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Innovation, Job Creation and Economic Growth in the U.S.*

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ABSTRACT

Unemployment is caused by workers moving to new plants utilizing new technology. ("Creative destruction effect.") (Aghion and Howitt, 1998)

Considering the goodness of fit and estimation results, we can see that, in the past, the evidence is strongly in favor of the capitalization effect of growth on unemployment in the U.S. economy. However, the increase of the estimated random coefficient in the early 2000s shows also the offset effect of creative destruction. In addition, we can see the decreasing trends of those capitalization effects.

Finally, we share a common view with Blanchard (2006) that the relatively high unemployment rate in 2002~2003 comes from investors' skepticism about the economy (and productivity growth), which cannot lead to a high rate of investment (little "capitalization effect").

Introduction[1]

We can ask whether technological progress through R & D creates or destroys jobs in the U.S. On one hand, it is said that productivity growth stimulates demand and the creation of jobs because firms want to capitalize on more rapidly growing productivity. On the other hand, there is the view that technological progress destroys jobs. (Aghion and Howitt, 1998)
In Principles, Ricardo touched on the negative effect of innovation on unemployment. In this paper, we show how modern economic tools can be used to analyze under what conditions the encouragement of more innovation will reduce unemployment.

"…I have been of opinion that such an application of machinery to any branch of production as should have the effect of saving labor was a general good,………" (Ricardo, p. 269)

In this paper, we discuss the most recent three decades of data on the input for knowledge, R & D, and unemployment. In particular, we explore the hypothesis that technological change represented by R & D investment increased the unemployment rate. We argue that technological change would plausibly lead to a decrease in the unemployment rate in the U.S.

1 The author thanks participants at the WEAI Conference.

Davis and Haltiwanger (1992) show those 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.
In general, unemployment is caused by workers moving to new plants utilizing new technology. This is called the "creative destruction effect." However, technical advances can take a form that can be utilized by existing plants. Then investors will be encouraged to create new jobs to benefit from future technical advances. This is called the "capitalization effect" (Aghion and Howitt, 1998).

Nishida M., A. Petrin and S. Polance (2013) estimate the decomposition of labor productivity in 25countries due to input reallocation. They conclude that weak gains from measured reallocation and strong gains from within-plant reallocation[2].

Schimer (2012) proposes that employment exit probability is irrelevant to macroeconomic labor market model. He uses time-series data to estimate job finding and separation rate. His argument may contradict to endogenous growth model, but we examine this issue in future research.

The past 30 years are implicative since we saw a productivity slowdown common to industrialized countries with continuing structural economic change. In the meantime, the U.S. and other developed countries are often said to have so-called "jobless growth." In spite of economic growth, the rate of employment does not rise accordingly. "Jobless growth" has been an important concern in the U.S. in recent years.

Table 1: The rates of economic growth (GROWTH) and unemployment (UNEMP) in the U.S. (%)(OECD)

ENTRY	2000	2001	2002	2003	2004	2005	2006
UNEMP	4.0	4.7	5.8	6.0	5.5	5.1	4.6
GROWTH	3.69	0.76	1.61	2.52	3.65	3.08	2.87

The question of whether faster technological progress speeds up the destruction of jobs in the US will be the main focus of the present paper. We review new models of intentional industrial innovation. We deal with innovation that enhances a plant unit's productivity (Aghion and Howitt, 1998).

Economic Growth Model and Data

2.1 Labor markets

Labor markets are characterized by high rates of turnover. In the U.S. manufacturing sector, more than 3% of workers leave their jobs in a typical month. In addition, there is high turnover of jobs themselves. In the U.S. manufacturing sector, at least 10% of existing jobs disappear each year.[3] These data suggest that a large portion of unemployment is the result of the dynamics of the economy. Constructing a friction model for the labor market requires moving a market with matching process. When workers and jobs are heterogeneous, the labor market has no characteristics of a Walrasian market. Workers and firms engage in a process of trying to match up specific needs. Since this process has some friction, it results in unemployment[4] (Romer, 2006).
Much literature has tried to characterize how equilibrium unemployment reacts to the rate of technological change. Two approaches are divided on that view (Hornstein et al., 2005).

The first approach (Aghion and Howitt, 1998) argues that new equipment enters the economy through the creation of new matches ("creative destruction effect").[5]

2 They use variants of the Baily et al. (Brookings Papers Econ Act Microecon 1:187–267, 1992) (BHC) decompositions

3 Davis and Haltiwanger, 1992.

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

5 Generally, "creative destruction" is used to point the following fact. The successful monopoly innovator destroys the profits(rents) of the previous generation by reducing it obsolete.

The second approach (Mortensen and Pissarides, 1998) proposes the alternative view that the new technologies enter into firms through the process of upgrading plant units. For small values of the upgrading cost, unemployment falls with growth ("capitalization effect").

Hornstein, Krusell and Violante (2003) try to resolve the issue quantitatively. When they parameterize the model to match some features of the U.S. economy, they find that (in the vintage-matching model) the link between capital-embodied growth and unemployment does not strongly depend on the form through which new technology enters into capital goods. The intuition for this (equivalence) result is that upgrading can be more effective if it is costly for vacant firms to find and hire workers.

