultimately to diffusion. Having in account that scientific discovery is the only source of innovation, scientific and technological policies were directed to the support of R&D. This linear way (pipeline type, in the words of Caraça, [57]) of explaining innovation leads to “technology-push” [58] and “market-pull” (or “demand-pull”; Mowery and Rosenberg, [59]) models.

✓ **The “Chain-Linked Model” (the Interactive Model):** Kline and Rosenberg [60] criticized in detail the linear model. For these authors, the linear model distorts the

nature of the innovation process in several ways, especially because it considers R&D as the only source of innovation and since it ignores important feedback loops and interactions among the distinct stages of the innovation process. Innovation is considered a complex process where there is interaction between firms, organizations of the education system, of the scientific and technological system, and where innovative activities influence and are influenced by the market.

✓ National Innovation Systems (NIS) Approach: There is a prevailing consensus among innovation theory scholars that a systems approach to understand the dynamics of innovation is more realistic and provides a more useful policy guide than does the linear model of innovation. The systemic approach to innovation was initiated with the “chain-linked” model of Kline and Rosenberg [62] and broadened and deepened by the NIS approach. The modern version of the innovation systems concept is the result of several authors’ contributions, such as Lundvall [61-63], Freeman [64], Dosi et al. (eds.) [65]; Niosi et al. (eds.) [66], Nelson (ed.) [67]; Edquist (ed.) [25]; Edquist and Johnson [68]; Edquist [69], Lundvall, Johnson, Andersen and Dalum [70] and, Malerba [71].

Edquist [25,71] defines innovation system as «all important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion, and use of innovations». Depending on the objective and the level of analysis, innovation systems can be supranational, national, regional, sectoral or technological systems of innovation.

The NIS approach has a systemic view of innovation. Innovations are mainly the result of various agents’ actions and relations/interactions with each other. This approach considers that successful innovations depend on long-term relationships and close interaction between the innovative organization and external organizations and institutions.

This systemic approach to innovation considers that innovative activities and interactions between innovative agents are strongly influenced by the institutional environment. Organizations are «formal structures with an explicit purpose and they are consciously created» [70]. Firms, universities, venture capital societies, research centers (public or private) are examples of organizations.

All of the above innovation process definitions and innovation process models contain two parts:

1. one part for creation new idea or variation and,
2. A part for selecting appropriate variation.

These two parts are the mechanisms of evolution. In other words, continuing evolution, there must be mechanisms to increase or create variation and mechanisms to select appropriate ones (decrease the variation). This called the paradigm of variation and selection. (Fig. 1)

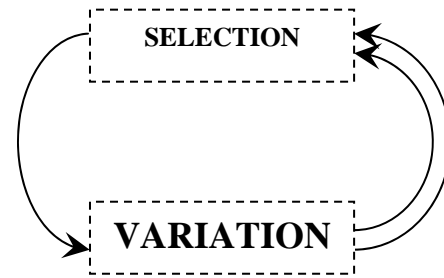


Fig 1. Evolution cycle

### 3. Evolutionary Innovation Approach

The analysis of technological change and innovation must be considered in a dynamic perspective. From a certain moment, existing technologies may no more satisfy the firm, and many problems can only be solved by innovations.

However, the results of these innovations cannot be fully anticipated and, in many cases, incremental innovations are still required, showing the inevitable uncertainty of this process.

A number of historical case studies have investigated evolution, development and management of technologies [see: 53, 72-74]. These studies have a process focus and explore dynamics of resolving unanticipated technical problems in different areas that emerge when a new technology is being developed.

In the process of solving a problem in one area scientists and engineers are likely to find new problems in related technological areas. The process of developing and shaping new technologies is not linear or intendedly rational. It involves many dead ends, new beginnings and a series of bottlenecks that are overcome through combination and recombination of existing known solutions and, on occasion, discovery of entirely novel technological advances [74].

It appears that technologies tend to develop within technological paradigms [75] that offer technology specific opportunities and along trajectories [76] that to some extent are decoupled from market influences. Arthur [77] developed a probabilistic model demonstrating that when two new technologies appear in the market it is not always the case that the superior technology emerges as the dominant design.

Dynamic increasing returns to adoption may shift the adoption preference to the more highly adopted technology, because related services are likely to emerge sooner, because of network and externality effects and establishment of technical standards. Classical examples include the QWERTY keyboard [78] and VHS/Betamax case [79].

From an evolutionary point of view:

- ✓ Firms cannot be treated as having the same objectives because they are different and these differences are essential to their understanding.

Each firm has its own routines, strategies and specific competencies that will determine their capacity of surviving [80]. This is directly related to the way it

perceives and solves problems: innovations are answers to those problems faced by the firm.

