The Growth Pattern of R&D Activities with Innovation in the Digital Economy

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<Abstract>

그 동안 R&D와 관련된 많은 연구는 다양한 성장모형을 이용해 경제성장과 연구개발 투자사이의 관계를 보이는데 중점을 두어왔으나, 디지털 경제에서의 지식 혁신에 의한 R&D활동의 성장패턴을 보이는 연구는 이루어지지 않고 있다. 따라서 본 연구에서는 IT기업의 생산과정에서 R&D활동에 따른 비중의 변화가 생산성을 증가시키는 성장의 패턴을 다양하게 힐 수 있음을 보이고자 한다.

Key word: R&D Activity, Growth Pattern, Digital Economy, Innovation of Knowledge

I. Introduction

As R&D activity is staidly on the increase, company ranging local to national levels will inevitably face bold investment decisions. This sort of trend, combined with innovation knowledge, is not limited to developed countries, but rather on a universal scale making competitiveness a global issues in the near future.

While R&D activity with regards to innovation knowledge, R&D (IK), is economically influenced and heavily focused, it is a difficult to forecast growth patterns because of a wide range of digital economies and varying R&D activities.. The R&D activity is accompanying innovation process in the industry as well as each firm level. In this respect, innovation[1], dealing with advanced technology, provides the principal source of change for firms as well as industries in terms of productivity. These activities involve the creation and utilization of new scientific, technological, and organizational knowledge which brings technological change with diffusion of innovations. That is, R&D activities at the level of firm and industry have a large role on increasing and expanding the economic growth of each firm and industry through the effective process of innovation. Since, the process of innovation in the mechanism of connecting the growth to the firms and industries, R&D activities tries out new ideas, and seeks information that is yet unknown to connect with the growth through expanding the size of innovation.

The relevance between R&D and productivity have been recently researched and reviewed in many developed countries. For example, Ronald P. Wilder and Stanley R. Stansell (1974) developed a model of the determinants of R&D outlays of privately owned electric utilities, and tested the model empirically with data for the years 1968 through 1970. They found that R&D outlays had an elasticity greater than one with respect to firm size, and were positively

1) Innovation is generally defined as the activities of developing and commercializing new products and processes.

associated but relatively inelastic with respect to profitability. These results suggested that increasing firm size, either through merger or internal growth would have a favorable effect on R&D outlays. Tor Jakob Klette (1996) presented an alternate specification of knowledge production and derived a structural econometric model with properties providing a simple framework for empirical studies of the relationship between firm performance and R&D. The main empirical findings are as follows: (i) R&D has a positive effect on performance, (ii) the appropriable part of knowledge capital depreciates at a rate of .2, (iii) there are significant spillover effects of R&D across lines of business within a firm, and (iv) there are significant spillovers in R&D across firms that belong to the same interlocking group of firms. Carl Davidson and Paul Segerstrom (1998) presented an endogenous growth model in which some firms devote resources to developing higher-quality products (innovative R&D) and other firms devoted resources to copying these products (imitative R&D). Although consumers benefited from the knowledge created by both types of R&D activities, only innovative R&D subsidies lead to faster economic growth; conversely imitative R&D subsidies actually lead to slower economic growth. A key assumption in driving these conclusions is that R&D activities are subject to decreasing returns. While R&D activities are subject to constant returns, as is commonly assumed, the only equilibrium with both innovation and imitation is unstable

By looking throughout the related works, we recognize that most of the R&D types literature emphasizes for the role of R&D activity itself in terms of firm's size, productivity, and government policy. This implies that R&D activities are related to the growth of the firm's return or profit, through the process of innovation. However, no paper to date shows the possibilities of a variation of growth patterns due to change in the share of R&D activities in the process of firm's production.