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

2.2 The 1990s in the U.S.[6]

In the short term, an increase in the rate of technological progress can lead either to a decrease or an increase in the unemployment rate. The last decade in the U.S. provides an example of each type. (Blanchard, 2006)

During the latter half of the 1990s, the increase in productivity growth came with a large increase in output growth and a steady decrease in unemployment. Productivity growth was unusually high during the second half of the 1990s (1996-2000). The increase in growth rates is related to an increase in the use of information technology (IT).[7] The result of output growth in excess of productivity growth was a steady decrease in unemployment.[8]

During the late 1990s, output growth was high, and firms had optimism. For firms, the New Economy appeared to justify high rates of investment. If technological advances took a form that could be utilized by existing plants, investors would be encouraged to create new plants and vacancies ("capitalization effect").

In 2001, the U.S. economy went into a recession. However, output growth was positive in 2002 and 2003. Surprisingly, unemployment was still high. The recovery was the jobless growth (recovery). Labor productivity growth (averaging 3.7%, Blanchard 2006) and total factor productivity growth (over 2%, OECD) were high. Therefore, the plants seemed to have a short lifetime, and hence, the proportion of workers released was high ("direct creative destruction").[9]

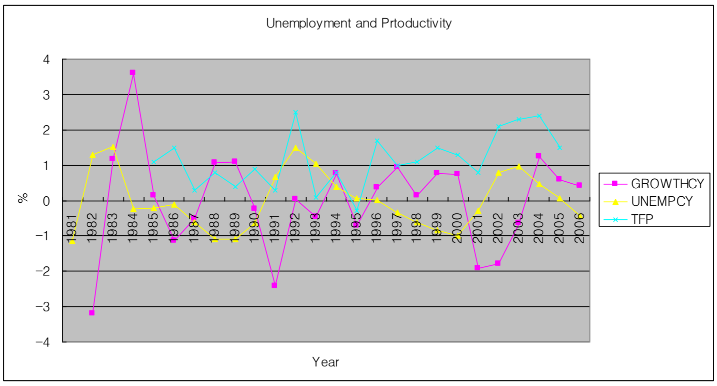


Figure 2.1: Cyclical Factors in GDP and Unemployment Rate in the U.S. (Source: OECD)[10]

6 Blanchard, 2006.

7 By the late 1990s, this contribution of capital accumulation had risen to 0.8% points from 2.5% output growth. In addition, they say that the half of the rise in total factor productivity(TFP) growth is due to the information technology.(Bureau of Labor Statistics, 2000)

8 We can consider the following elementary identity.(Blanchard et al. 1996, Blanchard 2006)

Employment= (output) / (productivity).

9 Chang and Hejkal(2004) see "jobless growth" as increasing of lags for cyclical lagging of employment.

10 TFP denotes the growth rate of productivity.

We extracted the cyclical factors for growth and unemployment through this HP filter (Fig. 2.1). Overall, an increase in the GDP (GROWTHCY) is associated with a decrease in the unemployment rate (UNEMPCY). We can also find that during the late 1990s, (denoted * in Table 2.1 output growth was high. The increase in productivity growth came with a steady decrease in unemployment.

Later, in 2001, the U.S. economy went into recession, but output growth was positive in 2002 and 2003 (denoted P in Table 2.1). However, unemployment was high then.

Figure 2.2: The Growth Rates of TFP and Unemployment Rate in the U.S. (Source: OECD)[11]

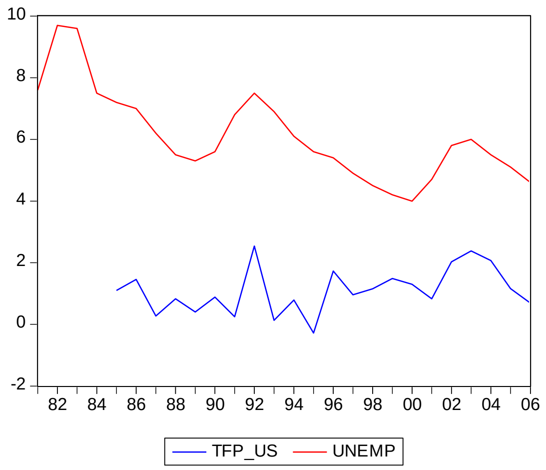


Table 2.1: The Growth Rates of TFP, GDP and Unemployment Rate in the U.S. (Source: OECD)

	TFP growth (%)	Unemployment rate (%)	GDP growth
1996	1.73	5.4	3.75%
**1997*	*0.96*	*4.9*	*4.55%*
**1998*	*1.15*	*4.5*	*4.22%*
**1999*	*1.49*	*4.2*	*4.49%*
2000	1.3	4	3.69%
2001	0.83	4.7	0.76%
2002	2.03	5.8	1.61%
2003	2.38	6	2.52%
P2004	*2.07*	*5.5*	*3.65%*
P2005	*1.16*	*5.1*	*3.08%*
2006	0.69	4.6	2.87%

2.3 Growth and unemployment: Schumpeterian Growth Model (Aghion and Howitt; 1994, 1998)[12]

The economy comprises (infinitely lived) workers.[13] Each worker is endowed with one unit of labor services and a stock of X units of human capital. All individuals maximize the linear preferences:

11 The upper curve denotes the change in the rate of unemployment.

12 We can also consider search and matching model (Pissarides 1985; Romer 2006), but omit in this study.

13 We index them from 0 to 1.

$U(c)= E_0 \int c_t e^{-rt}dt$

r: the subjective rate of time preference (= interest rate)

c_t: the current consumption flow at time t.

Each plant unit embodying a technology[14] consists of a worker and a variable amount of human capital x. A worker is well matched and the plant-specific.

The production function for output is given by

$Y=A_tF(x-a)$ (1)

a :(> 0) the minimum human capital input representing overhead costs.