✓ Another characteristic of technological development and evolution involves the localized nature of innovation research and development.

In general firms tend to explore new opportunities and technical advances by searching and learning in areas closely related to or adjoining their existing applications and practices [81, 82].

Existing applications and knowledge may be sub optimal or inadequate, but for reasons of bounded rationality, satisfying decision-making and technological and organizational lock-in the firm may not be able or willing to search for or adopt new technological solutions or make changes to the hierarchy of routines. Kogut and Zander [82] have argued that innovating firms need to develop combinative capabilities as exploration mechanisms for facilitating dynamic transformation of current knowledge and acquisition of new knowledge and for generating new application from existing knowledge. More generally, the dynamic capability of firms determines their ability to respond to competition in a highly changing environment by effectively adapting, integrating, coordinating and re-configuring internal and external organizational skills, resources and functional competencies [83].

The organizational capacity for dynamically combining and recombining knowledge is a distinguishing characteristic of innovating and imitating firms because capabilities of a firm cannot be separated from its current organization.

Generally, following conditions are necessary for having evolution [84]:

1. Dynamism is needed for any evolution.
2. This dynamism must be towards perfection not decline.
3. Perfection must be innate.
4. This type of dynamism towards perfection is only possible in self-aware issue.

Human is a self-aware body of any dynamic innovation process. Therefore innovation process can become evolutionary if it includes 2 and 3 above conditions. Perfection in innovation process means the increasing total performance and fitness of configuration, and innate means increasing total knowledge that used for developing configuration or embedded in configuration. Next section will develop evolution cycle of innovation process for covering these conditions.

#### 4. Evolution Cycle in Innovation Process

The mechanisms of evolutionary innovation are knowledge emergence (internal knowledge), knowledge flow, recombination, internal and external selection. These mechanisms are grouped into two classes; those that increase the variation of configurations and those that decrease variation by selecting appropriate ones. (Fig.2) Variety is defined as a multiplicity of distinctions. The existence of variety is necessary for all changes, choices, and information.

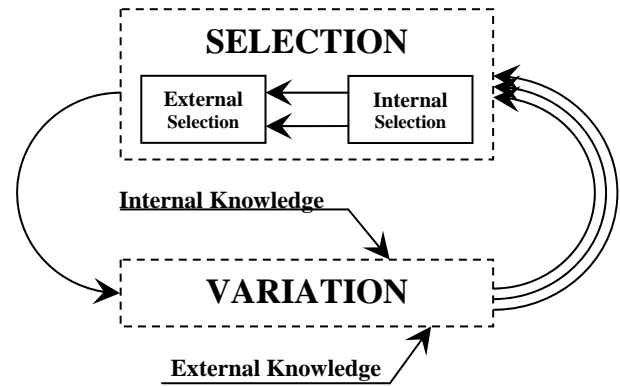


Fig 2. Evolution cycle of innovation

##### 4-1. The Mechanism of Selecting Appropriate Configuration

When a market accept new product; one can say that market select the product. A reduction in the quantity of variety is the process of selection. In selection process some of the possibilities or alternatives are eliminated, others are retained. Selection processes are endemic in innovation theories. In selection process, stable configurations or schemes are retained and unstable ones are eliminated. Result of selection process is increasing total performance and fitness. Selection mechanisms cover the condition two of evolution.

The word “configuration” or “scheme” denotes any phenomenon that can be distinguished. It includes everything that is called feature, property, idea, state, pattern, structure or system.

Selection is the elimination or reduction of part of the variety of configurations produced by variation. Selection decreases disorder by reducing the number of possibilities. The existence of selection follows from the fact that in general not all variants are equivalently stable or capable of (re) production: those that are easier to maintain or generate will become more numerous relative to the others [85]. If all possible configurations are equally likely to be produced or conserved, there is no selection.

Selection can be internal, as when an unstable system spontaneously annihilates, or external, as when a system is eliminated because it is not adapted to its environment [86].

##### 4-1-1. Internal Selection

Producers are the first selector of innovations, because they don't accept all of the prototypes or even any recommendation that developed in their R & D departments. Firm's internal paradigms, abilities, cost performance, organization culture, future image, strategy and policies, routines, internal selection regimes, are the first filters that reduce improper variation of new ideas.

Path dependence, path trajectory, innovation policy and etc. are examples of internal selection conditions. New version of software must support the old one; this can be called as path dependence. Microsoft Windows is a good example of software that support not only previous Windows version but also it support MS DOS commands. Market leaders continuously make new

norms and the followers must accept them for market share, this is path trajectory. Compatibility of any pieces of computer with IBM standard is an example of path trajectory in computer devices.

