R&D Activities, Imperfect Competition and Economic Growth

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Summary: Ideas do not become exhausted, and there are no diminishing returns in the creation of knowledge. Nonetheless, growth ultimately ceases in this simplest model of endogeneous innovation. But, if we treat knowledge capital as a public capital considering of its non-appropriable benefits, economic growth can be sustained in the economy.

We showed that considering goodness of fit of regression model, we can see that the empirical evidence is strongly in favor of the character of knowledge as the public knowledge capital. So, we can expect that by product differentiation, economic growth can be sustained in the Korean economy.

Key Word: R&D investment, product differentiation, knowledge capital, public capital, sustained growth, monopolistic competition

1. Introduction

In the 1920s and 1930s considerable progress was made in the analysis of economic equilibrium, "monopolistic competition revolution".

Monopolistic competition was introduced by Chamberlin(1933). His concern was to deal with market structures characterized by advertising and product differentiation. If a firm is making a profit selling a product in an industry, and other firms are not allowed to perfectly reproduce that product, they still may find it profitable to enter that industry and produce a similar but distinctive product. Economists refer to this phenomenon as product differentiation. Each product has its following of consumers, and so has some degree of market power.

Since Harrod(1939) and Domar(1946), economists have looked to captital formation for their explanation of rising standards of living. It was Solow(1956) who formalized the idea that capital deepening could cause labor productivity to rise in a dynamic process of investment and growth. The model's critical assumption concerning the product function is that it has CRS(constant returns to scale) in its two arguments, capital and labor. In addition, intangibles such as human capital and knowledge capital have pecular economic properties that may not be well represented by the standard formulations.

The starting point for discussions of the pure theory of trade and productivity is Ricardo's *Principles*. A country will choose to obtain goods through trade when a unit of labor applied to exports will produce more goods for home use than will result from the application of labor to produce these goods domestically. This will be the case whenever the relative labor costs involved in the production of different commodities differ from one country to another. This difference comes mainly from the difference of productivity. If one country invests in R&D activities, then that country can lower labor costs relatively and exports more commodities. An alternative approach to the pure theory of trade and productivity originated in the work of Hecksher(1919) and Ohlin(1933). Hecksher's purpose was to analyse the effects of trade on the income distribution between factors of production.

Although Linder(1961) stressed increasing returns to scale(IRS) in trade theory, it was not until much later (Krugman, 1979) that a more formal treatment of trade and productivity under IRS was provided. One of the problems with incorporating IRS into a theory of trade and productivity is the need to deal with imperfect competition. Krugman uses a model of monopolistic competition to show that trade can be viewed as a means of exploiting economies of scale in the presence of a less than completely elastic home market.

Grossman and Helpman(1991) developed coherent theoretical framework that previous discussions of trade, growth, development, industrial organization(IO) and innovation have lacked. They attempted to integrate the theory of IO with the theory of growth. As growth theory, they focused on the economic determinants of technological progress. As IO theory, they applied tools from the theory of IO to develop aggregate models of ongoing investemnts in new technologies. Their premise was that new technologies stem from the intentional actions of economic agents responding to market incentives.

In this paper, we review new models of intentional industiral innovation. We deal with innovation that serves to expand the range of goods avaliable on the market. Firms devote resources to R&D in order to invent new goods that substitute imperfectly for existing brands. Producers of unique products earn monopoly rents, which serve as the reward for their prior R&D investments. In addition, we adapt new growth theory to real Korean economy data by empirical analysis.

2. Economic model and empirical analysis

2.1 Imperfect competition and new growth theory

It was Solow(1956) who formalized the idea that capital deepening could cause labor productivity to rise in a dynamic process of investment and growth.

Many of the early models treated technological progress as an exogeneous process driven only by time. The view that innovation is driven by basic research, which is implicit in the models with exogeneous technology, was made explicit in a paper by Shell(1967).

Arrow(1962) was the first to view technological progress as an outgrowth of activities in the economic realm. Romer(1986), who discussed the possibility that learning-by-doing might be a source of growth, maintained this treatment of technological progress as wholly the outgrowth of an external economy.

Now we let the productivity of labor depend upon the economywide cumulative experience in the investment activity, that is, on the aggregate stock of capital. Then aggregate output of Z will be given by

$$Z=F[K,\ A(K)L].$$

The first argument in F( ) represents the private input of capital by all firms in the economy. The second argument reflects their aggregate employment of effective labor, which depends in part upon the state of technology, as represented by the term A(K).

