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INNOVATIVE ENTREPRENUERSHIP UNDER UNCERTAINTY

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ABSTRACT

Purpose- This paper analyzes the economic activity of innovative entrepreneurship under uncertainty. We examine the profit maximization model of innovative firm under two kinds of uncertainties. The first kind of uncertainty pertains to market conditions. Erratic behavior of future prices creates market uncertainty.

Methodology- This uncertainty is at least partly resolved by rational expectations hypothesis. But repercussions of market imperfections still loom large in the background of theoretical framework. The second kind of uncertainty is caused by technological changes and the patterns of innovations. We use the black-box approach methodology to production function and then improve it with a learning model.

Findings- The pace and space of innovation adoption is retarded and narrowed by technological uncertainties. This problem is tackled by neoclassical innovation models to some extent. In particular, endogenous growth models and the industrial dynamics model attempt to endogenize the innovation and technology under rational expectations.

Conclusion- But these models provide incomplete insights for they do not deal with learning behavior of innovative entrepreneurs. We propose an alternative learning model which takes into account the adaptive and imitative behavior of individual innovators whose economic actions matter in the general framework of real life economics.

Keywords : Innovation, technology, uncertainty, entrepreneurship, expectations
JEL Codes :O30, O32, O33

1. INTRODUCTION

More than half a century ago, the call for a synthesis between economic history and economic is now a necessity to tackle the contemporary complex economic phenomena in a more humane manner: "Economic historians and economic theorists can make an interesting and socially valuable journey together, if they will. It would be an investigation into the sadly neglected area of economic change" (Schumpeter, 1947). The economic inquiry into the causes and consequences of economic change requires multifaceted analysis in which theoretical links are deepened on the background of historical roots. The theory of innovative enterprise urges upon the integration of economic theory and history to understand economic phenomena in which *markets are outcomes rather than causes of economic development* (Lazonick, 2013). In neoclassical economics, the determinants of economic change particularly pertain to the technological breakthroughs and these changes are depicted as shifts along production curve. Thereby, the standard analysis in economic change becomes an equilibrium analysis in which technological innovations enter into the economic models as exogenous shocks. This level of analysis is insufficient since it only concerns with consequences in the aftermath of transient disturbance. What happens when an economy experiences a technological transformation is reflected as a movement from one equilibrium point to another in a classical comparative static fashion. Although factors of production consist of capital, labor and technology in a classical growth model, the human factor is underestimated, if not totally ignored. Individual involvement in economic development and change plays an important role in micro-meso-macro level of economic analysis. The micro-meso-macro analytical framework of evolutionary economic theory is a useful tool to reexamine the dynamic process of socio-economic change in which *one in many and many in one* act interdependently. The theory of evolutionary economics develops the analytical tools to understand the complex human behavior. Oscar Lange's article "The Rate of Interest and the Optimum Propensity to Consume" (1938) was fundamental part of a larger project for the development of economic evolution (Assous and Lampa, 2014).

Today people are both more rational and more irrational at the same time. Rational irrationality and irrational rationality are among the most common behavior patterns of individual economic actors of our era. All of these facts render sufficient reasons for an economist to work with a broader perspective from within the economic profession. Hence we need to go far beyond the spatial picture of geometrical movements along the production function for it will be no avail to map complex behavior patterns of human action by shifting positions of points on a plain diagram. After all, as long as the human factor is left out of its domain, the production function will be an 'implicit function' and thereby a black box. The black box approach to production function emanates from the fact that the general construction of the function subsumes but does not actually embed individual decision making process and strategic behavior (Lewin, 2000).

2. THE PROFIT MAXIMIZATION MODEL OF INNOVATIVE FIRM

Technically, the innovation is defined as a shift of production function from one locus to another on a geometrical plane. In Schumpeter's words "we will simply define an innovation as the setting up of a new production function" (Schumpeter, 1939, p. 87). This is of course oversimplified and very abstract definition of innovation. Actually this is *not* a definition of innovation as a cause, but it is rather a definition of the effect of innovation. Lange (1943) also pointed out the same problem and showed how wide this definition is by considering the fact that, except innovations, there are very many ways which change the shape and shift the position of production functions.