$A_t=A_0e^{gt}$ denotes the plant unit's productivity. A_t will eventually become unable to cover the unit's overhead cost (in human capital). At this point, the units force their workers into unemployment. We consider what will be the finite lifetime S of a production unit. As usual in endogenous growth model, A is assumed to be a function of R&D investment.(R&D-based model)

We can calculate the profit from the plant.

$\text{Max} \{ A_tF(x-a) - p x\}$

Because the price of human capital p grows at the steady-state rate g, the unit will produce less and less. In equilibrium, there is an inverse relationship between the growth rate and the duration of a plant S. We can explain unemployment and vacancies if we introduce some type of friction into the labor market. The key to unemployment and vacancies is the process of workers searching for jobs and businesses searching for workers.

During the process of search, some job seekers are unemployed, and some positions remain vacant. The rate of job finding depends on such things as the income available while unemployed and the level and shape of the distribution of wage offers.

We assume a time-consuming matching process with a finite rate of matching m(u+E, v).[15] The total matching rate m is an increasing function of v. Unemployment may be the result of matching workers and jobs in a changing and growing economy. Finally, the flows into unemployment also plays role in job matching process, so matching rate is also function of employment.

In steady-state, the equilibrium rate of unemployment is determined as follows. First, the flow of workers into unemployment is the rate of production units' obsolescence (= 1/S) × the number of units currently producing, (1-u). Second, the flow of workers out of unemployment is the rate at which they are matched with plants (job finding rate): p(v) = m(u+E, v).[16]

An adverse shock to a firm's production function could lead to a discharge.[17] The change in unemployment and vacancies involves the interplay between job finding and job separation.

In equilibrium, (1-u)1/S = p(v), or equivalently, using the above expression for lifetime of plants S,

$u=1-p(v)S$

This unemployment equation implies a direct creative destruction effect of growth on unemployment.[18] Meanwhile, the capitalization effect works in the direction of increasing the

14 A technology of vintage t.

15 The numbers of employed and unemployed workers are denoted E and u, and the numbers of vacant jobs are denoted v. 1(=u+E) is (normalized) whole labor force involved in the matching.

16 Since we can normalize the labor force to 1, we can represent it as m(1, v)/1.

17 The job separation rate would be higher in industries that are subject to frequent shocks to technology.

18 Holding vacancies constant, economic growth by R & D activities raises the job separation rate (1/S), thus increasing unemployment.

level of vacancies υ and decreasing unemployment. In the next section, we estimate this equation using a state space model to see which effect dominates the other in the U.S. economy. We focus on the determinants of natural rate of unemployment. It is determined by job-finding rate and job-separation rate.

Let (1/S) be the job separation rate and p(v) the job finding rate. The change in the number employed during a period, ΔL, is given by

$\Delta L = p(v) \times 1 - (1/S)(1-u)$ (2)

Note that the first term, p(v), is the number of unemployed who find jobs during a period, and the second term, (1/S)(1-u), is the number of employed who lose jobs. This equation says that the change in employment equals job findings less job separations.[19]

There also is a negative effect, namely a capitalization effect, whereby an increase in growth raises the rate of returns of a plant, thereby encouraging more job creation.

If we introduce the possibility that plants can upgrade their technology, the capitalization effects appear. Before becoming obsolete, production units can (costless) adapt to the newest technology. This capitalization effect increases the equilibrium level of vacancies and hence decreases unemployment. The increase in growth acts positively on the equilibrium rate of vacancy creation. It reduces the net discount rate at which production units capitalize the expected income from future upgrades.

In normal times, there are substantial flows into and out of unemployment. One good way to measure normal conditions is to take averages over specific long periods. For the period of 1994 through 1999 in the U.S., average conditions were as follows (Blanchard, 2006):

Job-separation rate, (1/S): 1.5% per month
Job-finding rate, p(υ): 1.8% per month

2.4 The Second Generation Endogenous Growth Models[20]

2.4.1 Implication of the model

The Schumpeterian second generation endogenous theory of growth [Young (1998), Aghion-Howitt (1998)] provides a way of deleting the scale effect.[21] However, in this paper, we retain the characteristic of "scale effect" in this Schumpeterian model.[22]

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

We consider the relationships between labor market variables. We introduce hiring costs ($=cA_t$) and assume that the wage being sought is proportional to the technology ($w_t=aA_t$).[23] There is also the quit rate, b, of workers.

19 In addition to the direct effect that works through the job-destruction rate, there is an indirect effect working through the job-creation rate p(v). This indirect creative destruction effect reinforces the direct creative destruction effect by reducing the job-creation rate p(v).

20 This classification and summary of growth models mainly come from Jones(1999).

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

22 Young (1998) argues that as population increases, the range of goods over which R & D is spread also grows.

23 Hiring cost may include fixed cost associated with maintaining a job equal to job posting cost.

In this Schumpeterian model, there are various exogenous variables: quit rate, the cost of hiring and parameter of real wage level, etc. Also, there are endogenous variables: job separation, job creation and (natural) rate of unemployment.(For details, see <Appendix>)

2.4.2 The Hypothesis Being Tested

From these analyses, we can choose some hypotheses for empirical testing research (Aghion and Howitt, 1988):

1) Growth Rate

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

2) Job Separation Rate

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

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 quit rate of workers 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 quit rate of workers b.

Ⅲ. Economic Growth and Labor Market: Empirical Analysis

3.1 Data and empirical analysis: Growth and unemployment

The data set consists of macro-economic variables, such as rate of unemployment, GDP, wage, etc., observed for 26 years (1981-2006) in the U.S. They were obtained from OECD and IFS. Multifactor productivity comes from BLS. In equation (1), it is denoted as A (t). Its baseline index is 2000=100.0. All employees for whom data was collected were aged for 16 years and over. White and Reiter (2011) construct plant-level Solow residuals. They estimate every contribution from U.S. manufacturing plant to industrial demand.