Romer(1986) provides an alternative interpretation of this specification. He views K itself as knowledge. Knowledge is created via an R&D process. Firms invest in private knowledge, but at the same time they contribute inadvertently to a public pool of knowledge, which is represented here by A(K).

Shell(1967) makes knowledge the intended output of those who create it. The production function $F[K_Z,\ AL_Z]$ describes the relationship between inputs and output of the final good. We assume that the same production function applies to the generation of knowledge as applies to the production of tangible commodities:

$$\triangle A=F[K_A,\ AL_A]$$

where K_A and L_A are the inputs of capital and labor, respectively, into the research activity.

Grossman and Helpman(1991) developed endogenous growth based on intentional innovation. Industrial research may be aimed at inventing entirely new commodities(product innovation). They incorporated tools from the theory of industrial organization(IO), and their extensions in trade theory to general equilibrium settings to develop aggregate models of ongoing investments in new technologies. They represent the set of brands available on the market by the interval [0, n]. With this convention n is the measure of products invented. They referred to n as the "number" of available varieties.

Monopolistic competition was introduced by Chamberlin(1933). It is probably the most prevalent form of industry structure. If a firm is making a profit selling a product in an industry, and other firms are not allowed to perfectly reproduce that product, they still may find it profitable to enter that industry and produce a similar but distinctive product. Economists refer to this phenomenon as product differentiation. Each product has its following of consumers, and so has some degree of market power.

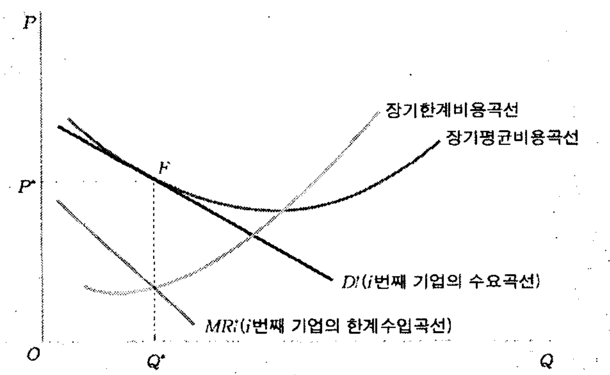
We can describe the (long-run) equilibrium of the industry in the following way:

(i) Each firm faces a downward-sloping demand.

(ii) Each firm makes no profit.

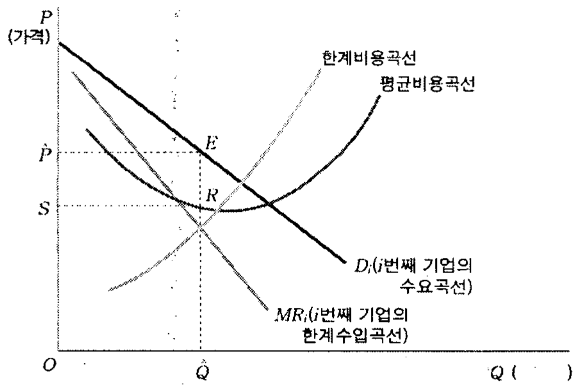
(iii) A price change by one firm has negligible effect.

<Figure 1> Long-run equilibrium in Monopolistic competition



If we treat commercial research as an ordinary economic activity, returns to R&D come in the form of monopoly rents in (short-run) imperfectly competitive product markets.

<Figure 2> Short-run equilibrium in Monopolistic competition



The representative household maximizes utility over an infinite horizon.

$$U(t)=\int_{t}^{\infty} e^{-\rho(\tau-t)}\log D(\tau)d\tau$$

Here $\log D(\tau)$ represents an index of consumption at time τ, and ρ is the subjective discount rate.

We adopt for D a specification that imposes a constant elasticity of substitution between every pair of goods. It is straightforward to show that, with these preferences, the elasticity of substitution between any two products is $\varepsilon = 1/(1-\alpha)$ (>1).

$$D=[\int_{0}^{n} x(j)^{\alpha}dj]^{(1/\alpha)} \qquad (2.1)$$

where x(j) denotes consumption of brand j.

It is useful to develop an interpretation of the consumption index D. We may think of households as consuming a single homogeneous consumption good in quantity D. We suppose that the final good is assembled from differentiated intermediate inputs or producer services.

