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R&D Investment, Job Creation, and Job Destruction in Korea : Technological Progress and Labor Market Equilibrium

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If technical advances are of a form that can be utilized by existing plants, then investors will be encouraged to create new plants (the "capitalization effect"), which will, in turn, create more vacancies and hire more workers. If technical progress occurs at a very fast pace, however, the proportion of workers released from production units will be high and leads to job destruction (the "creative destruction effect").

We tested several propositions and implications for labor market equilibrium of Schumpeterian growth theory against the data of the Korean economy. When we examine the results of our estimations and others tests, we find that the evidence suggests that the capitalization effect of growth on unemployment has been dominant in the Korean economy in the past through the labor market variables. The difference of this study from Kim (2007) is that we consider diverse market variables like separation rate, job-finding rate and unemployment rate through estimation. We can find significant relationships between market variables and technology accumulation (R&D).

Finally, recent "jobless growth" may be due to very little capitalization effects of productivity growth.

Keyword : R&D investment, technical innovation, economic growth, creative destruction, capitalization effect

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Ⅰ. Introduction

Prominent economists have proposed and held the view that technological progress destroys jobs.[1] Rifkin (1995) argued that IT technology makes workers be unnecessary in production process. However, Blanchard argue that there is no solid statistical relationship between technical growth and unemployment (Cahuc et al., 2004).

In this paper, we consider the most recent data on inputs for knowledge, R&D, and unemployment in the Korean economy. We tested the hypothesis that technological change represented by R&D investment increased the unemployment rate and we found that the data does not uphold the hypothesis, and we argue instead that technological change has led to a decrease in the unemployment rate in Korea.[2] We want to see separated effects of job creation and destruction of technical progress. First, R&D promotes productivity and return, so increases the incentive for job creation. Second, through creative destruction, R&D destroy jobs of old technology. OECD and Blanchard and Wolfers (2000) show that scatter diagram of unemployment and Solow residual reveals positive relationship, and this implies job destruction effect indirectly.

Pissarides (2000) gives standard matching model for analyzing job creation and destruction. Pissarides (1979) expresses job application of unemployed person and vacant jobs as tossing balls and urns, respectively. In standard models, mainly job offer rate or unemployment insurance are analyzed. Mortensen and Pissarides (1999)

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1) In *Principles*, Ricardo said something about the negative effect of innovation on unemployment (Ricardo, p. 269).

2) Davis and Haltiwanger (1992) show that periods of high unemployment tend to be periods of high job turnover. Since industrial innovations raise the job-destruction rate through skill-obsolescence, there will be a positive relationship between growth and unemployment according to them.

discuss endogeneous job destruction from negative (idiosyncratic) shock using matching model. This approach enables us to analyze the randomness of innovation, and the effect on employment. This is associated with Schumpeterian growth theory, which regards the output of R&D as increasing the probability of innovation success. But, direct linkage with (stochastic) job creation is not developed in economic literatures. Applying similar logic to Korea economy is Chang et al. (2004). Their discussion is very helpful in developing this study.

In contrast to those, Aghion and Howitt (1998) starts with a plant-worker model where a plant has a technology of vintage t. Technological progress may destroy existing matches between plant and worker or create new matches through constructing new plants. Their growth model is characterized as follows: Each inventor tries quality raising innovation whose success probability is determined by the input of R&D. If suceeds, she become monopolistic entrepreneur for (improved) intermediate product. Then, productivity increases, which contribute to the growth. If machine or factory embody the new technology, hiring and layoff of worker in final good production is affected by this technology implementation. This model determines the number of unemployed persons as a function of parameters of technical progress and match-related labor market variables.

In general, unemployment is caused by workers moving to new plants that embody new technology, where this is called the "creative destruction effect". This effect can be seen as a shortened lifespan of a job due to the increase of productivity. This also seems to be social cost of introducing new technology into jobs. It destroys existing matches between workers and jobs using obsolescent technology.

Technical advances, however, can also take a form that can either be utilized immediately by existing plants or be utilized by existing plants after minor upgrades. In such a case, investors will be encouraged to create new (vacant) jobs in order to be able to benefit from future technical advances. This is called the "capitalization effect" (Aghion and Howitt 1998). It also means that profit opportunity increases resulting from active job creation of firm. This opportunity comes from constructing more structures like factories (plants), and this leads to more new jobs (vacancies). It affects vacancies through reducing discount rate of future returns of newly constructed plants using existing technology. High rate of productivity growth reduces the discount rate used by investors.

Pissarides (2000) analyzes these two effects using the Beveridge curve and the "tightness" variable. We do not go further beyond Aghion and Howitt (1998), since discussing job creation and destruction in Korea using only tools of them is sufficient enough.

We need to distinguish "disembodied" and "embodied" technical progress. In Solow's neoclassical model, most progress is disembodied. But, the model used in this paper involves embodied progress, so firm owners should invest fund to physical capital for implementing progress.

Now, we examine some macroeconomic data for analyzing these issues.

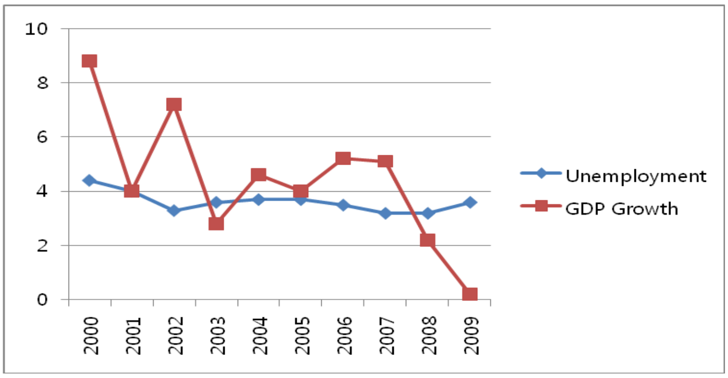
Over the past 30 years, continuing (economic) structural changes have occurred across several countries. The U.S. and other developed countries are often said to exhibit so-called "jobless growth."[3] The possibility of falling into such a growth pattern has been an important concern in Korea in recent years. <Table 1> shows the case of jobless growth especially in 2006 and 2007. Though the growth reached to 5.1-5.2%, unemployment did not decreased substantially. More accurately, the concept of growth used in this section is different from that used in most growth literatature. The former sees the growth of actual GDP, but the latter watches the change in the trend of (per capita) GDP.