Some monthly data for labor market variables, like the job separation rate used in section 3.4, were obtained from BLS.[24] We use a proxy variable for the growth index of industrial production for the period of March 2003 to October 2007. The job hire (job creation) rate comes from BLS, and is based on total nonfarm workers. Employment level is collected for 16 years and over.[25]

[24] In general, job separation rate may be obtained from JOLTS.
[25] BLS provides the employment rate rather than job hire (creation) rate. It may cause some problems in interpretation of results.

The total separation rate is based on total nonfarm workers.
In this section, we mainly test the predictions for growth and unemployment set forth by Aghion and Howitt (1998).

3.1.1 Natural Rate of Unemployment: HP Filter

The Hodrick-Prescott filter is a smoothing method that is widely used among macroeconomists to obtain a smooth estimate of the long-term trend component of a series. The method was first used in a working paper by Hodrick and Prescott (1997) to analyze postwar U.S. business cycles.[26]

We extracted the series for (unobservable) natural rate of unemployment (HPTREND01; u) through this HP filter: <Table 3> (Column 1) Estimation Results for Natural Rate of Unemployment (HP Filter)[27] - Capitalization Effect

Figure 3.1: Estimation Results for Natural Rate of Unempolyment (HP Filter)

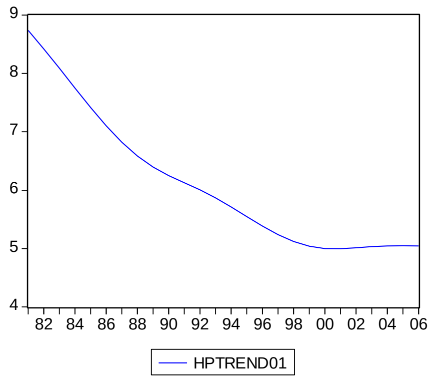


Table 3: Estimation Results[28]

	1) Cap.		2) Cap.				3) Creative	
Dependent Variable	U(trend)		U(cointegration)		TFP		SEPAR	
Sample	1982 2006(annual)		(annual)		(annual)		2003 2007(monthly)	
	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
C	−7.767	0.045*			– 5.507776	0.0235*	2.167728	0.0004*
LOG(RD)	−0.679	0.005*	−1.709	0.088*	1.26073	0.0078*		
WAGE	0.036	0.001*						
LOG(CPI)	1.973	0.009*						
IPTREND							0.011096	0.0478*
TFP								
R&D efficiency								
GROWTH*100								
AR(1)	0.944	0.000*			– 0.235457	0.0078*	0.342542	0.0112*

	4) Cap.		5) Creative	6) Creative	
Dependent	TFP(GMM)	U(GMM)	U	HIRER	HIRER/IP

26 Technically, the HP filter is a two-sided linear filter that computes the smoothed series s of y by minimizing the variance of y around s, subject to a penalty that constrains the second difference of s. That is, the HP filter chooses s to minimize some objective fuction.

27 If estimated coefficient is statistically significant, we denote *, or **, by 5% or 10% significance level, respectively. And, AR(1) denotes first-order autocorrelation coefficient, hereafter.

28 If estimated coefficient is statistically significant, we denote *, or **, by 5% or 10% significance level, respectively. And, AR(1) denotes first-order autocorrelation coefficient, hereafter.

Variable										
Sample	(annual)				(annual)		(monthly)		(monthly)	
	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
C	−6.1731	0.0111	5.251053	0.3975	3.198633	0.1338	3.548754	0	0.034097	0
LOG(RD)	1.388635	0.0026*								
WAGE			0.396332	0.791						
LOG(CPI)										
IPTREND										
TFP			−1.23198	0.0691**						
R&D efficiency					1.013505	0.0964**				
GROWTH*100							−0.08408	0.0007*	-0.000931	0.0003*
AR(1)					0.885974	0	0.5974	0	0.606257	0

We examined a simple regression model of the natural rate of unemployment u_t for technical innovation represented by a proxy variable, R & D: [29] In a steady state, the growth rate of output is equal to the growth rate of A.[30]

$u_t = \alpha + \beta x_t + \varepsilon$ (3)
u: the estimated natural rate of unemployment
x: R & D investment (RD), wage

GLS considering autocorrelation regression produces the results in <Table 3-1>. Considering the goodness of fit, we can see that the evidence is strongly in favor of the capitalization effect of growth on unemployment.

Significantly estimated elasticity of R & D to the decrease of the natural rate of unemployment is 0.58. The wage variable is used to control for confounding factors (e.g., changes in the labor market).

From these estimation results, we can see that the increasing effect of the level of vacancies υ and, consequently, 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].

In addition to GLS, we performed (polynomial) finite distributed lags(DL) estimation. A PDL (q) model is expressed as:

$$u_t = \beta + \beta(0)\, RD_t + \beta(1)\, RD_{t-1} + \beta(2)\, RD_{t-2} \ldots + \beta(q)\, RD_{t-q} + \theta(0) WAGE_{t-1} + e_t \quad (4)$$

Table 3.1: Estimation Results of Polynomial Distributed Lag Model for Natural Rate of Unemployment ; Capitalization Effect

Dependent Variable: HPTREND01			
Sample (adjusted):			
1986 2006(annual)			
Lag Distribution of LOG(RD)			
i	Coefficient	Std. Error	t-Statistic
0	-3	1.42	-2.11*
1	-1.16	1.05	-1.1
2	-0.29	0.83	-0.35
3	-0.18	0.74	-0.24
4	-0.61	1.01	-0.6

29 If estimated coefficient or test result is statistically significant, we denote *, or **, by 5% or 10% confidence level, respectively.