The existence of diversity and variation among firms within an industry is due to “differing histories of strategic choice and performance” [87] or due to different managerial decision-making. Empirical studies testing the relative importance of industry and firm effects in predicting performance have found that industry effects only explained 17 to 20 percent of the variance in financial performance [88-90]. Mauri and Michaels [91] and, Brush et al., [92] found that firm effects outweighed industry effects in affecting firm performance.

#### 4-1-2. External (Natural) Selection

External selection denotes the effects of environmental turbulences such as economic ones to choosing new configurations. Judy A. Siguaw, et. al. [93] noted that Environmental turbulence may moderate the relationship between innovations, including:

1. the form,
2. rate,
3. type,
4. performance outcomes.

Environmental uncertainty, or turbulence, may be viewed as occurring along a continuum, with “clarity, certainty, and stability about environmental demand at one extreme and ambiguity and uncertainty at the other” [94].

Under conditions of high competitive intensity, technological change, regulatory uncertainty, and market turbulence, there is a greater likelihood that the synchronization between the firm's innovation orientation and the form, type, number and speed of innovations may be affected. Simply put, “the effectiveness of a firm's orientation is conditioned by the nature of its market” [95].

The innovation literature supports the idea that environmental turbulence facilitates innovation (e.g. [96,-100]). The logic underlying this association is as follows: Product innovation is generally an expensive process for which the costs are rarely recouped [101]; therefore, firms in stable environments have less need of incurring these costs, while firms in turbulent environments must constantly innovate to stay ahead of the competition and to meet changing customer needs [102, 103]. Li and Atuahene-Gima [32] found that environmental turbulence serves to strengthen the relationship between innovation and performance.

Following these opinions one can differentiate two types of environmental turbulence:

1. Excitatory turbulence,
2. Inhibitory turbulence.

Environmental turbulence, which increases the average of competitiveness, can be classified as excitatory turbulence. Increasing trade tariff by a country is an example of excitatory turbulence for local firms.

In excitatory turbulence, firms want to increase their production rate without any innovation.

Environmental turbulence deteriorating the average competitiveness will be labeled as inhibitory turbulence. Increasing oil prices is a case of inhibitory turbulence for car producers; because they must produce a new car with lower gas consumption. Tokyo carbon dioxide reduction agreement and California car emission law are other examples of inhibitory turbulence. Inhibitory turbulences are forces that remove unfit configurations (ideas and inventions) as they arise via variation and creativity. In inhibitory turbulences firms should do innovation keep them alive.

For calculating probability of external selecting of a configuration one can use the fitness function. Fitness defined as the ability for survival (competitive and reproduction). Fitness is a measure of the likeliness that a configuration will be selected, i.e. that it will survive, reproduce or be produced.

Hence, from evolutionary perspective, innovation can be defined as:

Innovation: any systemic internal changes (at component, process, of systemic level) that increase the average fitness of system.

And also we may have devolution instead of evolution. Any dynamism that is towards decline is called devolution. Hence one can define den ovation for showing any systemic internal changes which its result is configuration decline. Den ovation can be defined as:

Den ovation: any systemic internal Changes (at component, process, of systemic level) that deteriorate the average fitness of system or has no effect on average fitness.

Den ovation is not quite the opposite of innovation. Den ovation is ostensibly the abandonment of an idea or technology and is a stepping back from something that had formerly been seen as a step forward.

Any new product of a company is example of den ovation when it has not any success in market and can't return it's R&D or license expenditure. An example of den ovation:

“...Osborne shipped his first computer in July 1981. In two months the company had its first \$1 millions in sale, and by the second year its net revenues reached \$100 million. Six months later the company was bankrupt. ... Kaypro, a competitor company, introduce new technology.

To counter Kaypro's new technological advantage, Osborne announced that it would introduce new technology that would meet consumers' demand for a better display. The timing of the announcement was major mistake, because Osborne had a large inventory” [104].

The timing of announcements is very important. Companies should not announce new improvements while holding large inventories. Customers are not likely to purchase an old model when they know that a new and improved model will go the market soon. In this case new innovation because of companies mistreats became denovation.

#### 4-2. Mechanisms that Increase Configuration Variation

Both external and internal selection mechanisms decrease configurations variation. If they were the only mechanisms of innovation evolution, configurations would eventually become homogeneous and further evolution would be impossible. There are, however, mechanisms that replace variation depleted by two selections. Knowledge emergence (internal knowledge), knowledge flow and recombination are the mechanisms that increase configuration variation and are the source of new novelties and products.