The question of whether faster technological progress speeds up the destruction of jobs in Korea will be the main focus of the present paper. We review new endogenous growth models of intentional industrial innovation. In particular, we deal with innovation that enhances a plant unit's productivity (Aghion and Howitt 1998). This productivity means factors other than the amount of variable factor that affect

3) In spite of growth in economic activity, the rate of increase in employment does not rise accordingly.

〈Table 1〉 The Rate of Increase in Economic Growth and Unemployment in Korea (%)

	Unemployment	GDP Growth
2000	4.4	8.8
2001	4.0	4.0
2002	3.3	7.2
2003	3.6	2.8
2004	3.7	4.6
2005	3.7	4.0
2006	3.5	5.2
2007	3.2	5.1
2008	3.2	2.2
2009	3.6	0.2



the output of plant unit. In this study, we use TFP data for approximating this representative plant's productivity factor.

Previously, Kim (2007) analyzed the existence of capitalization effect using R&D investments data. Main progress of this study is that we consider the movement of labor market variable that affects job creation and destruction in matching process. In addition, we give some answers for what effect technological progress has on the variable in matching process between jobs and workers. Especially, we give empirical answers to the hypotheses of Aghion and Howitt (1998). Their propositions are worth being tested using real- world labor market data of South Korea enough.

Our study investigate proper econometric methods for estimating economic relationships between innovation and labor market variables. Previous literature discussing these relationship is somewhat rare, and we may give contribution of empirical evidence.

This paper is composed as follows: Section 2 surveys new growth theory and its (testable) implication. Section 3 performs empirical research for the implication of theory. Section 4 summarizes and concludes.

Ⅱ. Backgrounds: Economic Growth and Unemployment

1. New growth theory and Labor Market: The 1990s in Korea

In general, labor markets are characterized by high rates of turnover. In the Korean manufacturing sector, more than 2% of workers leave their jobs in a typical month. In addition, there is a high turnover in the jobs themselves. In Korean manufacturing sector, for example, at least 10% of existing jobs disappears each year (Kim 2006). These data suggest that a large portion of unemployment results from the dynamics of the economy.

Constructing a friction model for the labor market requires moving into a market with a matching process. When workers and jobs are heterogeneous, the labor market does not have the characteristics of a Walrasian market. Workers and firms engage in a process of trying to match up specific needs. Since this process has some frictions, it results in unemployment[4] (Romer 2006). Romer (2006)'s model is based on Pissarides (1985). If there occurs technical progress that increases the output given the amount of input, equilibrium employment increases. Technical progress increases the return of vacant jobs.

4) In addition, it may have implications for how employment respond to technological progress.

Much literature has tried to characterize how equilibrium unemployment reacts to the rate of technological change. There are two main approaches to the problem that yield contrary effects (Hornstein et al. 2005).**(Summary 1)**

The first approach argues that new equipment enters the economy through the creation of new matches (“creative destruction effect”).5) These new matches occur through obsolescence of old plants and separation of workers.

The second approach proposes an alternative view that the new technologies enter into firms through upgrades to pre-existing plant units. For small values of upgrading costs, unemployment falls with growth (“capitalization effect”). These matches implies increased vacancies and possibility of job creation.

We now turn to the analysis of how technological progress affects frictional unemployment in the matching model.

[Fig. 1] shows a labor-force dynamic model that defines the determinants of the natural rate of unemployment. In each period, a fraction 1/S of the employed loses their jobs due to “creative destruction,” and a fraction *m* of the unemployed find jobs due to the “capitalization effect.” This gives the idea of determing employment through matching heterogeneous jobs and workers. Our study focuses on the role of embodied technical progress on the job creation and destruction.

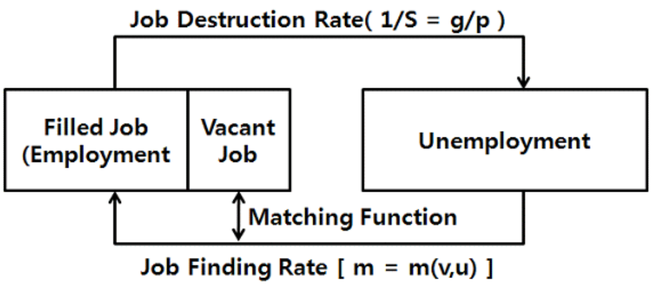
In the above diagram, filled job can be regarded as labor demand, and the sum of filled job and unemployment be labor supply(Table 2). We can also draw Beverage curve from two variables(Fig. 2).

(Summary 1) Technical Progress and Unemployment (Hornstein et al., 2005)

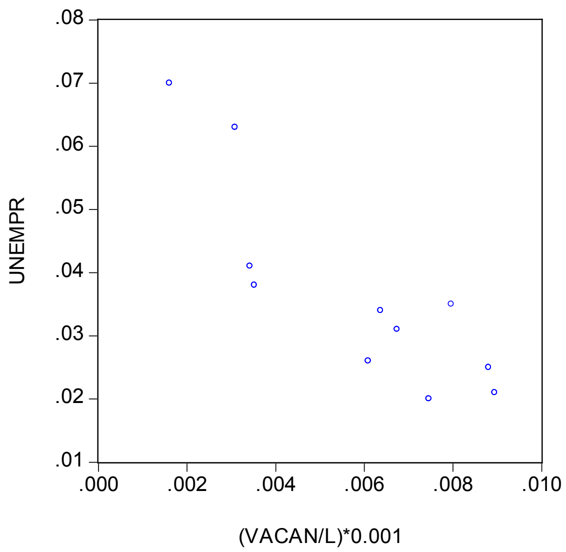
Approach	Aghion and Howitt (1998)	Mortensen and Pissarides (1998)
Effect of Technical Progress On Unemployment	“creative destruction effect”	“capitalization effect”
How	the creation of new matches	upgrading process of plant unit

5) In this process, the increase of growth rate raises job destruction rate(=growth rate/lifetime of plant).