"*Innovations are such changes in production functions, i.e., in the schedules indicating the relation between the input of factors of production and the output of products, which make it possible for the firm to increase the discounted value of the maximum effective profit obtainable under given market conditions*" (Lange, 1943, p. 21, emphasis in original).

Lange's analysis of innovations is based on the theory of the firm and the main motive behind innovative production is expected profit maximization that is discounted to the present value at a continuous expected interest rate as a cost of capital. Lange (1943) formulates the discounted present value of the expected profit (*P*) of a maximizing firm as follows:

$$P = \int_0^H s(t) e^{-\int_0^t i(t)dt}\, dt. \tag{1}$$

In Lange's terminology, $S(t)$ is the surplus expected at time *t* and it is identical to the difference of the receipts $R(t)$ and the expenses $E(t)$ at time *t*:

$$S(t) \equiv R(t) - E(t). \tag{2}$$

The receipts and the expenses are respectively related to the demand price and supply price of particular innovative product that the firm plans to produce. At the equilibrium point, demand price and supply price will be equal and only normal profit accrues to the competitive market participants. But the normal profit of perfect competition is not sufficient to take on an innovation decision of a production project for an innovative firm. Hence there will be no incentive to enter into the market for innovative entrepreneurs as long as the expected surplus is not more than to compensate the expected implicit and explicit expenses (or cost of production) and expected interest rate (or cost of capital). In this case, the expected surplus and thereby economic profits will be zero as a condition for perfect competition.

The difference of entrepreneurial profit from the normal profit enters into the model in the framework of innovation decision making criteria. In order for an innovative firm to take on a production project, entrepreneurial profit opportunity is to be greater than normal profits. The period of innovative production by the profit maximizing representative firm is defined by the term of 'economic horizon' and the length of the horizon is denoted by *H* according to Tinbergen (1933). The continuous expected interest rate as a function of time is $i(t)$ in the formula (1) and it denotes the cost of capital. The element of time is set to zero in order to denote the present moment: {t = 0}.

Amendment of Lange's model according to the theory of rational expectations will suffice for our analysis. The representative firm is supposed to maximize its profits according to the rational expectations hypothesis. Innovative expectations are classified under the general formulation of rational expectations. There are two kinds of uncertainties concerning the profit maximization in innovative activity. First one is called the "uncertainty of the market." It reflects unpredictable patterns of future demand and supply functions, and thereby future prices. The other one is "technological uncertainty" which relates to the mode of state-of-the-art production and consumption.

3. UNCERTAINTY OF THE MARKET AND RATIONAL EXPECTATIONS

The market uncertainty emanates from the general movement of future prices. Rational expectations hypothesis under perfect competition and full information assumption provides robust theoretical solution for the market uncertainty. Tinbergen (1932) was the first to form an explicit function of rational expectations. In Tinbergen's model, uncertainty and expectations are linked with a probability theory. Keuzenkamp (1991) made a comparison between rational expectations models of Tinbergen (1932) and Muth (1961).

Though there is almost thirty years between two papers, models and the language they use are similar. The theoretical way they connect mathematical expectations to the expected value of economic variables, in other words subjective and objective expectations, resemble. The difference comes from the fact that Muth analyzes autocorrelated processes whereas Tinbergen uses the assumptions of normal probability distribution where disturbances are serially independent (Keuzankamp, 1991).

Lange (1943) also uses Tinbergen's terminology in his profit maximization model of innovative firm and these two models can be connected to construct an innovation expectations model. Innovation expectations can be decomposed into two main components according to the profit function of the firm. First component is of demand price and the second component is of supply price. The difference between these two components will be entrepreneurial profit. First component corresponds to market uncertainty whilst the second component corresponds to technological uncertainty.

Entrepreneurial profit maximization condition occurs where price is greater than average cost. In this sense, innovative entrepreneurial activity resembles to monopoly power in its very nature. Because every innovation in its initiation is unique. It takes time to imitate an innovation for competitors.