In this paper, we use the growth model[2] to see if the R&D activity with

2) On the other hand, the newly developed theory of endogenous growth (pioneered by, among others, Paul M. Romer [1986], Robert E. Lucas[1988], and Gene Grossman and Elhanan Helpman [1991]) has equipped economists with a rigorous microeconomic

innovation knowledge is connected to the growth mechanism; We shall also examine what happens in the growth pattern if the share of the R&D activity with innovation knowledge varies in the digital economics. The purpose of this paper is to look at the relationship between R&D activity and the process of innovation, R&D activity, and the initial economic performance of firm level. We, then, we consider the theoretical model of R&D and economic growth, where we demonstrate that change in the share of R&D activity through the process of innovation leads to different growth patterns of economic growth.

This paper is organized as follows: Section 2 shows framework that illustrates the relationship among R&D activity and economic growth by including the process of innovation knowledge. Section 3 presents a model and analysis of the basic economic relationship between R&D activity and economic growth. We also show the steady state analysis and transitional dynamics of the model, where we draw some propositions for the model. Lastly, section 4 concludes and describes some implications and limitations of the model, and show future extension of this paper.

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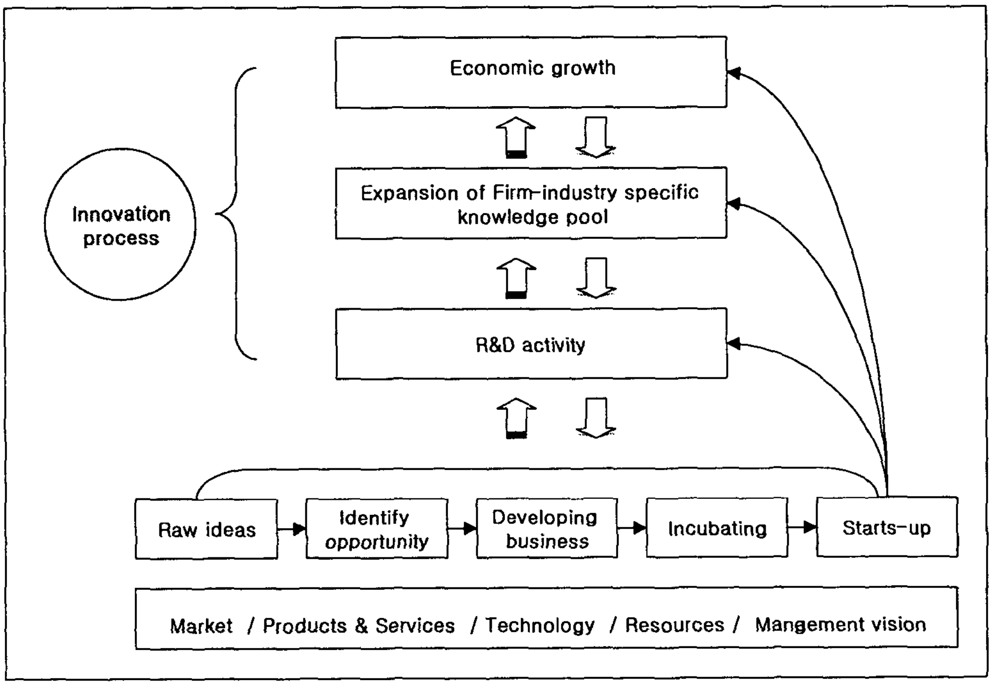
foundation of the growth process.

II. R&D activity, Innovation Process, and Economic Growth



<Figure 1. R&D activity, Innovation, and Economic Growth Dynamics>

The following frame illustrates the relationship between R&D activity and the economic growth by considering the innovation process. As the Figure 1 illustrates, there are two types of interactions. Interaction is a central element in the process of innovation with economic growth. The first interaction concerns processes within a firm(i.e. intrafirm networking), such as loops that link R&D activities based on general environment of the firm, and the creation of the value proposition by starts-ups. The second type of interaction, includes the expansion of firm-industry specific knowledge pool, which leads to firm's economic performance by the process of innovation.