〔Fig. 1〕 Matching Model: Technical Progress and Unemployment (Aghion and Howitt, 1998) 〔m(u, v): total matching rate, v: vacancy, : u: unemployment[6], 1/S: production units' obsolescence, p(v): job-finding rate, S: lifetime of plants, g/Γ: job separation rate, Γ: economic lifetime of a plant〕



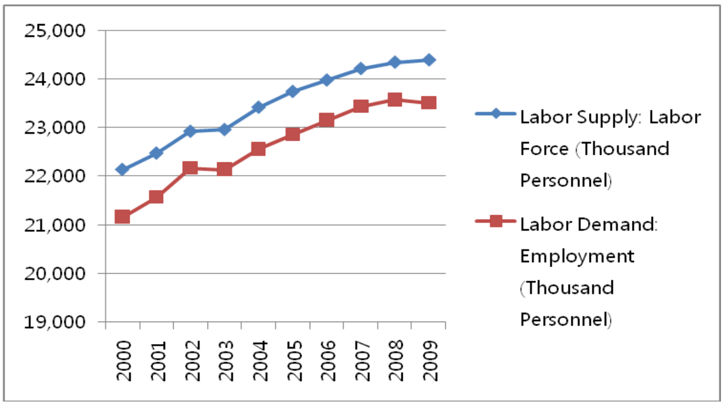
〔Fig. 2〕 Beveridge Curve(vacancy rate and unemployment rate)



6) The participation from non-labor force to labor force (unemployment) is determined by reservation wage, but, in this model, this fact is neglected.

〈Table 2〉 Labor Supply and Labor Demand

	Labor Supply: Labor Force (Thousand Personnel)	Labor Demand: Employment (Thousand Personnel)
2000	22,134	21,156
2001	22,471	21,572
2002	22,921	22,169
2003	22,957	22,139
2004	23,417	22,557
2005	23,743	22,856
2006	23,978	23,151
2007	24,216	23,433
2008	24,347	23,577
2009	24,394	23,506



Now, we briefly overview the situation of the labor market in the Korean economy.[7)]

First, we consider the supply side of the market. In terms of the economically active population (older than 15 years), the big problem in Korea is that of the "aging society"; this means that the size of the total population and labor force will shrink in the near future. Recent labor force participation growth also suggests that the size of the labor force is becoming stationary. Total labor hours (per week) declined sharply to about 40 in the 2000's. On the other hand, the level of human capital per

7) Chung (2006), Ahn (2006): Korean textbooks.

worker shows a steady increase due to the increase of persistent human investments such as schooling.

Next, we consider the demand side of labor market. During the 1960-2004 period, total employment increased from 7.7 to 22.6 million persons. The elasticity of employment to production shows a recent steadily decreasing trend; in the manufacturing sector, it shows a value of nearly “zero”.

During the period of 1970~2009, the increase in real GDP came with a large increase in total employment growth and a steady decrease in unemployment. Productivity growth was unusually high during the second half of the 1970s, and 1980s.

The result of output growth in excess of productivity growth was a steady decrease in unemployment.[8] After the late 1990s, during which financial crises occurred, output growth was high, but firms and consumers were not optimistic; for firms, there were no factors and incentives that appeared to justify high rates of investment.

In 2001, the Korean economy went into recessions.[9] After this recession, output growth, however, was positive and showed about 4.5% in 2004 and 2005. In these periods, unemployment was high. The recovery seemed to be a jobless growth (recovery).[10]

Labor productivity growth (averaging 5%, BOK) and total factor productivity growth (1~3%, STEPI)[11] was high. The plants seemed to have a short lifetime and the proportion of workers released was therefore high (“direct creative destruction”).[12] This may be due to the pessimism (or skepticism) of firms about the effect of productivity growth on the economy.

We extracted the cyclical factors for growth and unemployment through this HP filter(Fig. 3).

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8) We can consider the following elementary identity (Blanchard 2006).
Employment= (output) / (productivity).

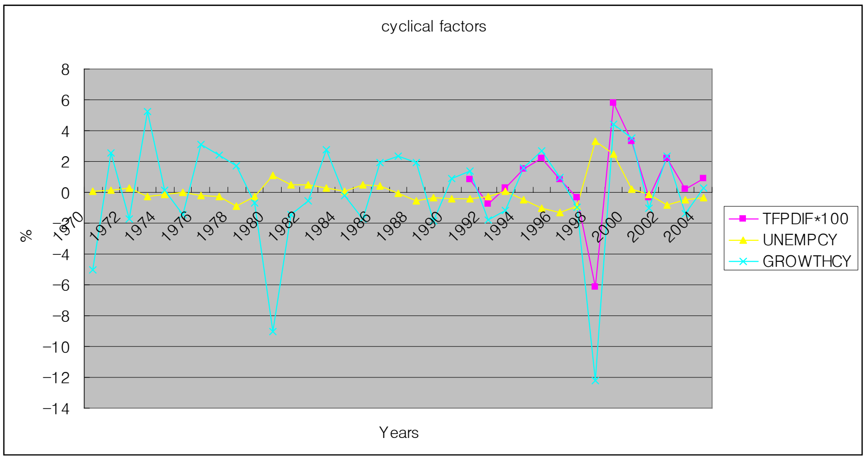
9) To be more accurate, the recession that started in Aug. 2000 ended in July 2001. And, expansion continued until Dec. 2002, so the growth rate was positive (the comment of reviewer).

10) This high unemployment might come from recession also.

11) Shin, T., Effects of R&D Investment on Economic Growth and Income Distribution, 2006, STEPI.

12) Generally, in macroeconomics, the labor productivity is known as procyclical variable.

〔Fig. 3〕 Cyclical Factors in GDP and Unemployment Rate in Korea

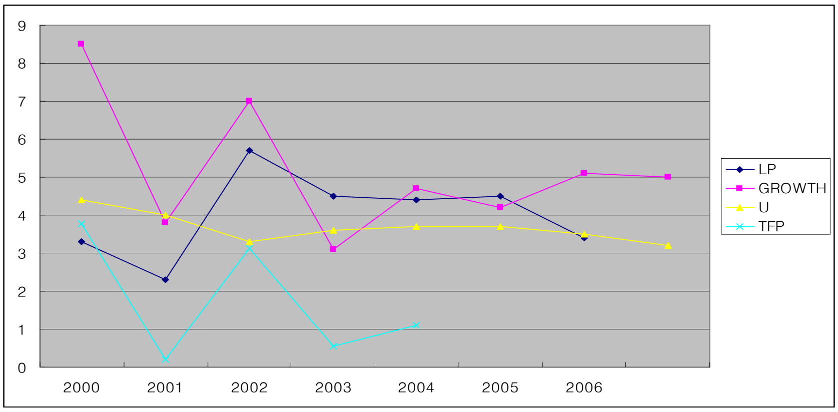


Source: BOK.

From this, we find that after the late 1990s, output growth was relatively high. Furthermore, the increase in productivity growth compared to GDP growth did not come with a steady decrease in unemployment. We can see recent trend in labor productivity from <Table 3>. It shows downward trend since 2007.