An innovative firm's production project will depend upon (i.) the profit function, (ii.) the time horizon and (iii.) the price expectations according to Tinbergen (1932).

(i.) *The profit function*: For convenience, the profit function with respect to price is set to be linear as follows:

$$\pi(p_t) = \pi_0 + \pi_1 p_t. \tag{3}$$

The level of profit will change according to the price change (Δp) and it is expressed as a first derivative of profit function: $\pi' = \pi_1$.

(ii.) *The time horizon*: The term 'economic horizon' as defined by Tinbergen (1933) is denoted *H* and for the general formulation of rational expectations, it is assumed to be infinite:*H* = ∞. The point of time denoted by {*t* = 0} represents the "present" moment.

(iii.) *Price expectations*: Price expectations are assumed to be rational. The general formulation of rational expectations under perfect competition and with full information assumption is as follows:

$$p_t = \sum_{t=0}^{\infty} E(p_t|\omega_t). \tag{4}$$

In the formula (4), p_t, the actual demand price of the innovative product that the innovative firm plans to produce at time *t* is equal to the expected demand price conditional upon the information set denoted by ω_t that the firm has at time *t*. The period spans over an infinite horizon {*H* = ∞} and begins from the "present" moment {*t* = 0}.

4. TECHNOLOGICAL UNCERTAINTY AND INNOVATION DECISIONS

Technological uncertainty creates hindrances for innovation adoption. Hence models of technological uncertainty concern with firms' research and development (R&D) strategies. These are essentially non-deterministic models of innovation since the stochastic element of expectations enters into the framework. The modeling of R&D decisions in a neoclassical framework of equilibrium analysis can be classified into two types. The first type is endogenous growth models and the other type is industrial dynamics models. (Oltra and Yıldızoğlu, 1998). The both types of models based on the assumption of rational expectations under perfectly competitive market structure. Profit maximization for competitive innovative firms requires R&D process and thereby costs considerations of inputs into this process. The human factor plays an important role in R&D process. Skilled and professional labor is the main input in R&D studies of innovative firms.

5. NEOCLASSICAL MODELS OF INNOVATION

The accumulation and diffusion of knowledge in the economic system is an intangible engine of economic development. Standard neoclassical growth models ignore the role of entrepreneur in economic development. However, endogenous growth models take innovation decision process into account and to some extent try to endogenize it. The endogenous growth models are based on the rational expectations hypothesis and rest upon the pivot of equilibrium analysis. Although the technology and innovation are considered in the dynamics of economic development, the role and function of innovative entrepreneur is absent from the theoretical framework.

5.1. The Endogenous Growth Models

The important contributions in economic literature to endogenize the accumulation of knowledge were of Romer (1986) and Lucas (1988). The endogenous growth model of Aghion and Howitt (1992) takes vertical innovations as a source of growth and thereby analyzes R&D decision and investment rules within the framework of intertemporal equilibrium through Schumpeterian idea of creative destruction. Firms make R&D investment as a stochastic innovation process in order to improve products. Old products are rendered obsolete by new products. Each innovationary phase of production entails the innovative firm the patent and monopolistic power, and thereby supernormal profit until the next phase of innovation arrives.

The creative destruction is the key concept for neoclassical endogenous growth models and described by Schumpeter (1942, p. 83, emphasis in original): "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, … [This process] incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism."

Under rational expectations hypothesis, firms have perfect future foresight and full information of the cost of innovation. The cost of innovation consists of inputs in R&D process. The inputs of R&D process are skilled labor and specialized labor. For this reason, the expected wage rate is used to calculate the expected value of innovation. Under intertemporal equilibrium condition of perfect competition, the technological uncertainty turns into an optimal decision making under risk (Oltra and Yıldızoğlu, 1998).