In detail, when firm or industry is planning to determine the size of R&D activity, he or she should consider the general environment, where market, products, technology, resources, and management should be considered by the R&D management. R&D activity decisions vary with many economic factors, how is the market going to react in the future? What kinds of products and services are needed to be targeted given the firm's resources and direction? Those factors should be applied to each stage of R&D development, namely from raw ideas to starts-ups in order to get the return of investment. Subsequently, they generate a field of commercially promising ideas and can be identifies as potentially viable research projects. Whatever the source of the idea, they must be screened to determine each firm's strategies and capabilities, for potential economic significance, and for uniqueness and originality.

So, it is recognized in this model that R&D activity leads to expansion of the firm-industry specific knowledge pool. This in turn, can make the economic performance of firm level by cooperating the process of innovation.

III. Theoretical Approach to R&D activity and Economic Growth

3.1 The Model

In this chapter, we provide a common type production function, where we consider R&D activity (R&D) and labor (L) as the production factors for the firms growth. This implies R&D activity with innovation knowledge to replace the pure concept of capital in the process of economic production according to the characteristic of digital economic environment. It is a well known fact that capital and labor input are the traditional factors for the production in the literature of economics growth[3].

3) In Neoclassical growth models, the process of technological change is observable

Based on the assumption that production of each firm takes place with digital type economic factors, R&D activity with innovation knowledge and labor to show firm's production growth.

The production function is described as following:

$$Y = F(R\&D, L) = (R\&D)^{\alpha} L^{1-\alpha} \qquad (1)$$

Where Y is the output, R&D and L R&D activity with innovation knowledge[4] and labor in each firm's production process, respectively. And α is the relative parameter of the importance of R&D activity in producing output. In extreme cases, if $\alpha = 1$, the firm's production is carried throughout the use of R&D activity with innovation knowledge, which is a complete information-based automation economy. Conversely for the other case.

If we transform the level of total amount of R&D activity with innovation knowledge into per capita R&D activity, we need to divide R&D activity by labor (L), which is written as following:

$$y = (r\&d)^{\alpha} \qquad (2)$$

Equation 2 shows the firm's output per capita (y) is based on the per capita R&D activity (r&d), which represents the economic welfare better by considering the growth of population in this economy. (where y = Y/L, r&d = R&D/L)

R&D activity is the dynamic results of each firm's innovation knowledge based on the general interaction of economic factors. In the process of output in each firm, some amounts of R&D activity per capital are invested for production for each time. Subsequently, as new innovation knowledge arrives and replaces some of the previous innovation knowledge, there exists a depreciation of production factors. Based on these processes, we have the following equation for

mainly by its results, i.e. changes in the nature of inputs, variation of the production function or the Solow residual.

4) In this paper, innovation knowledge is viewed as information technology, which is produced with R&D activity like any other commodity in the market

the change in R&D activity over time:

$$\overset{o}{(R\&D)} = \Phi Y - \delta (R\&D) \qquad (3)$$

The point on the above in the R&D activity variable indicates the change in the amount of input in the process of producing output at each time by the R&D activity. In addition, equation 3 the R&D activity produces results of the innovation knowledge, so Φ refers to the relative amount of innovation knowledge in producing output; δ refers to the rate of depreciation of R&D activity, with δ being constant over the time. Also, we suppose that the labor growth of the economy grows constantly over the time.

Similar to equation 2, we need to transform the level of the R&D activity into per capita R&D activity. By dividing the R&D activity(R&D) by labor (L), we have the following equation in the below.

$$\overset{o}{(R\&D)} = \Phi y - (n+\delta)(r\&d) \text{ or } \overset{o}{(r\&d)} = \Phi (r\&d)^{a} - (n+\delta)(r\&d) \qquad (4)$$

Where Φ refers to the relative amount of innovation knowledge contributing to R&D activity per capita. n is the growth rate of population assuming it is constant over the time.