30 Most endogenous economic growth theory assumes TFP is an increasing function of innovation, that is, R & D activities.(Jones, 2002)

5	-1.37	1.11	-1.23
Sum of Lags	-6.61	1.24	-5.31*

Estimation results show that total multiplier which is the final effect on natural rate of unemployment of the increase in R&D investment after 5 years is significant and has expected negative sign. (<Table 3-1>)

3.1.2 Time varying random coefficient model and long-term relationship

We need to provide a multiple equation dynamic system for unemployment and innovation in state space form.[31] State space models have been applied in the econometrics literature to model unobserved variables: expectations, measurement errors, missing observations, permanent income, unobserved components, and natural rate of unemployment.[32]

We continue from '2.4 Growth and unemployment', where estimates of a growth model for unemployment (u) and innovation (and growth g) were obtained.[33]

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 time. A fully general approach would combine all the machinery of the traditional models with a model that allows β to vary across time (Greene, 2006).

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

$y_t = \beta_t x_t + \varepsilon_t$ (5)
where
$\beta_t = \beta_{t-1} + u_t, \quad u_t \sim N(0, \sigma)$

We examined a simple model of the natural rate of unemployment for technical innovation represented by a proxy variable, R & D:

$u_t=\alpha + \beta_t x_t + \varepsilon_t$ (6)
u: the observed rate of unemployment
x: R & D investment
β_t: ($=SV1_t$)

Estimation (considering autocorrelation of parameters) produces the following results in Figure 3.2. Considering the goodness of fit, we can see that the evidence is strongly in favor of the capitalization effect of growth on unemployment, except in the early 1990s and the early 2000s.
We can say that the increase of the estimated random coefficient in the early 1990s and the early 2000s shows the offset effect of creative destruction.[34]

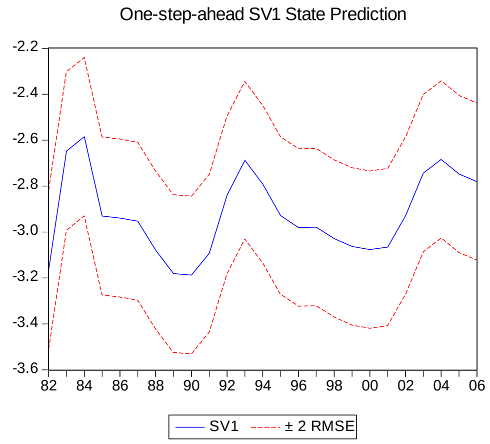
31 A wide range of time series models, including the classical linear regression model and ARIMA models, can be written and estimated as special cases of a state space specification.

32 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. The Kalman filter algorithm has been used, among other things, to compute exact, finite sample forecasts for Markov switching models and time varying (random) coefficient models.

33 This empirical analysis is also concerned with section 2.6.

34 If SV1 is estimated as -2.09, it means 1% changes in R & D expenditure decreases the unemployment rate by 0.0209. This holds when x is in logarithms and Y is in levels.(Stock and Watson, 2007)

Figure 3.2: Estimation Results for State Variable (State Space)



Now, we consider whether the R & D investment[log(RD)] and unemployment rate(UNEMP) are stationary. The reason for this is to avoid the spurious regression problem.

After performing a Dickey-Fuller unit root test, we see that the two series are nonstationary. Through Johansen's (1998) cointegration test, we conclude that the two variables are cointegrated; that is, they have a long-term equilibrium relationship. We estimate the cointegration coefficient to be -0.585 <Table 3>(Column 2).

3.2 Calibration the effects of growth and hypothesis tests

In this section, we perform calibration to test the predictions for growth and unemployment by Pissarides (1985) and Romer (2006).

Summary: The Effects of Growth on Unemployment (Aghion and Howitt, 1998)

Effect	Growth rate g	Job-destruction b	Job-creation p(v)	Level of vacancies v	Unemployment u
Direct Creative Destruction	↑	↑			↑*
Indirect Creative Destruction	↑		↓		↑*
Capitalization	↑			↑	↓*

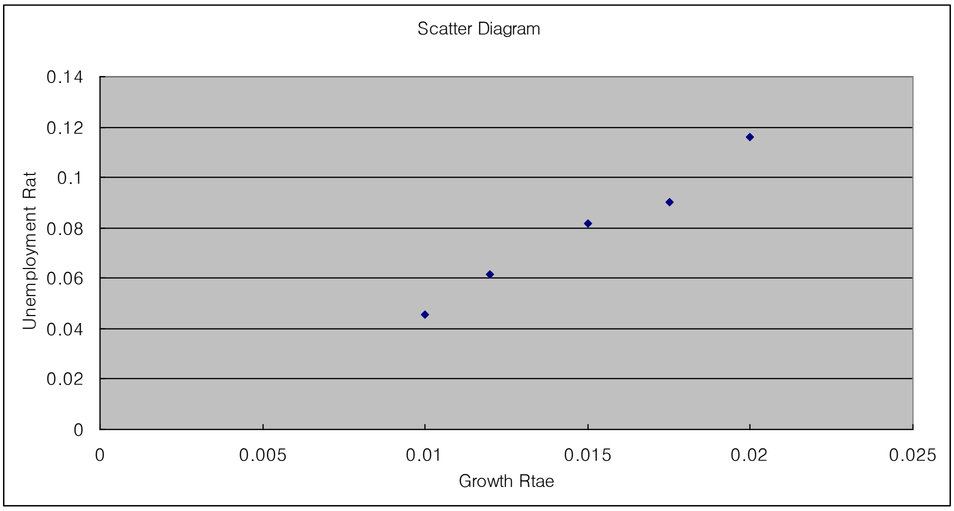
We calibrated this search model by assuming some parameter of the U.S. economy. The graph supports the "creative destruction effects." That means that as the growth rate increases, the unemployment rate also increases.[35] However, we should note that job vacancies also increase with unemployment rate.