In equilibrium manufacturers of consumer goods would employ equal quantities x(j)=x of each. Then (2.1) implies that $D = n^{(1/\alpha)}x$.

Then final output per unit of primary input(TFP) is given by $D/X = n^{(1-\alpha)/\alpha}$.

Firms may enter freely into R&D. An entrepreneur who devotes l units of labor to R&D for a time interval of length dt acquires the ability to produce dn=(l/a)dt new products.

The efoort creates value for the entrepreneur of v(l/a)dt, since each blueprint has a market value of v.

$$\Delta n = F[L_N]$$

It is known that when the initial number of brands exceeds n_0, there always exists a perfect foresight equilibrium with no product development.

Ideas do not become exhausted, and there are no diminishing returns in the creation of knowledge. Nonetheless, growth ultimately ceases in this simplest model of endogeneous innovation.

As yet, we treated knowledge capital as a private good. But, the originators of many new ideas often cannot appropriate all of the potential benefits from their creations.

So in this point, we modify formulation of knowledge creation to allow for the existence of non-appropriable benefits from industrial research.

Romer(1990) argued that each research project also contributes to a stock of general knowledge capital $K_N(t)$.

In place of technology for product innovation $\Delta n = F[L_N]$, we assume that

$$\Delta n = F[K_N,\ L_N] = (1/a)(K_N L_N)$$

where K_N and L_N are stock of general knowledge capital and aggregate employment in R&D, respectively. Of course the previous formulation is a special case of this equation with $K_N(t) \equiv 1$.

We take the knowledge capital stock to be proportional to the economy's cumulative experience at R&D.

$$K_N = n$$

Let's ask what the equilibrium implies about the rate of growth of final output and the rate of growth of GDP. When the differentiated products are interpreted to be intermediate goods, clearly faster innovation implies faster output growth.

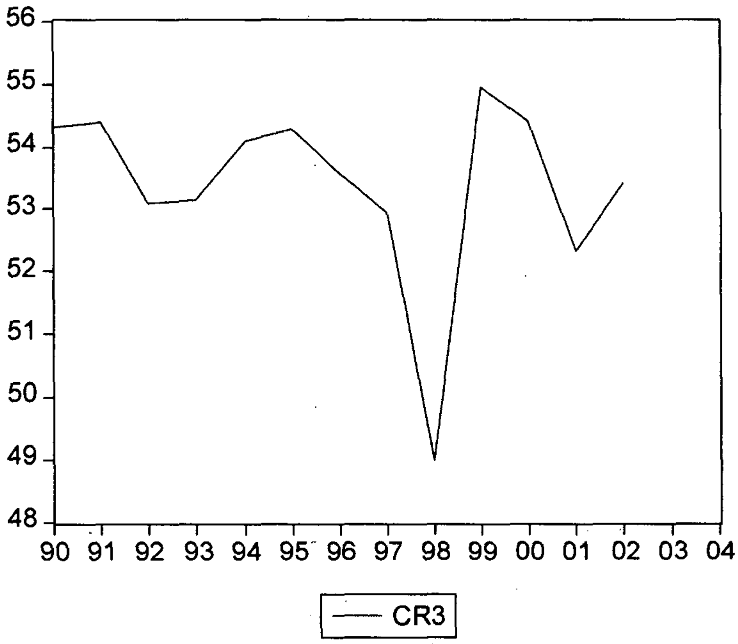
It is apparent that the economy innovates faster the larger is its resource base(large L), the more productive are its resources in the industrial research lab(small a), the more patient are its households(small ρ), and the greater is the perceived differentiation of products(small α).

If we treat knowledge capital as a public capital considering of its non-appropriable benefits, economic growth can be sustained in the economy.

IO economists have long tried to summarize the distribution of market shares among firms in a single index to be used in econometric and antitrust analysis. Such an aggregate index is called a concentration index.

The 3-firm concentration ratio(CR3), which adds up the 3 highest shares in the economy has been changed as in <Fig. 3> From this, we can infer that oligopolistic market structure like monopolistic competition is probably the most prevalent form of Korean industry structure.

<Figure 3> 3-firm concentration ratio of Korea(CR3)



2.2 Data and empirical analysis

The term "panel data" refers to data sets where we have data on the same individual(industry; i) over several periods of time(t). The main advantage is that it allows us to test and relax the assumptions that are implicit in cross-sectional analysis.