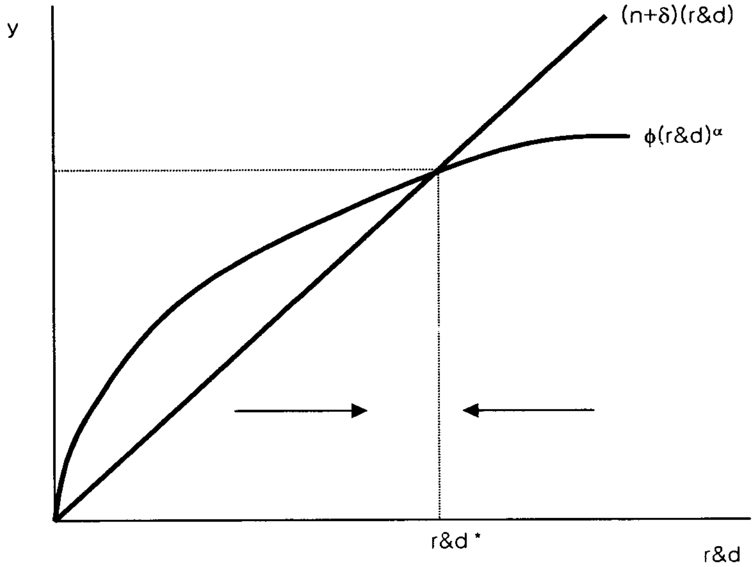
3.2 The Growth Pattern of the per capita R&D activity

In this section, we consider the various cases of the growth patterns of R&D activity per capita based on innovation knowledge. Specifically, based on the production by changing the rate of relative amount of the innovation knowledge for the per capita R&D activity in output.

3.2.1 The per capita R&D activity in the Steady State

If we consider the long-term view of the growth pattern, the per capita

R&D activity does not affect the growth of the output in this digital economy. In the steady state, we can find the optimal amount of innovation knowledge in the below figure.



<Figure 2: The per capita quantity of R&D activity in the steady state>

In steady state, various quantities grow at constant rate. In Solow type growth model, the steady state corresponds to $\overset{\circ}{(r\&d)} = 0$ in equation (4), to an intersection of the $\Phi(r\&d)^{\alpha}$ curve with the $(n+\delta)(r\&d)$ line in the Figure 2. The corresponding value of $(r\&d)$ is denoted $(r\&d)^{*}$. Algebraically, $(r\&d)^{*}$ satisfies the condition given:

$$\Phi(r\&d)^{\alpha} = (n+\delta)(r\&d) \qquad (5)$$

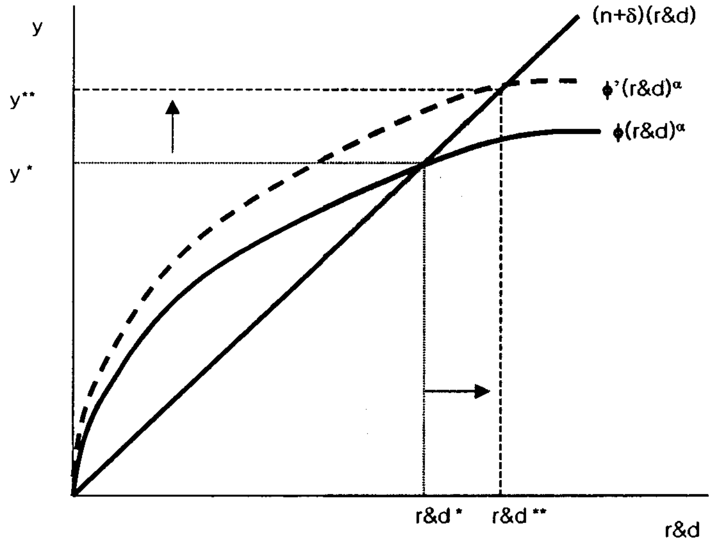
Since (r&d) is constant in steady state, y is also constant at the values, $y = (r\&d)^{*\alpha}$. Hence, the per capita quantities of y and (r&d) do not grow in the steady state based on the assumption that $0<\alpha<1$. The constancy of the per capita magnitudes means that the levels of variables, Y and (R&D) grow in steady state at the rate of population growth, n. So, the per capita quantities of (r&d) and y are given by:

$$(r\&d)^{*} = [\Phi/(n+\delta)]^{1/1-\alpha} \quad (6)$$

$$y^{*} = [\Phi/(n+\delta)]^{\alpha/1-\alpha} \quad (7)$$

Case I: Change in the amount of innovation knowledge in steady state.

Consider the case of change (increase) in the amount of innovation knowledge, α, in the process of R&D activity per capita ($\Phi \rightarrow \Phi'$(increasing))



<Figure 3: Increase in the amount of innovation knowledge in the steady state>

Figure 3 shows that increase in the amount of the innovation knowledge in production leads to shifting the curve, $\Phi(r\&d)^{\alpha}$ upward, which in turn leads to increasing $(r\&d)^{*}$ and y^{*} in steady state. The above Figure 3 shows the result of increasing the share of, Φ in the process of production.

3.2.2 The Transitional Dynamics

The long-term growth rate of (r&d) and y in the growth model are determined by exogenous elements. However, by considering the transitional dynamics, which shows the deviation of the steady state path, the model has more interesting implications. The transition shows how a digital economy's per capita innovation converges or deviates towards or from its own steady state value.

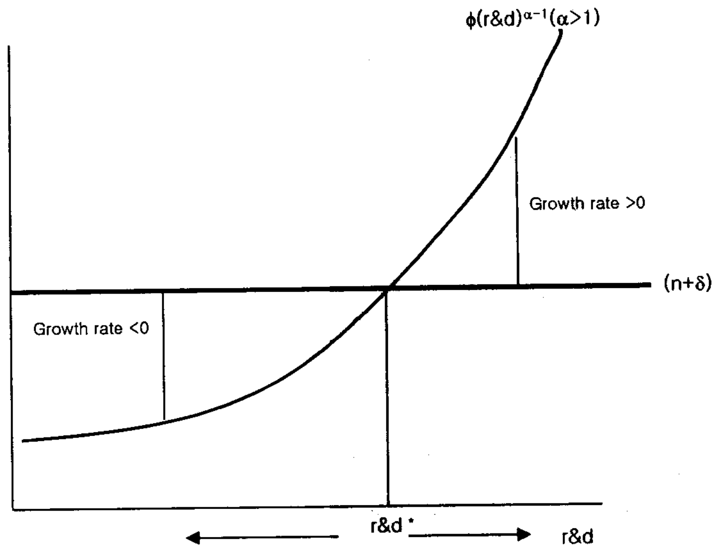
Division of the both sides of the equation (4) by (r&d) implies that the growth rate of (r&d) is given by:

$$\Psi_{r\&d} \equiv \overset{o}{r\&d} / r\&d = \Phi(r\&d)^{\alpha-1} - (n+\delta) \qquad (8)$$

Where Ψ refers to the growth rate of the R&D activity per capita. Note that, at all point in time, the growth rate of the level of R&D activity equals the per capita growth rate plus n; for example: $\Psi_{R\&D} = \Psi_{r\&d} + n$.

Subsequently, we shall find it convenient to focus on the growth rate of (r&d), as given in the equation (8). Equation (8) says that $\Psi_{r\&d}$ equals the difference between two terms, $\Phi(r\&d)^{\alpha-1}$ and $(n+\delta)$. In this case, the growth pattern of R&D activity and output are dependent on α, which is the relative parameter of the importance of R&D activity in output.