[Fig. 4] shows the trend in productivity, output growth and unemployment. We can

〔Fig. 4〕 The Growth Rate of TFP and Unemployment Rate in Korea (2000's) (%)

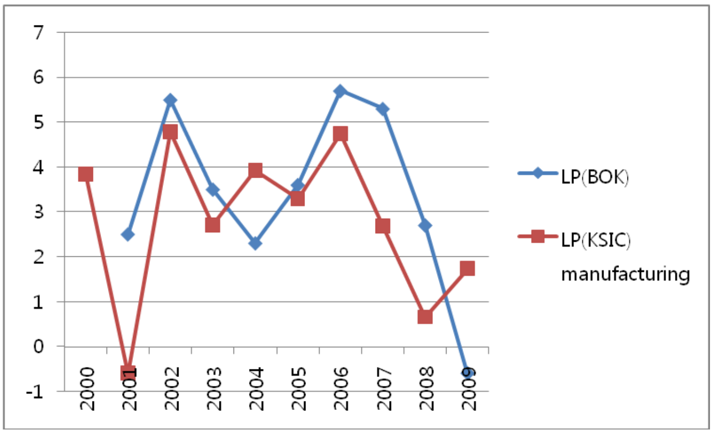


Source: BOK.

〈Table 3〉 The Growth Rate of Labor Productivity in Korea (%)

	LP(BOK)	LP(KSIC) manufacturing
2000		3.83
2001	2.5	-0.6
2002	5.5	4.78
2003	3.5	2.7
2004	2.3	3.92
2005	3.6	3.29
2006	5.7	4.73
2007	5.3	2.68
2008	2.7	0.65
2009	-0.6	1.73

Source: BOK Economic Statistics System Macroeconomic Analysis[13] & KSIC)[14]



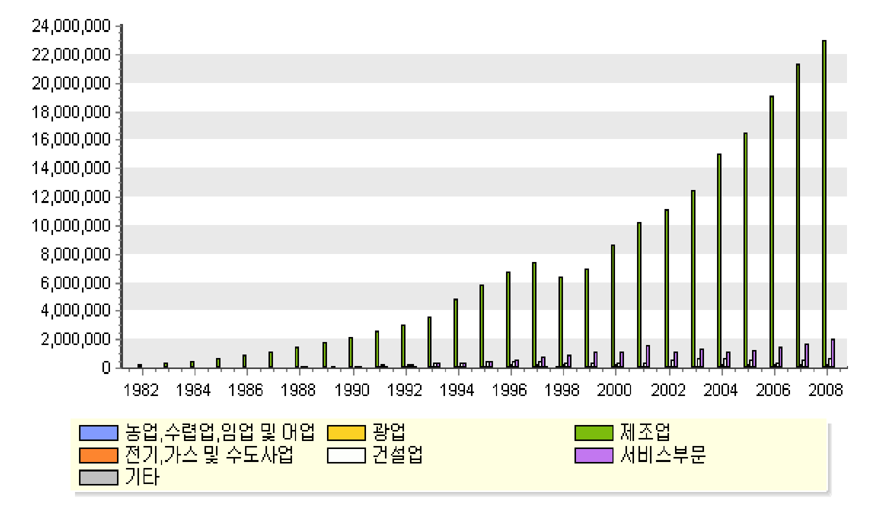
also check the periods of both high GDP growth and high unemployment.

[Fig. 5] shows that the increasing trend of R&D investment in Korea, and we investigate the effect of this on job creation and destruction through technical progress.

13) (Non-agricultural real GDP) / (employment multiplied by labor hour).

14) We can analyze robustness of results applied to different measures of productivity, but we postpone it into future research.

〔Fig. 5〕 Trend of R&D Investments in Korea (100 Mil. Won)



Source: National Technical Information Service:[NTIS][15)]

2. The Schumpeterian Endogenous Growth Model: The Hypothesis Being Tested

From analyses of the Schumpeterian growth theory with regard to unemployment (job destruction) and job creation, we can choose some hypotheses for empirical tests (Aghion and Howitt 1988). Main contribution of this study is focused on these hypotheses tests.

For details on the theoretical model, refer to <Appendix>.

1) Growth Rate

The growth rate of output g_A is an increasing function of R&D and fertility λ and a decreasing function of the level of real wages w, the hiring cost c, the (real) interest rate and the worker's quit rate b.

15) Spending on goods and services in R&D activities measured in GDP.

2) Job Separation Rate

The growth rate of output gA has a positive effect on the job separation rate.

3) Unemployment Rate

The employment level (or the unemployment rate) is a decreasing (increasing) function of the growth rate of output g_A, the hiring cost c, and the worker quit rate b.

4) Job Creation

The rate of job creation is a decreasing function of the growth rate of output g_A, the hiring cost c, and the worker quit rate b.

Ⅲ. Economic Growth and Labor Market: Empirical Analysis

1. Data and Empirical Analysis: Growth and Unemployment

The data set consists of some macro-economic variables, such as rate of unemployment, GDP, and wage, observed for 38 years (1970-2007) in Korea. These were obtained from OECD, BOK, KOSIS, Ministry of Labor and IFS. R&D data came from Ministry of Education (or STEPI, KOSIS) and Vacancy data from Ministry of Labor(Report on Labor Demand Survey). In this section, 3.1, we primarily test the prediction for growth and unemployment made by Aghion and Howitt (1998).

1.1 Capitalization Effects

We extracted the series for (unobservable) natural rate of unemployment (u*) through this HP filter. From our regression results, we find that R&D investment significantly lowers the trend of the unemployment rate (natural unemployment rate; UNEMP). <omitted >

In the regression of the number of job vacancies (VACAN) on the growth rate (log difference of GDP), there seem to be a significant “capitalization effect.” That is, an increase in the growth rate causes a significant increase in the number of vacancies (Table 4, first column)[16].

In this Table, multiple least squares regression method is mainly used for detecting the relationships between labor market variables and R&D. If there occurs incorrect estimation of standard error due to autocorrelation, we adopt GLS method, which uses the information of variance (estimate) of error in estimating coefficient parameter. If there is autocorrelation in the error of estimation equation, Gauss-Marcov Theorem no longer holds, and OLS estimator is not efficient. In addition, t-testing may be misleading.[17]

The main contribution of this study is that we can find statistically significant relationships suggested by endogeneous growth (in box below) model from real labor market data. Kim (2007) do not consider diverse relationships between labor market variables in matching and growth process.