Table 3.2: Calibration Results for Search Model of the U.S. (%, years, and persons); Creative Destruction

	G	lifetime	b	EMPLOYED(E)	Labor Force	VACANCY(v)	Jobs filled	Job finding	Unemployed Rate
US1	1.00%	10	0.10%	142,529,000	149,320,000	43,737,596	0.33%	2.10%	4.55%
US2	1.20%	10	0.12%	140,150,900	149,320,000	47,349,453	0.36%	1.83%	6.14%
US3	1.50%	10	0.15%	137,090,000	149,320,000	54,762,156	0.38%	1.68%	8.19%

35 In reality, the growth may affect the term productivity, A. We do not consider this problem in this paper.

US4	1.75%	10	0.18%	135,870,000	149,320,000	65,382,701	0.36%	1.77%	9.01%
US5	2.00%	10	0.20%	131,970,000	149,320,000	65,932,526	0.40%	1.52%	11.62%



In turns, we test the predictions for growth and labor market variables (unemployment) by Aghion and Howitt (1998).

1) Growth Rate

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

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

which is increasing as a function of the level of R & D, N.?

In Table 3 (Column 2), the regression coefficient for TFP (productivity growth) of the level of R & D (LNRD) is significant and of the expected sign.

2) Job Separation Rate

In the Schumpeterian model, the growth rate of output g_A affects the job separation rate positively. We extracted the trend component of the industrial production index.

We estimated how much of an effect the percentage growth rate (IPTREND) has on the job separation rate (SEPAR). Estimation results show that a 1% point growth results in a decrease in the separation rate by 0.01%. This result has the implication that creative destruction effects exist in the sample period from June 2003 to October 2007. <Table 3> (Column 3) Estimation Results for Job Separation Rate; Creative Destruction

3) Unemployment Rate

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

We consider the GMM estimator that is defined by a minimizing criterion function. It is based on the assumption that the error terms are not correlated with some instrumental variables.[36]

$g_A = \alpha + \beta \log(RD)_t + \varepsilon_t$, (7)
$u_t = \gamma + \delta g_{A\,t} + \eta \log(WAGE) + \varepsilon_t$,

The estimated productivity and unemployment rate equations are in <Table 3>(Column 4). Notice that the coefficient of productivity on unemployment is negative.

Among the estimation results in this paper, this regression supports "creative destruction." Generally, the effect of the increase in the frequency (efficiency; SV1) parameter in the R & D equation on unemployment (UNEMP) is known to be neutral (Aghion and Howitt, 1998).[37]

4) Job Creation

The rate of job creation (or the ratio of job creation to growth; HIRER) is a decreasing function of the growth rate (GROWTH) of output g_A, the hiring cost c, and the quit rate of workers b. <Table 3> (Column 6)

5) VAR: Impulse Response Function

Finally, we estimated a 3-variable (output growth g, productivity growth A, unemployment rate u) reduced-form VAR (vector-autoregressive) model to see what the impulse response functions look like using annual time series data(1981~2006). The graph also supports the "creative destruction effects."[38] In addition, we constructed another VAR with one quarter(3 months) lagged values for seeing relationships between labor market variables. Impulse response shows that increase in production first reveals Creative Destruction and then Capitalization effects.

36 In this model, there are M=2 equations, so it is necessary for at least M-1=1 variable to be omitted from each equation for identification.

37 But, they also admit that if growth depend partly on an exogenous process, then this neutrality may be no longer hold.(Aghion and Howitt, 1998)

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

Figure 3.3: Estimation Results for Impulse Response Functions: Creative Destruction

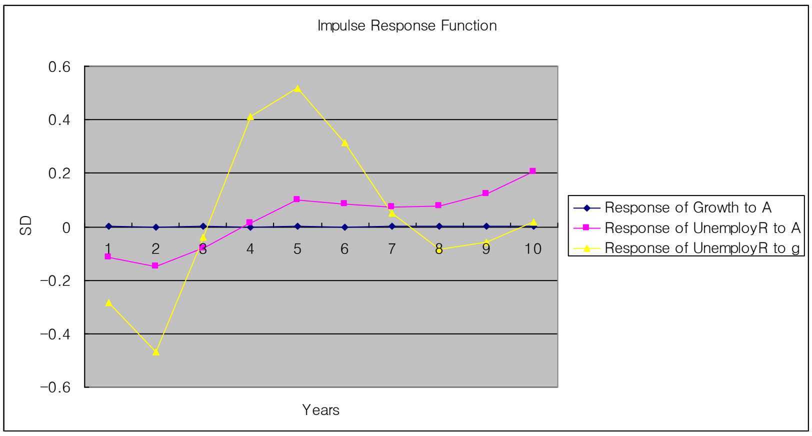
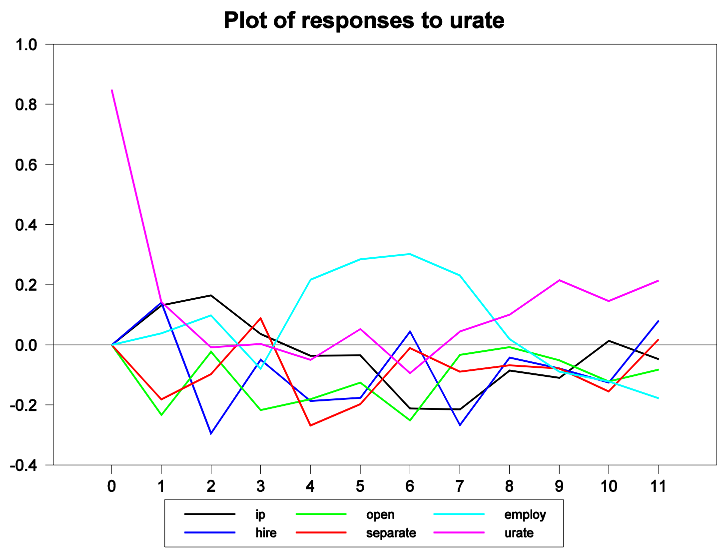