Case 1: $\alpha > 1$



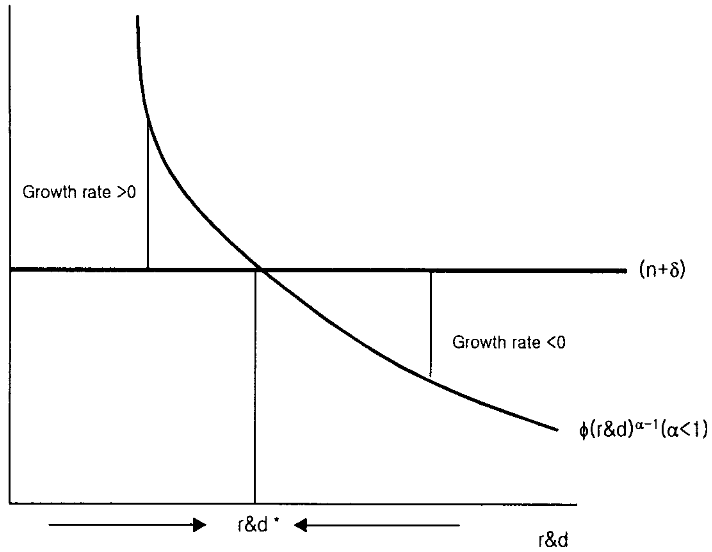
<Figure 4: Transitional Dynamics of the growth rate of R&D activity per capita >

That is, if $\alpha > 1$, the growth pattern will be two poles that deviate from steady state, implying that R&D activity per capital is greater than that of the quantities of steady state which leads to higher growth rate of the R&D activity and output. On the other hand, if R&D activity per capita is less than that of the quantities of steady state, then it leads to a deviation from the steady state point, which in turn results in lower growth rate of R&D activity and output.

Proposition 1[5] : Two pole of economic growth pattern (if $\alpha > 1$) leads to economic division between higher per capita R&D activity and lower per capita R&D activity. This showes that the initial situation of the quantities of the R&D activity per capita determine the growth pattern of this digital economy and results in digital technology division with deviations from steady state.

5) The type of growth pattern is regarded as the growth pattern in the digital economy.

Case 2: $\alpha < 1$



<Figure 5: Transitional Dynamics of the growth rate of R&D activity per capita>

However, if α<1, the growth pattern will be converge towards its own steady state point, implying that any point below the steady state implies that the marginal growth rate of R&D activity as the level of R&D activity decrease, on the other hand, any point that right of the steady state has a growth rate less than 0, showing with large level of the R&D activity, the marginal growth rate of R&D activity decreases. So, there exists only one point of (r&d)* in the steady state.

Proposition 2[6] : The economic growth pattern (if α<1) leads to economic convergence between higher per capita R&D activity and lower per capita R&D activity. This showes that regardless whether the initial situation of R&D activity per capita is higher or lower, they converge with the diminishing returns of the R&D activity per capita in real time. That is, it gives possibility of catching up effects of lower quantities of R&D activity per capita.

6) The type of growth pattern is called the traditional growth pattern due to the convergence with diminishing returns to R&D activity, that as r&d is relatively low, the marginal product of r&d is becoming higher, which leads to the steady state.

IV. Conclusions.

Using a simple growth model, we analyzed the patterns of economic growth in the R&D activity with regards to innovation knowledge. We found that while R&D(IK) is economically influenced, the growth patterns vary depending on the production processes of each firm. It is believed that R&D (IK) process provides the principal source of change of firm's productivity in steady-state.

Observing the transitional dynamics while varying the share of the per capita R&D activities, we have found that the share of the R&D activities lead to different growth patterns. This implies that as the share of the R&D activity per capita increase in the case of $\alpha>1$, there exists economic division between higher and lower R&D activity per capita. Conversely, if the share of the R&D activity per capita is $\alpha<1$, there exists economic convergence between higher and lower R&D activity per capita. Therefore, based on the R&D(IK), the digital economy may have different directions of the growth pattern.

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