From these estimation results, we can see that, in the past, the increasing effects of the level of vacancies υ and hence the job-finding rate p (υ) [capitalization effect] dominates both the increasing effect of job-separation rate (1/S) [creative destruction effect] and the decreasing effect of the job-creation rate p ( ) [indirect creative destruction effect].

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16) AR(1), AR(2) denotes first and second-order autocorrelation coefficient, hereafter. Some estimation equations do not reveal autocorrelation problem.

17) Our study’s limit may be the fact that we do not consider lagged effect, but only consider contemporaneous relationships. We can solve this problem by using, for example, distributed lag model, Almond lag or ARDL model.

〈Table 4〉 Estimation of Schumpeterian Growth Model[18]

Dependent Variable: LOG(VACAN)			LNTFP		LNTFP		SEPARR	
Sample (adjusted): 1995 / 2006			1971 / 2004		1971 / 2004		1994 / 2007	
	Coeffi-cient	Prob.	Coeffi-cient	Prob.	Coeffi cient	Prob.	Coeffi-cient	Prob.
C	13.28	0.33	0.003	0.97	0.52	0	14.75	0.0002
Growth Rate	9.07	0.00**						
REAL R	-0.00	0.90						
LNRD			0.136	0.00**			0.31	0.28
SV1F					19.90	0.00**		
LOG(WAGE)							-1.06	0.016**
LOG(GDP)								
LOG(UNEMPLOYED)								
LOG(VACAN)								
AR(1)	0.95	0.00*	0.69	0**	0.21	0.00**		
Adjusted R Square	0.682		0.984		0.943		0.873	

	Dependent Variable: UNEMP		FINDR		LOG(ENTER)		LOG(ENTER)	
	1976 / 2003		1994 / 2007		1994 / 2007		1994 / 2007	
	Coeffic ient	Prob.	Coeffic ient	Prob.	Coeffic ient	Prob.	Coeffic ient	Prob.
C	62.44	0.00	9.43	0.02**	5.60	0.00	5.42	0.03
Growth Rate			1.69	0.00**	1.05	0**		
REAL R		0.02	0.01	0.55				
LNRD	18.16	0.74						
SV1F	7.88	0.02**						
LOG(WAGE)	-12.99	0.01**	-0.49	0.06*	0.42	0.00**		
LOG(GDP)								
LOG(UNEMPLOYED)							0.28	0.12
LOG(VACAN)	0.66	0**	-0.01	0.92			0.38	0.00**
AR(1)					-0.85	0.08		

Adjusted R Square	0.449	0.813	0.233	0.856	0.477

18) Sample periods differ in each regression due to the differences of data availability.

We can say that the increase of the estimated random coefficient in the early 1980s and the late 1990s shows the offsetting effect of creative destruction.[19] That is, we can see a decreasing trend in the capitalization effect in a decrease of the absolute value of the state variable (regression coefficient), which suggests an increase in the creative destruction effect of growth (Kim 2007).

〈Table 5〉 Estimation Equation of Schumpeterian Growth Model

$VACANCY_t = \gamma + \delta g_{Y\,t} + \eta$ (INTEREST RATE-INFLATION) $_t + \varepsilon_t$,
$g_A = \alpha + \beta \log(R\&D)_t + \varepsilon_t$,
$g_A = \alpha + \beta$ (R&D EFFICIENCY) $_t + \varepsilon_t$,
SEPARATION $RATE_t = \gamma + \delta \log(R\&D)_t + \eta \log(WAGE)_t + \varepsilon_t$,
UNEMPLOYMET $RATE_t = \gamma + \delta \log(R\&D) + \zeta$ (R&D EFFICIENCY) $_t + \eta \log(WAGE)_t +$
$\Theta\ VACANCY_t + \varepsilon_t$,
JOB FINDING $RATE_t = \gamma + \delta g_{Yt} + \eta$ (INTEREST RATE-INFLATION) $_t + \eta \log(WAGE)_t + \varepsilon_t$,
ENTERING $WORKER_t = \gamma + \delta g_{Y\,t} + \eta \log(WAGE)_t + \varepsilon_t$,
ENTERING $WORKER_t = \gamma + \delta \log(R\&D)_t + \zeta$ (UNEMPLOYED PERSON) $_t$ +
$\Theta\ VACANCY_t + \varepsilon_t$,

1.2 Long-run Relationship

Meanwhile, there is a danger of obtaining apparently significant regression results from unrelated data when using nonstationary series in regression analysis. Such regressions are said to be spurious.[20] In order to account for this possibility, we performed two widely used unit root tests: the augmented Dickey-Fuller(ADF) test.[21]

19) Considering the goodness of fit from the state-space estimation model (Appendix 3), we can see that the evidence is strongly in favor of the capitalization effect of growth on unemployment for all years in our data except the early 1990s and the early 2000s (Kim, 2007).

20) Granger and Newbold (1974) argued that researchers had not paid sufficient attention to the warning of very high autocorrelation in the residuals from conventional regression models.

21) Strictly speaking, the previous estimation results in <Table 4> can be thought of Engle and Granger (1987)'s cointegration test results, because the relevant variables are all nonstationary and the residual series is stationary.

Test results report the test statistic as follows(Table 4). Since two variables are nonstationary series, we perform a cointegration test to see whether there exists a long-run relationship between them.

The Johansen (1988) cointegration test method is used to find long-run equilibrium relationship between R&D input (RD) and the rate of unemployment (u).[22] In the case where there are only two variables in an equation, there can be, at most, one linear combination of the two variables that is stationary. Test result shows that there is a long-run equilibrium relationship between u and R&D. and that the cointegrating coefficient is estimated to be significantly negative(Table 7). It is known that when there is cointegration relationship, OLS estimate is superconsistent. So, we may use OLS estimate instead of the estimate of cointegration vector.

〈Table 6〉 Unit Root Test Statistics

Null Hypothesis: LOG(RD) has a unit root		
	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.05	0.71
Null Hypothesis: UNEMP has a unit root		
	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-2.25	0.19

〈Table 7〉 Bivariate Johansen Cointegration Test and Estimation for Cointegrating Vector[23]

GROWTH	UNEMP	LOG(RD)	SEPARR
1	36.56	1	1.81
	(-11.65)**		(-0.13)**
GROWTH	SEPARR	RD	ENTER
1	-2.22	1	-2.39
	(-6.20)**		(0.71)**
LOG(RD)	UNEMP	UNEMP	SEPARR
1	0.58	1	3.34
	(-0.08)**		(3.28)

22) Studies in empirical macroeconomics related growth almost always involve nonstationary and trending variables, such as income, productivity (TFP) and R&D personnel.