The data set consists of 5 industries in manufacturing sector observed yearly for 15 years(1990-2004), a "balanced panel". Because of no missing data on some of the variables, we obtained 75 observations.

We examined a simple model for the technology for product innovation of 5 industries in manufacturing sector:

$n_{it} = \alpha_i + \beta' x_{it} + \varepsilon_{it}$

n: the number of firms in each industry

x: R&D investment, R&D stock, R&D personnel

The fixed effects approach takes α_i to be a group(industry) specific constant term in the regression model. The random effects approach specifies that takes α_i is a group(industry) specific disturbance in the regression model.

Fixed and random effects regression produces the following results. Estimated standard errors are given together. <Table> also contains the estimated technology for product innovation equations with individual industry effects.

<Table 2> Panel data by industrty classification

Industy variable (1990-2004)	R&D(OECD, STAT) Value Added(STAT)
FOOD	Food products, beverages and tobacco
CLOTH	Textiles, textile products, leather and footwear
CHEMICAL	Chemical, rubber, plastics and fuel products
METAL	Basic metals
MACHINE	Machinery and equipment, instruments and transport equipment

<Table 3> contains the estimated production function for blueprints(knowledge) with individual industry disturbances. Considering chi-squared statistic for testing for the fixed and random effects, we can see that the evidence is strongly in favor of the random effects model.

We examined the following model for the technology for product innovation of 5 industries in manufacturing sector:

$n_{it} = \alpha_i + \beta' x_{it} + \gamma GDP_t + \varepsilon_{it}$

x: R&D investment

Significantly estimated elasticity of R&D to the number of firms in each industry is 0.14. It means that if firms increase R&D by 1%, then the number of blueprint is increased by 0.14%. GDP variable is used to control confounding factors(eg. business cycle).

<Table 3> Random-effects model estimation for panel data[1]

Dependent Variable: LOG(N?)				
Method: Pooled EGLS (Cross-section random effects)				
Sample (adjusted): 1991 2004				
Included observations: 14 after adjustments				
Cross-sections included: 5				
Total pool (balanced) observations: 70				
Swamy and Arora estimator of component variances				
Period SUR (PCSE) standard errors & covariance (d.f. corrected)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.464819	1.136276	2.169208	0.0336*
LOG(RD?(0))	0.137833	0.044106	3.125044	0.0026*
LOG(GDP(-1))	0.38548	0.09349	4.123231	0.0001*
Random Effects (Cross)				
_FOOD--C	-0.37473			
_CLOTH--C	0.851245			
_CHEMICAL--C	0.425791			
_METAL--C	-1.46356			
_MACHINE--C	0.561251			
	Effects Specification			
Cross-section random S.D. / Rho			1.013221	0.9933
Idiosyncratic random S.D. / Rho			0.083326	0.0067
	Weighted Statistics			
R-squared	0.729983	Mean dependent var		0.203608
Adjusted R-squared	0.721923	S.D. dependent var		0.157329
S.E. of regression	0.082965	Sum squared resid		0.461168
F-statistic	90.5662	Durbin-Watson stat		0.874371
Prob(F-statistic)	0			

Next, we examined the following model for the economic growth by product differentiation of 5 industries in manufacturing sector:

<Table 4> contains the estimated grow rate function in each industry byproduct differentiation with individual industry effects. Considering F statistic for testing the joint significance of the industry effects, we can see that the evidence is strongly in favor of a industry specific effect in the data.

$$(\Delta V/V)_{it} = \alpha_i + \beta' n_{it} + \gamma GDP_{t-1} + \varepsilon_{it}$$

V: Value added by industry

Significantly estimated elasticity of product differentiation to the economic growth in each industry is 0.18. It means that if firms increase product differentiation by 1%, then the grow rate of industry is increased by 0.18%. Lagged GDP variable is used to control confounding factors(eg. business cycle).

1) If estimated coefficient is statistically significant, we denote *, or **, by 5% or 10% confidence level, respectively.