Figure 3.4: Estimation Results for Impulse Response Functions: First Creative Destruction and Then Capitalization



IP	hirer	openingr	separ	employ	urate
Industrial production	Hiring rate	Job opening rate	Job separation rate	Total employment	Unemployment rate

Ⅳ. Summary and conclusion

Aghion and Howitt (1998) analyzed the relationship between growth and unemployment endogenizing growth. New technology is embodied in plants, which are costly to build. Unemployment is caused by workers having to move from a plant utilizing old technology to one utilizing new technology.

In this paper, we showed that direct creative destruction is not the only effect of faster productivity growth. Suppose that some technological advances are of a form that can be utilized by existing plants. Then investors will be 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 rises. (Aghion and Howitt, 1998)

We showed that considering goodness of fit of the regression model, we can see that the empirical evidence is in favor of the character of the capitalization effect from R & D activities and economic growth. Therefore, we can conclude that through technological innovation, faster economic growth has decreased unemployment in the past in the U.S. economy.

The empirical results that show "creative destruction" are search model calibration, regression for hiring rate, and impulse response for unemployment rate in VAR model. The other results that show "capitalized effects" are PDL estimation, state space model for unemployment rate, cointegration test for unemployment rate, and GMM estimation for unemployment rate.

In summary, we adopted the approach that the expectations of investors play an important role in technical progress. If this expectation takes the form of optimism, technical progress affects unemployment negatively (reducing unemployment), and we call this phenomenon a "capitalization effect." This comes from the fact that plant units capitalize the expected income from future technology upgrades.

Assuming a simple aggregate production function and neglecting the physical capital, we can see that the following relationship exists (Blanchard, 2006):

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

We can conclude that the relatively high unemployment rate in 2002-2003 comes from investors' skepticism about the economy (and productivity growth), which cannot lead to a high rate of investment (little "capitalization effect").[39] This skepticism about future technology upgrades was, we think, the main factor driving "jobless recovery."

Finally, we can consider the following issues in future research.

First, in the U.S., there has been a shift in the structure of production away from manufacturing and toward the service sector. Davis and Haltiwanger (1992) analyze job creation and job destruction in the manufacturing sector only. They find that these rates are very large: about 10% in a year. However, of the 10% of job destruction, about 80% is replaced by newly created jobs. The omission of analysis of job creation by technical progress is a limitation of this paper.

Second, we analyzed the period of Great Moderation(1980s-2007). But, we can convert the estimation span into recession period before Great Moderation. In addition, extension of data covering into 2014 would also be significant.

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39 This pessimism prevented the new plants from entering and creating more job.

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<APPENDIX 1>

We use dynamic programming to express the values of employment (E), jobs filled (J), unemployed (U), and vacancy (V). (Romer, 2006)

$rV_E = w - b[V_E - V_U]$

$rV_J = (A - w - C) - b[V_J - V_V]$

$rV_U = p\ [V_E - V_U]$

$rV_V = -C + f\ [V_F - V_V]$ (3'')

We assume that the same of share of surplus is divided between workers and the plant's owner.

$V_E - V_U = V_J - V_V$

After some calculation, we get:

$rV_V = -C + A[f/(p + f + 2b + 2r)]$

The equilibrium level of employment is determined by the intersection of the rV_V locus with the free-entry condition, which implies $rV_V = 0$.

$-C + A[f(E)/(p(E) + f(E) + 2b + 2r)] = 0$ (5)

<APPENDIX 2>

We assume the same fraction of surplus is divided between workers and the firm.
If we denote the surplus generated by the plant as π, the cost of construction of the plant is (Aghion and Howitt, 1998):

$C = (1/2)e^{-rv/m(1,v)} \int e^{-rt}\ \pi\ dt$

However, an increase in economic growth increases the rate of return from creating the production plant. It also encourages entry by new production plants and job creation.
When we consider the possibility that plants can upgrade technology without being replaced by new plants, the capitalization effect can exist. Plant can (costless) adapt to new technology with probability p. Then the cost of capital (construction) will be:

$C = (1/2)e^{-rv/m(1,v)} [\int^{d} e^{-rt}\ dt + (1-p)\int^{S} e^{-rt}\ dt\ ] / (1 - p\ e^{-(r-g)d})$ (d: age of plant)

The change of capital cost affects the value of job filled and job vacancy.

$rV_V' = -C' + A[f/(p + f + 2b + 2r)]$ (3')

The equilibrium level of employment is changed by the intersection of the rV_V' locus with the free-entry condition, which implies $rV_V' = 0$.