Chang et al. (2004) show that the decrease of sectoral shifts caused the job-separation rate and unemployment rate to decrease over the past three decades in Korea. Our estimation results for the cointegrating vector support their assertion. The main difference of this paper, however, is that we see the change in labor market (job separation, unemployment) as coming mainly from productivity growth due to R&D efforts.[23)]

2. Empirical Tests

In this section, 3.2, we test the prediction for growth and labor market variables (unemployment) by Aghion and Howitt (1998).

1) Growth Rate

The growth rate of output gA is an increasing function of R&D and fertility and a decreasing function of w, c, r and b. The steady-state growth rate is

$$g_A=\lambda g(R\&D/A),$$

which is an increasing function of the level of R&D.

First, we estimate the R&D (LNRD) elasticity of productivity (LNTFP) by using annual data from 1970-2006. Final state was estimated statistically significant. The method used in this estimation is state-space model which extracts unobserved time-varying coefficient from data given [<Table 4> Estimation Results for Total Factor Productivity on R&D] (second column of upper table).

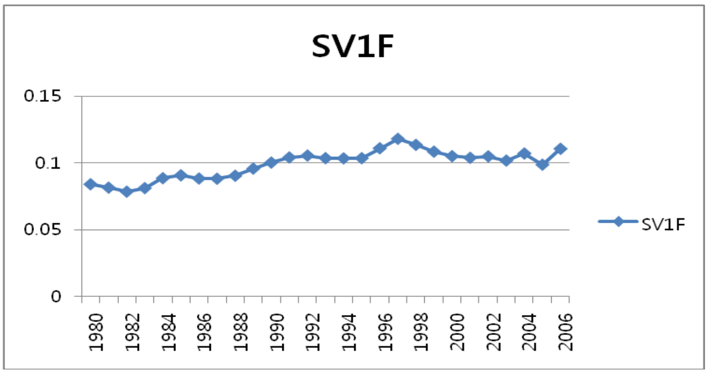
23) In addition, we do not agree with their argument that the growth rate is not the primary reason for the decrease of unemployment rate. They argue that similar East Asian countries did not show noticeable trends in unemployment rate. We should watch the relationship in those countries, however, between unemployment and per capita income growth as well as productivity growth.

24) ( ): s.e.

We also regress the level of productivity (LNTFP) against the efficiency of R&D, λ (SV1). It was significantly estimated and had the expected sign. The efficiency of R&D was estimated by a random coefficient model (state-space model) (Fig. 6). The advantage of this maximum likelihood estimation is to get time-varying regression coefficients.

[<Table 4> Estimation Results for Total Factor Productivity on R&D Efficiency] (third column)

〔Fig. 6〕 Estimation Results for R&D Efficiency



〈Table 8〉 Estimation of State-Space Model

Method: Maximum likelihood (Marquardt)
Sample: 1970 / 2006

	Coefficient	Std. Error	z-Statistic	Prob.
α	-2.27	2.11	-1.07	0.28
β	-11.50	1.24	-9.21	0.00**

2) Job Separation Rate

The growth rate of output g_A affects the job separation rate positively.

We regress the job separation rate (SEPAR) on the level of R&D investment (LNRD). The coefficient was estimated to be insignificantly positive.

[<Table 4> Estimation Results for Job Separation Rate](fourth column in first row)

3) Unemployment Rate

Since the rate of productivity growth and the unemployment rate are jointly determined, we consider the simultaneous equations model.

We consider the SUR (seemingly unrelated regression) estimator, which is based on the assumption that there are contemporaneous correlations in the errors across equations. The advantage of SUR is that considering contemporaneous correlation gives efficiency gains in GLS. SUR estimate individual equations jointly using correlation information between errors This gives smaller standard error for coefficient estimate.

$$g_A = \alpha + \beta \log(RD)\ t + \varepsilon t,$$

$$u_t = \gamma + \delta\ g_{At} + \eta \log(WAGE) + \varepsilon_t,$$

Other than γ and δ, all coefficients were estimated to be significantly positive. This means that the growth of productivity (g_A) reduces the rate of unemployment (UNEMP; “capitalization effect”) and u is increasing function of the wage (WAGE). Pesaran and Smith (1995) used this systems of regression equations method for analyzing wage determination of UK 38 industries. The difference from ours is that they used lagged dependent variable as explanatory variable.

Next, since the rate of growth is determined by R&D productivity (SV1), we estimated how the latter affects the rate of unemployment (UNEMP). The coefficient is estimated to be significant and positive at the 5% significance level. Among the estimation results of this paper, this is the only regression that does not support the dominance of the “capitalization effect.” Generally, the effect of the increase in the frequency (efficiency) parameter in the R&D equation on unemployment is known to be neutral (Aghion and Howitt 1998)[25].

25) However, they also admit that, if growth depends partly on an exogeneous process, then this neutrality may longer hold. (Aghion and Howitt 1998)

[<Table 4> Estimation Results for the Rate of Unemployment on R&D Efficiency] (lower table)

〈Table 9〉 SUR Estimation Results

Estimation Method: Seemingly Unrelated Regression
Sample: 1971 2006

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.37	0.02	15.77	0.00**
C(2)	-0.02	0.00	-11.22	0.00**
C(3)	50.45	25.00	2.01	0.05*
C(4)	-48.85	16.85	-2.89	0.00**
C(5)	-3.15	1.73	-1.82	0.07*

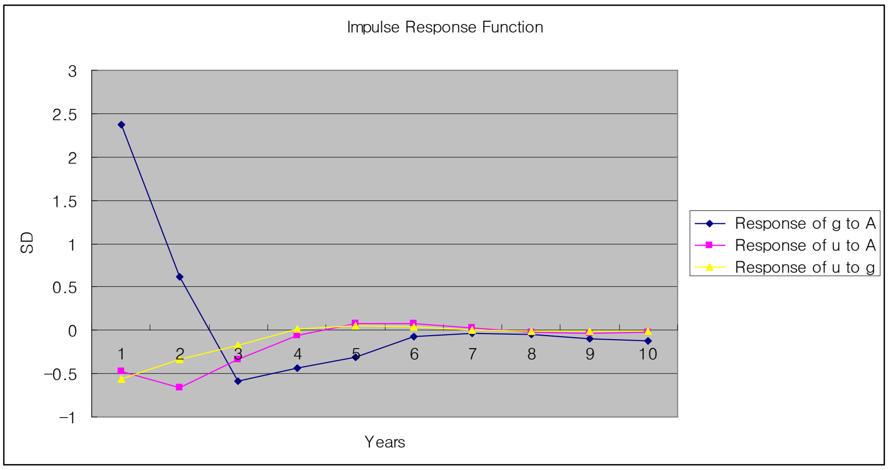
Equation: LNTFP = C(1)+C(2)*LNRD
Equation: UNEMP = C(3)+C(4)*LNTFP+C(5)*LOG(WAGE)

4) Job Creation

The rate of job creation is a decreasing function of the growth rate of output g_A, the hiring cost c, and the worker quit rate b.