<Table 4> **Fixed-effects model estimation for panel data**

Dependent Variable: LOG(V?)-LOG(V?(-1))				
Method: Pooled Least Squares				
Sample (adjusted): 1992 2003				
Included observations: 12 after adjustments				
Cross-sections included: 5				
Total pool (balanced) observations: 60				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.126298	0.662803	3.208037	0.0023*
LOG(N?(0))	0.178434	0.102772	1.736217	0.0883**
LOG(GDP(-1))	-0.282846	0.071846	-3.936838	0.0002
Fixed Effects (Cross)				
_FOOD--C	0.074848			
_CLOTH--C	-0.151938			
_CHEMICAL--C	-0.083044			
_METAL--C	0.288039			
_MACHINE--C	-0.127905			
	Effects Specification			
Cross-section fixed (dummy variables)				
R-squared	0.345753		Mean dependent var	0.079265
Adjusted R-squared	0.271688		S.D. dependent var	0.078827
S.E. of regression	0.067272		Akaike info criterion	-2.450877
Sum squared resid	0.239850		Schwarz criterion	-2.206537
Log likelihood	80.52631		F-statistic	4.668201
Durbin-Watson stat	2.252562		Prob(F-statistic)	0.000704

Next, we examined the following model for the production function for blueprints(knowledge). We analysed the model to see whether the knowledge is a private good or public capital.

Considering goodness of fit, we can see that the evidence is strongly in favor of the character as the public knowledge capital.

We examined the following models for the technology for product innovation of 5 industries in manufacturing sector:

$$\Delta n_{it} = \alpha_i + \beta' RL_{it} + \gamma n_{it} + \varepsilon_{it} \qquad (2.2)$$

$$\Delta n_{it} = \alpha_i + \beta' RK_{it} + \varepsilon_{it} \qquad (2.3)$$

$$\Delta n_{it} = \alpha_i + \beta' RL_{it} + \gamma RK_{it} ++ \varepsilon_{it} \qquad (2.4)$$

$$\Delta n_{it} = \alpha_i + \beta' n_{it} + \varepsilon_{it} \qquad (2.5)$$

$$\Delta n_{it} = \alpha_i + \beta' RL_{it} + \varepsilon_{it} \qquad (2.6)$$

RL: R&D personnel

RK: R&D capital(stock)

Considering goodness of fit of regression model, we can see that the evidence is most in favor of the equation(2.5).(<Table 5>) That result gives the implication that by product differentiation, economic growth can be sustained in the Korean economy.

<Table 5> Pooles LS estimation for panel data

Dependent Variable: (N?(0)-N?(-1))				
Method: Pooled Least Squares				
Sample (adjusted): 1992 2004				
Included observations: 13 after adjustments				
Cross-sections included: 5				
Total pool (balanced) observations: 65				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-92.21473	289.6156	-0.318404	0.7512
N?	0.040503	0.016040	2.525210	0.0141*
R-squared	0.091914		Mean dependent var	522.0462
Adjusted R-squared	0.077500		S.D. dependent var	1319.392
S.E. of regression	1267.235		Akaike info criterion	17.15735
Sum squared resid	1.01E+08		Schwarz criterion	17.22425
Log likelihood	-555.6138		F-statistic	6.376684
Durbin-Watson stat	1.652972		Prob(F-statistic)	0.014092

3. Summary and conclusion

The model of Grossman and Helpman(1991) predicts equal rates of productivity growth in the sectors that manufacture innovative goods in each country. But high technology comprises a larger share of the national economy in the human-capital-rich country than it does in the unskilled-labor-rich country. It follows that real output growth is faster in the former country than in the latter.

In the endogeneous growth model which treats knowledge capital as a private good, it is known that when the initial number of brands exceeds some number(eg. n_0), there always exists a perfect foresight equilibrium with no product development.

Ideas do not become exhausted, and there are no diminishing returns in the creation of knowledge. Nonetheless, growth ultimately ceases in this simplest model of endogeneous innovation.

But, if we treat knowledge capital as a public capital considering of its non-appropriable benefits, economic growth can be sustained in the economy.

We showed that considering goodness of fit of regression model, we can see that the empirical evidence is strongly in favor of the character of knowledge as the public knowledge capital.

So, we can expect that by product differentiation, economic growth can be sustained in the Korean economy.

<Table 6> Panel analysis summary

Causal relationship	Innovation	(Elasticity)	Industry structure	(Elasticity)	Growth
Monopolistic competition	R&D investment(X)	⇒(0.14)	Product differentiation (N)	⇒	(0.18)Economic growth in industry($\Delta V/V$)

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