5.2. The Industrial Dynamics Model

The industrial dynamics model of Ericson and Pakes (1995) analyzes an exogenous stochastic process of innovation. Profits are determined by the competition outside of the industry. Cost of inputs, demand schedule, state-of-the-art production methods come from the outside. In this framework, innovation is exogenous. The level of R&D investment maximizes the expected value of discounted profits described in the Lange's model (1). Industrial dynamics under rational expectations ensures that firms use all information available to them until marginal cost of acquiring another increment of information equals its marginal benefit. In the exogenous model of Ericson and Pakes (1995) information set of innovative firms consists of following elements:

(i.) The history of all past innovative states of the industry;

(ii.) The history of firm's own past innovationary investment decisions;

(iii.) The current innovative state of the industry;

(iv.) The probability function pertaining to the evolution of innovative states over time.

The industrial dynamic model follows the Markov process for it accurately reflects the beliefs of each firm under rational expectations. The coordination failure of firms is ruled out in the intertemporal equilibrium analysis since firms have perfect information of industry structure and rational expectations for the future outcomes.

The distinction between neoclassical general equilibrium analysis and entrepreneurial innovation is made by Schumpeter (1934). According to this distinction, the entrepreneur breaks the "circular flow" of equilibrium establishment which is a comparative static system of price adjustment. The innovative entrepreneur 'dynamizes' this closed system with a deep perception and perspective of future. Entrepreneur creates or captures disequilibrium conditions in a static and closed economic system (Kirzner, 1997).

6. EVOLUTIONARY MODELS OF INNOVATION DECISION PROCESS

The rational expectations hypothesis underlying the neoclassical endogenous growth models are criticized by being far from reality of ordinary economic life. Under imperfect competition and in heterogeneous market structure, all economic agents are rarely rational. Irrationality is more prevalent than rationality because of strategic interaction between economic agents. Also, full information assumption is almost impossibility. Since innovative entrepreneur breaks out of the boundaries of equilibrium analysis by its very nature of creativity, innovation is a matter of disequilibrium and dynamic process. Adaptive behavior rather than rational behavior is adopted by learning individuals. Learning is a fundamental aspect of innovative entrepreneurship. Rational behavior model takes learning for granted and focuses on the end result—*i.e.*, equilibrium. But learning process determines the innovation decisions. For this reason, evolutionary models shed light on the irrational part of human action by concentrating on the adaptive and learning behavior.

6.1. Adaptive Learning Models

Nelson and Winter (2002) gave a brief historical account on the evolution of evolutionary theorizing in economics. "During the first several decades of the twentieth century, evolutionary thinking and language was widespread in economics. But as one contrasts the economic textbooks and journals from prior to World War II with after, it is clear that while economics before the war still contained many evolutionary strands and concepts, these seemed to vanish in the early postwar period. What happened?" (Nelson and Winter, 2002, pp. 23-24).

The equilibrium notion of economic theory invaded the field after World War II. Profit maximization has become a mathematical question with respect to constraints. However, the essential problem was to perceive the difference between optimizing firm and innovative firm. The optimizing firm operates under the cost and revenue functions subject to technological and market constraints. The optimization process is a managerial task. On the other hand, innovative firm paves new ways to operate and is not restricted with the cost and revenue functions. For this reason, the innovative firm's operations are not subjected to optimization (Lazonick, 2013).