We tested the effect of the growth rate (GROWTH) on the job-finding rate

〔Fig. 7〕 Estimation Results for Impulse Response Functions



(FINDR) and the number of persons who enter into new jobs. Economic growth increases the job finding rate and the number of job entrances (ENTER). Furthermore, entrances increase with the number of vacancies (VACAN).

[<Table 4> Estimation Results for the Job Finding Rate and the number of Job Entering persons]

5) VAR: Impulse Response Function[26)]

Finally, we estimated a 3-variable (g: growth, A: productivity, u: unemployment rate) VAR (vector-autoregression) model to see what the impulse response functions look like. In contrast to the discussions so far, VAR considers simultaneous determination of variables and dynamic interactions. This has an advantage over static estimation methods analyzed so far.

Impulse responses use the estimates of parameters to depict the path of endogeneous variables after one-shot of exogeneous(innovation) shock occurs. This graph also supports the dominance of "capitalization effects."[27)]

IV. Summary and Conclusion

Aghion and Howitt (1998) analyzed the relationship between growth and unemployment where growth was endogenous.[28)] In this paper, we showed that direct creative destruction is not the only effect of faster productivity growth in the past of Korea.

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26) In principle, we should use structural VAR instead of reduced-form VAR. But, in this study, we simply assume as identifying restriction sthat there is no contemporaneous correlation between variables.

27) We had better recognize that the relationship between three variables are simultaneously determined. So, we use VAR model.

28) New technology is embodied in plants which are costly to build. Unemployment is caused by workers having to move from a plant embodying old technology old technology to one embodying new technology.

Investors were encouraged to create new plants and vacancies by the possibility of benefiting from future technological advances. This capitalization effect could more than offset the creative destruction effect, resulting in an overall decrease in unemployment when growth the growth rate rose.

We showed, with a high goodness of fit in our regression models, that the empirical evidence is strongly suggestive of a capitalization effect from R&D activities and economic growth. The number of vacancies was increased by an increase of growth rate, and there was a negative long-run equilibrium relationship (cointegration) between R&D investment and unemployment rate.

Contrary to Kim (2007) using state-space model, we used GLS and cointegration method for seeing capitalization effect. In this study, job separation effect is not significant in GLS.

But, in cointegration method, R&D was negatively correlated with the job separation rate, and productivity growth has decreased the rate of unemployment. In addition, the job-finding rate was increased by economic growth.[29]

The empirical results of diverse econometric model that show "capitalization effects" are the state space model for the unemployment rate, the cointegration test for the unemployment rate, the SUR estimation for unemployment rate, and the impulse response for unemployment rate in the VAR model.

In summary, we propose that the expectations of investors play an important role in the effects of technical progress. If investors are optimistic, then technical progress affects unemployment negatively (reducing unemployment); we call this the "capitalization effect".[30]

We can conclude that the relatively high unemployment rate in 2002-2004 came from investor skepticism concerning the economy (and productivity growth), which could not lead to high rates of investment (i.e., very little "capitalization effect").

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29) More accurately, finding cointegration vector cannot say anything about causation relationship.

30) Assuming simple aggregate production function neglecting the physical capital, we can see the following simple relationship exists.

Δ employment = Δ output(determined by expectation) - Δ productivity

Algan et al. (2002) discuss public sector job creation using Pissarides (1985). In the US, about 16% of total jobs in filled by the government sector. Technical innovation may also affects job creation in public sector, but we do not consider this in this paper.

Finally, generic efficiency wage models like Shapiro-Stiglitz model(1984) can also give some insight of the effects in productivity on employment, but we postpone the analysis for future research.

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〈Appendix〉

1. An Augmented Schumpeterian Model: Growth and Demand for Labor

The Schumpeterian 2nd generation endogenous theory of growth [Young (1998), Aghion-Howitt (1998)] provides a way to account for the scale effect.[31] In this paper, however, we retain the characteristic of "scale effect" in these Schumpeterian models. Young (1998) argues that as population increases, the variety of goods also grows over which R&D is spread.

A single final-good (or aggregate consumption) sector produces a homogeneous output good C, according to the CES technology

$$C= [\int_0^B Y(i)^{\alpha\upsilon} di]^{(1/\upsilon)} ,$$

where B is the variety of goods, Y(i) is the consumption, and $\upsilon<1$ is related to the elasticity of substitution.

Let each variety Y(i) be produced according to the following equations:

$$Y_i= (A_i L_{Y\,i})^{(1-\alpha)} K_i^{\alpha} ,$$

where K_i is physical capital in each variety sector.

$$\Delta A_i/A_i = \delta L_{A\,i}$$

To complete the model, we need to explain how B changes over time. We assume that

31) "Scale effect" means that the same R&D effort can lead to sustained growth of productivity.

$B=L^{\beta}$

In the 2^{nd} generation growth models, $\beta=1$ holds: the variety of consumption goods is proportional to the population.[32)]

The growth of productivity comes from R&D, which uses final output (GDP) as its input. The rate of innovation g_A in a sector to which N_t units of output in R&D is given by:[33)]

$g_{At}=\lambda g(N_t/A_t)$

Growth in productivity parameter A comes from the knowledge spillovers. The measure of the marginal impact of R&D on public knowledge is equal to 1/B.

The rate of technological progress is

$g_A = \Delta A_i/A_i = \lambda g(N/A)$

We consider the relationships between these variables and labor market variables. We introduce hiring costs ($=cA_t$), and assume that the wage set at a level proportional to the technology level ($w_t=aA_t$). There also is quit rate b of workers.

In the steady state, the cost of labor for the each variety firm is

$w_t^*=A_t^*a^*= A_t^* [a+(b+g_t+r-g_A)c]$ (1)

The demand for labor by variety firms will be

$L_{Dt} = \Sigma L_{Yi} = l^*(r^*, a^*e^{g(s-t)})$

The value of innovation (or the price of patent) is:

32) These implications of growth model mainly come from Jones (1999).