Different variant of a configuration are called allele. Alleles are different configurations that have the same main function. Button and zipper of a cloth are allele, because they do the same function in cloth. Microsoft Windows O.S. and Linux O.S. are also allele and one can use each of them as an alternative of another. Allele is a new configuration and it may be a component, product, process or a system.

Any kind of variation mechanisms create new alleles. Creation of new allele depends on existing new knowledge or new combination of old knowledge. Existing version of a configuration can be replaced by its new allele and make a new version. New allele increases knowledge of configuration so the condition 3 (in section 3) of evolution is covered.

Next part discusses variation mechanisms.

##### 4-2-1. Emergence of Knowledge

Scientists continually generate new knowledge and change global stock of knowledge. Emergence of knowledge changes global knowledge stock. New knowledge called emergent Knowledge. Emergence of knowledge can be occurred in a discipline, between disciplines, branch or field of knowledge. Some emergence of knowledge is neutral regards to fitness. Some of them are helpful for fitness and increases competitiveness of firms, organizations etc. and finally some of new knowledge is harmful for existing firm's fitness and try to obsolete existing knowledge.

Emergence of knowledge enters fully new allele to global knowledge stock and new configuration emerges.

##### 4-2-3. Knowledge Flow

New knowledge may enter to local knowledge stock (at firm, organization and etc. level of knowledge stock) by movement from other knowledge stocks.

Knowledge flow: entering knowledge from an external knowledge stock to local knowledge stock is called knowledge flow.

If knowledge mates within the knowledge stock, it can bring new alleles to the local knowledge stock. Learning, human mobility, all types of knowledge and technology transfers, are some kinds of knowledge flows.

In a rapidly changing world the existing knowledge and information of individuals, firms and other organizations become quickly obsolete. During the last decades acceleration occurred in both knowledge creation and knowledge destruction. This context of rapid transformations, accelerating innovations and intense

competition has been called as a "learning economy" [105-107,72]. This concept refers to those economies where the ability to learn is crucial for the economic success of individuals, firms, regions and national economies. Individuals, organizations and institutions need to renew their competencies more often than before, because the problems they face change more rapidly.

Johnson and Lundvall [108] define learning «as the acquisition of competencies and skills that make the learning agent – be it an individual or an organization – more successful in pursuing his/its own goals». Economic agents face the need of being rapid learners, learning to do new things and to handle new situations as well as getting access to new knowledge and information. Lundvall [65] stresses very well this idea by saying, «the most fundamental resource in the modern economy is knowledge and, accordingly, the most important process is learning». Learning is an activity that takes place in all parts of the economy. Innovation is rooted in processes of interactive learning [108]. Interactive learning is a process that takes place when agents interact with other agents. The term knowledge interaction is used to describe all types of direct and indirect, personal and non-personal interactions between organizations and/or individuals, directed at the exchange of knowledge within innovation processes [109].

The channels used for transferring knowledge depend on the characteristics of knowledge, such as the degree of codification, the tacitness or the embeddedness in technological artefacts. The potential economic value of knowledge affects the way which knowledge is exchanged between actors, demanding for knowledge interactions, that ensure secrecy, increase trust between actors and allow for exclusive appropriation of knowledge [110].

##### 4-2-3. Recombination

Recombination creates new combinations of alleles (or new alleles). Novelty (New Configuration) is that novel combinations of the existing means of production. The means of production are transferred from prior use into new configurations (including locations), and consequently change the use of existing resources, which result in alterations in the economic system. However, in a genuine Schumpeterian sense new combinations are not to be conceived as novelty if they happen in a continuous incremental way [111].

Van de Ven et al. [30], defined innovation as "the process of developing and implementing a new idea. The idea may be a recombination of old ideas, a scheme that challenges the present order, a formula or a unique approach that is perceived as new by the individuals involved." As the "new combinations" may in time grow out of the old by continuous adjustment in small steps, there is certainly change, possibly growth, but neither a new phenomenon nor development in our sense [112].

Behind innovations there is knowledge. Thus, the capacity to produce, transmit, absorb and recombine knowledge influences the innovation processes and, consequently, determines firms and countries success.

The process of developing and shaping new technologies is not linear or intendedly rational. It involves many dead ends, new beginnings and a series of bottlenecks that are overcome through combination and recombination of existing known solutions and, on occasion, discovery of entirely novel technological advances [74]. It appears that technologies tend to develop within technological paradigms [77] that offer technology specific opportunities and along trajectories [78] that to some extent are decoupled from market influences. The organizational capacity for dynamically combining and recombining knowledge is a distinguishing characteristic of innovating and imitating firms because capabilities of a firm cannot be separated from its current organization.