$-C' + A[f(E)/(p(E) + f(E) + 2b + 2r)] = 0$ (5')

<APPENDIX 3>

In this section, we show that the capitalization effect experienced a change around 1993. We use the Chow test, which is an F-test for the equivalence of two sub-period regressions. (Hill et al., 2008)

Test results show that the absolute value of elasticity was reduced in 1993.

Table 1: Chow Test Results for the Rate of Unemployment

Chow Breakpoint Test: 1993				
Equation Sample: 1982 2006(annual)				
F-statistic	5.95875		Prob. F(4,17)	0.0035*
Log likelihood ratio	21.90816		Prob. Chi-Square(4)	0.0002*
Wald Statistic	19.20558		Prob. Chi-Square(4)	0.0007*

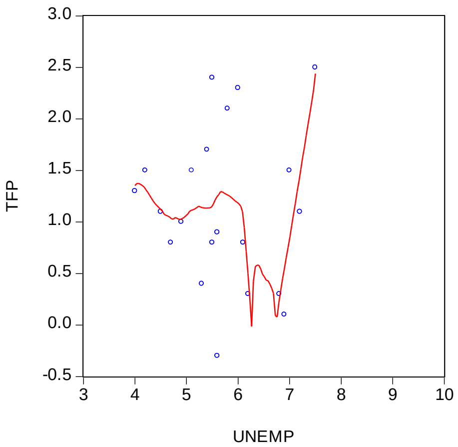
Dependent Variable: UNEMP				
Sample (adjusted): 1982 1993(annual)				
	Coefficient	Std. Error	t-Statistic	Prob.
C	68.85551	12.97704	5.305948	0.0007*
LOG(RD)	-19.91577	4.469751	-4.455677	0.0021*
WAGE	0.495402	0.132976	3.725504	0.0058*
AR(1)	0.134561	0.240083	0.560479	0.5905

Dependent Variable: UNEMP				
Sample: 1993 2006(annual)				
	Coefficient	Std. Error	t-Statistic	Prob.
C	49.2827	18.05715	2.729262	0.0212*
LOG(RD)	-12.21645	4.694116	-2.602503	0.0264*
WAGE	0.230477	0.081867	2.815244	0.0183*
AR(1)	0.481561	0.252896	1.904185	0.086

<APPENDIX 4>

Using data from productivity growth (TFP) and the rate of unemployment (UNEMP), we derive kernel fit.<Figure> It implies that the relationship between two variables may not be linear.

Figure A1: Kernel Regression Fit for TFP Growth



<APPENDIX 5> Productivity and Unemployment Rate (Blanchard, 2006)

We examine a simple model of the unemployment rate and productivity. For this, we assume the following aggregate production function:

$Y=AL$

This equation means producing output Y requires (AL) workers. Firms set prices according to markup $(1+\eta)$. The price setting relationship is as follows:

$p=(W/A)(1+\eta)$

Similarly, wage setting follows:

$w=pAf(u,b)$

The price setting relation determines the real wage:

$w/p=A/(1+\eta)$

Under the scenario that expectations are correct, the wage-setting equation will be:

$w/p=Af(u,b)$

This model has the following implications.

First, when, productivity growth varies, the change in unemployment rate depends on the firm's expectation for productivity of workers. If a slowdown in productivity occurs, the natural rate of unemployment may increase. This is because it takes some time for workers to update their expectations. Second, if a growth in productivity occurs, the rate of unemployment may decrease. This also is because it takes some time for workers to update (increase) their expectations of productivity growth.

In the short term, an increase in the rate of technological progress can lead to either a decrease or an increase in the unemployment rate. The last decade in the U.S. provides an example of each type.[40]

This simple model of Blanchard (2006) gives some implications for the "jobless recovery" of 2002~2003 in the U.S. That is, in spite of some upward productivity shifts, workers might expect more than the real productivity growth.

<APPENDIX 5> Implication of the 2nd Generations Endogenous Growth Model

The Schumpeterian second generation endogenous theory of growth [Young (1998), Aghion-Howitt (1998)] provides a way of analyzing the relationship between growth and employment.

In the second generation growth models, the variety of consumption goods is proportional to the population.[41] The growth of productivity comes from R & D that uses final output (GDP) as the input. The rate of innovation g_A in a sector to which N_t units of output in R & D are given is:[42]

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

Growth in productivity parameter A comes from 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

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

40 During the later half of the 1990s, the increase in productivity growth came with a large increase in output growth and a steady decrease in unemployment. Productivity growth was unusually high during the second half of the 1990s(1996-2000). The increase in growth rates is related with an increase in the use of information technology(IT).

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

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

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

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

$$w_t^*=A_t^*a^*= A_t^* [a+(b+g_t+r-g_A)c] \qquad (6)$$

The demand for labor by variety firms will be

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

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

$$V_t=A_t\, v(r+g, a^*, g_A) \qquad (7)$$

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

$$r=\rho+\varepsilon g_A \qquad (8)$$

We have the following arbitrage equation:

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

The steady-state growth rate is

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

The demand for labor by monopolistic firms is

$$L_D =\Sigma L_{Y\,i}= l^*(r^*, a^*)$$

$$=l^* [\rho+(\varepsilon+1)g_A, w+(\rho+\varepsilon g_A+b)c]$$

In this Schumpeterian model, there are various exogenous variables: quit rate, the cost of hiring and parameter of real wage level, etc. Also, there are endogenous variables: job separation, job creation and (natural) rate of unemployment.