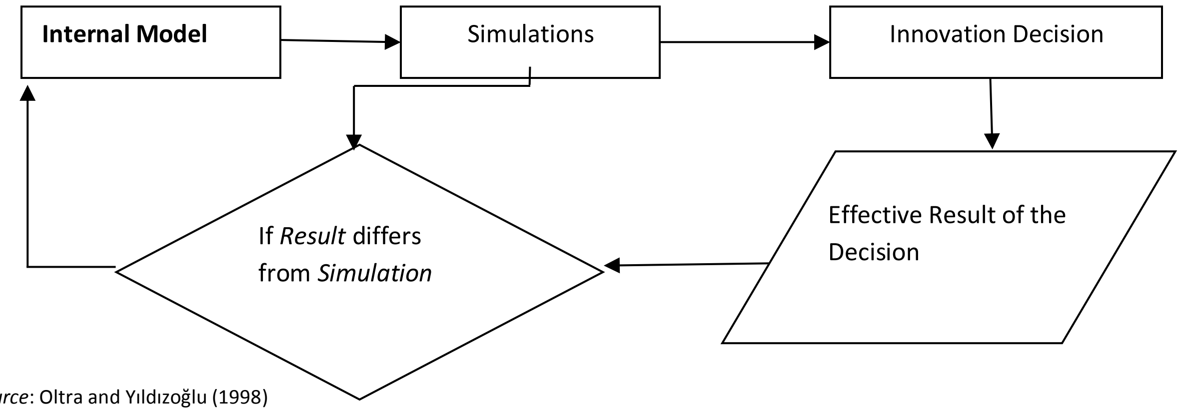
Nelson and Winter (1982) construct an evolutionary theory of economic change. It introduces Simon's (1982) concept of bounded rationality to innovation decisions. Winter (1984) introduces adaptive behavior to R&D decision rules. However, this adaptive behavioral rule is similar to imitation rather than learning in the sense of Schumpeterian creative destruction. Silverberg and Verspagen (1995a, 1995b, 1999) improve the simple rule of Winter (1984) so as to turn it into a simple imitation with strict informational assumptions for a random experience and mutations. After all, learning can best be defined by mutation from one point of time to another where the arrow of time is irreversible.

6.2. The Concept of Internal Model

Oltra and Yıldızoğlu (1998) adopt a "black box" strategy by introducing the concept of "internal model" to overcome the problems of Artificial Intelligence. They describe the dynamics of the internal model in a flow diagram depicted below.

The dynamics of the internal model represent a circular flow and the concept of internal "model" is very loose: It is not a simple mathematical formulation, it represents the innovative entrepreneur's perception of the economic environment (Oltra and Yıldızoğlu, 1998). The innovative entrepreneur compares *ex post* situation of actual observations to that of *ex ante* situation of expectations resulting from simulations. If actual experience contradicts the "internal model," then the latter is updated. This dynamic structure is depicted in the following Figure 1.

Figure 1: The Dynamics of the Internal Model



Source: Oltra and Yıldızoğlu (1998)

The main idea behind the "black box" or "internal model" approach is explained as "an intelligent being learns from experience, and then uses what it has learned to guide expectations in the future" (Dennett, 1998, p. 185). The nature of learning also requires learning from failures. For this reason, failed predictions can serve as well as overt reward as a basis for improvement. Particularly, the intelligent being who observes economic environment and learns from experience is innovative entrepreneur.

There are several drawbacks of "internal model" which considers innovation decision process as a "black box." First of all, the formal representation of the internal model is problematic. It uses an artificial neural network (ANN) that feeds forward with one hidden layer. This contradicts the backward looking nature of adaptive expectations. The other drawback of "internal model" is that the economic environment is not strategic. In other words, it does not represent the strategic interaction of economic agents. As long as strategic interaction is neglected, to model the true nature of learning process is not possible.

6.3. Learning Model

As an alternative to "internal model" of *black box* approach, we propose Bayesian learning model of the innovative entrepreneur in a competitive market. Under Bayesian learning process innovative entrepreneurs start as adaptive learners and undergo a mutation to become rational agents. We use state-space Hidden Markov Model (HMM) to analyze Bayesian learning process under disequilibrium. Under strategic interaction and technological uncertainty, the profit function (4.1.1) is redefined as follows:

$$\pi_{i,t} = \pi_{i,t}(P_{i,t}, \overline{P}_{-i,t}, M) \tag{5}$$

Assume that there are *n* number innovative entrepreneur in a market at particular point of time *t*and *n* is defined by a set of positive natural numbers $\{n \in \mathbb{N}\}$with an index as such*i* = {1, 2 , 3, …, *n*}. The nominal price of the innovative product for the innovative entrepreneur *i* at time *t* is $P_{i,t}$ and $\overline{P}_{-i,t}$ represents nominal average price for the rest of the entrepreneurs {*n* – 1} in the same marketplace and under the same technological uncertainty. *M* is nominal money supply and it is assumed that the money is neutral.