33) The following (augmented) Schumpeterian model comes from Aghion and Howitt (1998).

$V_t=A_t\ v(r+g,\ a^*,\ g_A)$ (2)

When consumption grows at the rate g, the rate of interest is:

$r=\rho+\varepsilon g_A$ (3)

We have the following arbitrage equation.

$1=\lambda\ v(\rho+(\varepsilon+1)g_A,\ w+(\rho+\varepsilon g_A+b)c,\ g_A)$

Once again, the steady-state growth rate is

$g_A=\lambda g(N/A)$

Therefore, the demand for labor by monopolistic firms is

$L_D=\Sigma L_{Y\ i}=l^*(r^*,\ a^*)=l^*\ [\rho+(\varepsilon+1)g_A,\ w+(\rho+\varepsilon g_A+b)c]$

2. Implication of the Simple model for Economic Growth[34)]

We can modify the above analysis by assuming R&D uses only labor as the input. We assume there are no horizontal innovations, B=1 and β=0. Since each intermediate good Yi is used in the same amount ($Y=Y_i$), C is equal to Y. Per capita output growth is: $g_c = g_A$

With the Romer (1990) production function for new knowledge, the growth rate of A now depends on R&D effort per variety L_A: $g_A = \Delta A/A = \delta\ s_R\ L$

Substituting this result yields the growth rate of output per capita in the model (Jones, 1999)

34) This sub-section may be irrelevant in this paper. But, it's useful to understand Schumpeterian growth model.

$g_c = \delta s_R L$

s_R: R&D intensity

With β=0, one derives the following results. 1) The scale effect exists. 2) sR also affects long-run growth.

3. Time Varying Random Coefficient Model(Kim, 2007)

We need to provide multiple equation dynamic system for unemployment and innovation in state space form.[35] We continue '3.1.1 Capitalization Effects' where estimates of a growth model for unemployment (u) and innovation (and growth g) are obtained.[36]

Parameter heterogeneity across times can be modeled as stochastic variation. Suppose that we write

$$y_t = \beta_t x_t + \varepsilon_t,$$

where

$$\beta_t = \beta_{t-1} + u_t, \qquad u_t \sim N(0, \sigma)$$

We examined a simple model of the natural rate of unemployment for technical

35) Diverse time series models can be written and estimated as special cases of a state space specification. State space models have been applied in the econometrics literature to model unobserved variables: permanent income, unobserved components, and natural rate of unemployment.
There are two main benefits to representing a dynamic system in state space form. First, it allows unobserved variables(state variables; natural rate of unemployment) to be incorporated into, and estimated along with, the observed model. Second, it can be analyzed using a powerful recursive algorithm known as Kalman filter.

36) Generally, the model $y_t = X_t\beta + \varepsilon t$ is analyzed within the frameworks of constant coefficients. It does entail the not entirely plausible assumption that there is no parameter variation across times. A fully general approach would combine all the machinery of the traditional models with a model that allows β to vary across times.

innovation represented by proxy variable, R&D:

$u_t = \alpha + \beta_t x_t + \varepsilon_t$

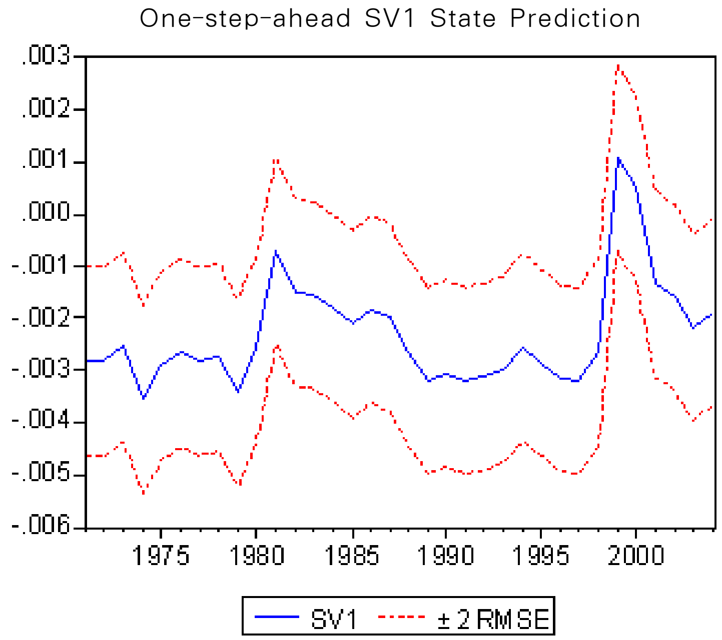
u: the observed rate of unemployment

x: R&D investment

Estimation (considering autocorrelation of parameters) produces the following results in <Figure>.

We can say that the increase of the estimated random coefficient in the early 1980s and the late 1990s shows the offsetting effect of creative destruction.

〔Figure〕 Estimation Results for Rate of Unemployment (Random Coefficient) (Kim, 2007)



abstract

한국에서의 **R&D** 투자와 일자리 창출 및 소멸 : 기술진보와 노동시장 균형

김병우

기술진보에 따른 혁신이 현존 기술을 사용하는 설비로 실행 가능하다면, 투자자들은 동일한 신규 설비를 더 건설할 충분한 인센티브를 지니게 된다. 이는 '자본화 효과'로 불리며 공석을 많이 창출하게 되어 보다 많은 일자리를 창출하게 된다. 그러나 기술진보의 속도가 빨라 기존 설비가 진부화된다면 생산설비로부터 방출되는 근로자 비중은 높아지고 '창조적 파괴'로 불리는 일자리 파괴가 발생하게 된다.

본 연구에서는 한국경제의 실제 데이터를 통해 슘페테리안 성장이론에서 시사하는 노동시장 균형에 대한 가설을 검정한다. 상당 부분의 추정 및 가설검정 결과는 '자본화 효과'의 우위를 시사한다. 본 연구와 김병우(2007) 간의 주된 차별성은 이직률, 구직률, 실업률 등 다양한 노동시장 변수들을 고려한 데 있다. 본 연구에서는, 또한 노동시장 변수와 지식축적 간의 유의한 관계들을 발견하였다.

마지막으로, 최근의 '고용 없는 성장' 현상은 생산성 향상에 대한 자본화 효과 발생의 미미함에서 그 원인을 찾을 수 있다.

핵심용어 : R&D 투자, 기술혁신, 경제성장, 창조적 파괴, 자본화 효과