#### 4-3. Innovation Operator

Now it is needed some operator for combination of three variation mechanism to generate new configuration. The essential part for innovation consists of a set of distinctive innovation operators, which individually or in combination with others generate the required base for creative recombinations. (See: Douglas R. Hofstadter [113] introduced some operators for computer programming and J. Terninko & A. Zusman & B. Zlotin [114] for 40 inventive principles of TRIZ). Using an enlarged list from Hofstadter and adapted list from Terninko, it can be identified at least ten innovation operators as below:

- 1- Adding,  
Adding is the integration of a new building block into an existing configuration. Developing a product by adding new component for additional function or for better performance are two cases of adding operator. Flywheel (or hydraulic system) has added to engine for storing energy when a vehicle stops, so the motor can keep running at optimum power. Adding sterilize stage for all instruments that needed for a surgical procedure before it, was a great progress in medicine.
- 2- Breaking,  
Breaking is the differentiation of at least one configuration into two disjunctive building blocks. USA Shuttle spacecraft is an innovation that uses breaking innovation operator. In that Shuttle space-rocket break in two building Blocks; one block contain fuel rocket and another block is Shuttle that carry astronaut and satellite. Breaking large truck into truck and trailer and, separating development and production activities in companies are other examples. Breaking is also common innovation operator on using work breakdown structure for a large project; a large project can be broken into smaller units for individuals to perform.
- 3- Crossing-over,  
Crossing-over is breaking of at least two configurations and their merging into a new ensemble. Cement trucks with mixing vessels, and organizational division by function rather than product, are two cases of using crossing-over innovation operator.
- 4- Deletion,  
Deletion means destruction of a specific building block from a set of configurations. Using single wing instead of twin in airplane and making holes in a structure to reduce the weight or save martial are examples of deletion.
- 5- Duplication,  
Duplication is repeated insertion of at least one identical configuration. Cassette with two type or Cassette with 6 CD's to increase music time and variety are two cases of duplication innovation operator.
- 6- Inverting,  
Making of copies with an opposite scheme or component. Such as make the movable part of an object, or outside environment, stationary- or stationary part movable. Some example of inverting is moving staircase with standing people instead of staircase with walking people, rotating the part instead of the tool. The position of each components of dumper is inverting vs. of a track.
- 7- Merging,  
Merging means integration of at least two existing configuration into a new configuration. Pencil with eraser, cell-based Manufacture, Multi-media presentations, Thousands of microprocessors in a parallel processor computer, electronic chips mounted on both sides of a circuit board are cases of merging.
- 8- Moving,  
Moving means the shifting of configurations out of its established boundaries. Mobile car service, mobile library, using transistor first time for radio manufacturing, are examples of using moving operator for innovation. Using military innovation in civil and also using civil innovation in military is another case of moving.
- 9- Replacing,  
Substitution of a particular sub- configuration by another one is called replacing. The purpose of replacing is using simpler and inexpensive copies or alleles of a configuration instead of an unavailable, expensive, fragile object. Replacing mainframe computer by personal computers and quartz crystal oscillations drive high accuracy clocks instead of mechanical clocks are examples of replacing.
- 10- Swapping,  
Swapping is vertical movement of a particular configuration from a level  $L_i$  to a different level  $L_j$ .



An example of swapping is Mercedes Benz vision which changed from 'the best or nothing' to 'the best for our customers'- i.e. shift from internal to externally focused vision statement.

The important point which can be over-emphasized lies in the universality of these operators across various evolutionary systems.

### 5. Conclusion

In this paper an evolutionary cycle in innovation process is introduced, this cycle consists of two fundamental parts, selection and variation. Selection part combine firms or organizations internal set of criteria, cultures, routines, and policies with external turbulences that affects in selection and implementation of innovation. The selection process eliminates the unstable configurations and retains stable ones. Selection process increases total performance and fitness of configurations. Another fundamental part of evolutionary cycle in innovation process is the mechanisms that increase configuration variation. Knowledge emergence, knowledge flow and recombination are three mechanisms that increase configuration variation. Knowledge emergence is the drive of knowledge economy and emphasize on generating new configuration from emerging knowledge. Knowledge flow stresses on using external knowledge and learning for developing new configuration. Recombinations highlight attention to new combination of existing scheme. For combination of three variation mechanisms we introduced the innovation operators by which one can generate new configurations. Innovation operators guide for becoming creative and making more new configurations.

This paper advances a new theoretical framework for evolutionary innovation and also identifies and sorts mechanisms of evolutionary innovation. This framework is co-direct with evolutionary economy theory and can develop towards evolutionary system approach to innovation systems.

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