Learning innovative entrepreneurs start as imitators who have adaptive expectations and after a particular period of time become rational innovators by fully adopting new technology as they update their information gradually(Hacıoğlu, 2015). Thereby, adoption of a new technology requires an adaptation process which is defined by Bayesian learning procedure. The initial equilibrium is disturbed by a leading innovative entrepreneur who introduces an innovative product to the market. Under disequilibrium, supernormal profit opportunity arisesand attracts the attention of competitors. This is reflected on the Lange's model in the discounted present value of the expected profit of a maximizing firm in (1).

The price expectation of a particular imitative entrepreneur P_i^e depends upon the average price of other entrepreneurs: $\overline{P}_{-i}$. They formulate their learning expectations on the forecasting of average price forecast of other entrepreneurs in the market. This is similar to the Keynesian beauty contest: "It is not a case of choosing those [faces] that, to the best of one's judgment, are really the prettiest, nor even those that average opinion genuinely thinks the prettiest. We have reached the third degree where we devote our intelligences to anticipating what average opinion expects the average opinion to be. And there are some, I believe, who practice the fourth, fifth and higher degrees" (Keynes, 1936, p. 156). Since market entry is free and no oligopolistic collusion is allowed, the competition in the market is atomistic. Bayesian expectations of imitator-learners are formulated in a distributed lag model as follows:

$$P_{i,t+1}^{e} = \alpha_0 P_t + \alpha_1 P_{t-1} + \alpha_2 P_{t-2} + \cdots + \alpha_l P_{t-l}. \tag{6}$$

with increasing weight of parameters where $\alpha_0 > \alpha_1 > \alpha_2 > \ldots > \alpha_l$ and the sum total of all parameter values are set to unity such that $\sum_{j=1}^{l} \alpha_j = 1$ where l denotes the number of past periods. Current period is {l = 0}. The factor of price adjustment or revision is denoted by the parameter α and information is contained in it.

Bayesian expectations are a kind of rational expectations that every particular price expectation at a particular period of time is conditional upon the information set available in the market as in (3.2). If we add the price adjustment parameter of current and past periods to the model then we have the following formula:

$$\alpha_l p_t = \sum_{t=0}^{\infty} E(p_t | \omega_t) \tag{7}$$

whereω_t denotes all possible information available for an imitative-learner i, and $I_i(\omega)$ represents imitative-learner i's information function. The updated information { $\omega \in \Omega$ } contains the knowledge of actions in the past and present. The general formulation of the information set of all past and present periods is formulated as follows:

$$(\Omega, \Pi) = [(\omega_{t-1}, \pi_{t-1}), \ldots, (\omega_{t-l}, \pi_{t-l})] \tag{8}$$

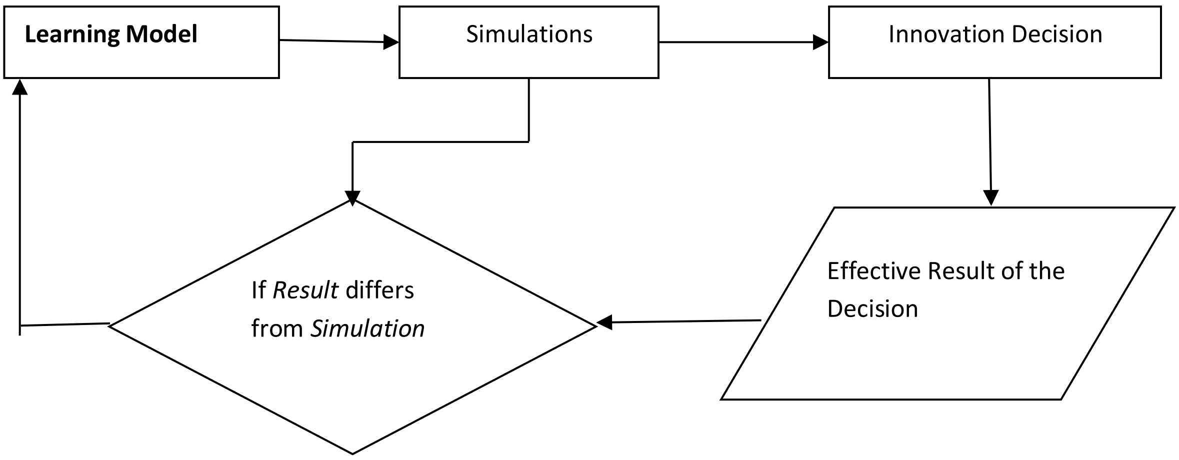
In particular, the formula for the individual imitative-learners' information function with Bayesian expectations is as follows:

$$I_i(\omega) = [(\omega_{i,t-1}, \pi_{i,t-1}), \ldots, (\omega_{i,t-l}, \pi_{i,t-l})] \tag{9}$$

Every imitative-learner entrepreneur updates information function from one period to another and profit function enters into the information set indirectly.

The state-space Hidden Markov Model (HMM) allows us to keep track of learning process in which transition from one learning state to another follows Markov process. In HMM, states are hidden which means that learning state is unobserved beforehand. This model is similar to that of *black box* approach of "internal model." The difference is that learning model uses forward-backward algorithm for HMM to form expectations. Expectations are Bayesian and rational which mean that they are adaptive in nature but updated rationally with forward pass and backward pass in time horizon. The particular state sequence of an imitative-learner i for all past and present periods is a set of each learning state such as $S_i = \{S_{i,t}, S_{i,t-1}, \ldots, S_{i,t-l}\}$. The corresponding set of actual prices (observed outcomes) is arrived at by agent i after the transition from a prior state to a present one through learning. The particular price at a particular period is conditional upon the relevant learning state.The dynamics of the learning model are represented in the following flow diagram. Although this circular flow seems similar to that of "internal model," the chief difference is that the learning creates *short-circuit* in the vicious circle of *black box* approach.

Figure 2: The Dynamics of the Learning Model



Innovation decisions are periodically updated with the flow of new information. Imitative-adaptive learner entrepreneurs approach to the sophisticated state of innovative entrepreneur as they update their knowledge state after state. The *short-circuit* created by the dynamic learning process can be translated into economics as a disturbance of equilibirium. In this dynamic system, there is an innovative entrepreneur who benefits from disequilibrium conditions. The dynamics of the learning model depicted in Figure 2 represent the stylized fact of Schumpeterian theory of creative destruction.

7. CONCLUSION

The integration of innovative entrepreneurship to the general neoclassical models of economic change and development requires considerable effort from economic theorists. Entrepreneur is absent from the production function and the role of innovation is taken for granted without its propulsive power behind the scene. However, in an era of technological breakthroughs the absence of entrepreneurial activity from the general locomotion of economic growth is no longer tolerable. Hence, there is an urgent need to analyze innovative entrepreneurship in contemporary market conditions. The classical profit maximization paradigm of economics can be used as a motive for innovation decisions. Since the behavior of innovative entrepreneurs is an action of disturbance for equilibrium state of the economy, the study of innovative entrepreneurship is a dynamic disequilibrium analysis. When Schumpeterian "creative destruction" is in operation, every innovation that comes successively one after the other is a wave of "doing things in a new way." Every new wave of innovation washes off the old techniques so that the production function is reconstructed from the outset. To tackle this task, we used the profit maximization model of innovative firm to analyze the innovation decision process. In competitive markets, innovation decisions are arrived under uncertainty, because the length and frequency of innovative waves are unforeseen by their very nature. Market and technological uncertainties are two important factors that push economic agents forth to form innovation expectations for the future. Neoclassical models of innovation deal with uncertainty in perfect competition where agents are fully rational. But this strong assumption ignores the learning process which is a central concept in innovation economics. We suggest an alternative model of learning to understand the actual course of action of innovative entrepreneurs under uncertainty. In this way, the circular flow of *black box* approach to innovation decision making is broken and new vistas are opened for the future research.

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