R&D, Unemployment, and Labor Market Policies

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Abstract

This paper studies the effects of labor market policies on R&D activities and unemployment. I develop a search and matching model in which firms' R&D decisions are endogenously determined. The model demonstrates that more intensive labor market policies that protect workers reduce the levels of R&D activities. This study offers a theoretical framework to understand the relationship between R&D activities, labor market policies, and unemployment which is discussed in empirical studies.

R&D, Unemployment, and Labor Market Policies*

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Abstract

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Keywords: Labor market policies; R&D; Search and matching model
JEL: E24; J40; J64

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1 Introduction

Over the years, economists have been interested in the relationship between economic growth and unemployment. The simultaneous slowdown of productivity growth and the rise in unemployment in OECD countries in the latter half of the 1970s has led many economists to believe that there is a close connection between these trends. Both theoretical and empirical studies have investigated the influence of technological progress on unemployment. Recently, several empirical studies demonstrate that labor market policies that affect unemployment, such as a firing tax, a payroll tax, and an unemployment subsidy, also have effects on technological progress (Nicoletti et al. 2002; OECD, 2002). However, there have been only a few theoretical studies on the effect of such labor market policies on the R&D activity that is main driving force of technological progress. Especially, there has been no study on effects of labor market policies on R&D decisions in a search and matching model.

The purpose of this paper is to develop a search and matching model in which R&D decisions are endogenously determined and to analyze the effect of labor market policies on R&D activities. For this purpose, I incorporate R&D activities into the search and matching model with disembodied technological progress developed by Pissarides (2000). While the economic growth rate is determined purely exogenously in Pissarides' model, in my model, it is influenced by the level of R&D activities. That is, the higher the level of R&D activities, the higher the growth rate.

By introducing endogenous R&D decisions into the equilibrium unemployment model of Pissarides (2000), this study is able to explore the effects of various labor market policies on unemployment and the level of R&D activities. I focus on three labor market policies such as a firing cost, a payroll tax, and an unemployment benefit. The model demonstrates that these policy interventions to the labor market discourage firms from opening new jobs, leading to higher unemployment. Furthermore, increases in the firing cost and the unemployment benefit reduce the value of having a filled job, therefore discouraging firms from investing in R&D. The effect of an increase in the payroll tax on the level of R&D activities is qualitatively ambiguous due to a lower workers' outside option from lower labor market tightness.

This study treats endogenous R&D decisions, which have not been treated in the standard search model of Diamond (1982), Mortensen (1982) and Pissarides (2000). Chen, Mo, and Wang (2002) also analyze a search economy with R&D activities, but their focus is to construct a model of endogenous growth with labor market frictions and to study firms' decisions to adopt new technology. Furthermore, none of these papers discusses the effect of labor market policies on R&D activities, which is the main focus of this study.

This paper is also related to the literature on growth and unemployment. The search and matching theory predicts that the impact of growth on unemployment depends on the extent to which new technology is embodied in new jobs (Mortensen and Pissarides, 1998; Pissarides and Vallanti, 2007). The matching model with disembodied technological progress predicts that a faster growth rate reduces unemployment through the so called capitalization effect (Pissarides, 2000). On the other hand, in the model with embodied technological progress, faster growth can increase unemployment through creative destruction (Aghion and Howitt, 1994, 1998; Postel-Vinay, 2002). Motivated by the empirical evidence that productivity growth decreases the unemployment rate, Pissarides and Vallanti (2007) demonstrate that totally disembodied technology is necessary for the model to match empirical evidence. In this paper, I follow Pissarides and Vallanti (2007) and assume that technological progress is disembodied. Furthermore, my model pushes their argument one step further, since in my model the rate of economic growth is influenced by R&D activities, while the economic growth rate is determined purely exogenously in models of Pissarides (2000) and Pissarides and Vallanti (2007).

My work is closely related to Mortensen (2005). Mortensen (2005) develops the Schumpeterian growth model with labor market friction and investigates the effects of labor market policies on growth and unemployment. While technological progress is assumed to be embodied and the creative destruction effect plays an important role in the model of Mortensen (2005), in my model technological progress is totally disembodied and the capitalization effect plays an important role. Although this study and Mortensen (2005) share the same implication for the effects of labor market policies on unemployment and the innovation level, the underlying mechanisms are different. While labor market policies affect unemployment and the innovation level through the job creation side in my model, they affect unemployment and innovation through the job destruction side in the model of Mortensen (2005). Furthermore, the predictions for the relationship between the growth rate and unemployment are different. My model generates a negative relationship between growth and unemployment, while their relationship is theoretically ambiguous in Mortensen (2005). These differences come from the assumption of technological progress, whether it is embodied or disembodied.

The remainder of this paper is organized as follows. The model is presented in Section 2. In Section 3, the steady-state equilibrium of the model is characterized. Section 4 presents comparative statics results. Conclusions are presented in Section 5.

2 The model

Consider an economy consisting of a continuum of workers normalized to one and a large number of identical risk-neutral firms. All agents are infinitely lived and maximize the present discounted value of their income stream with discount rate r. Time is continuous.

A firm has only one job that can be either filled or vacant. One job is filled by one worker.[1] A firm can produce output if its job is filled. If it is vacant, the firm produces no output and searches for a worker. A worker can be either employed or unemployed. If a worker is employed, he produces output and earns an endogenous wage but cannot search for other jobs. If he is not employed, he searches for a job.

Once a firm and a worker are paired, they separate with the exogenous probability δ at each time. After a matched firm-worker pair separates, the firm leaves the labor market or reopens a new vacant job at flow cost Γ_t. The worker enters the unemployment pool and looks for another job.

Production takes place in one firm-one worker pairs. The match produces a flow of output p_t at time t. Suppose that the leading technology in the economy is driven by an exogenous invention process that grows at the rate g. In order to study the effect of R&D activities on technological progress, I assume that the productivity growth rate of a firm is positively related to the level of R&D investment. Let y be the level of R&D activity. Then, the output of a firm at time t is given by

$$p_t = p_0 \exp(g\phi(y)t),$$

where $\phi(0) = 1$, $\phi_y > 0$, $\phi_{yy} < 0$, and $p_0 > 0$ is some initial productivity level which is normalized to be one.[2] To make economic sense, I assume that r is large enough so that $r > g\phi(y)$.

When a firm with a vacancy meets an unemployed worker and an employment contract is signed, the firm chooses the level of R&D investment and incurs the cost $C_t(y)$. $C(y)$ is the total cost function that is necessary to make y units of investment and satisfies $C_y > 0$ and $C_{yy} > 0$.

In this paper, I analyze the effects of three policy instruments τ, F_t, and Z_t that determine payroll taxes, a firing tax paid by a firm, and an unemployment subsidy, respectively. In the model, a firm has to pay payroll taxes. Let τ represent a proportional payroll tax paid by the firm. In addition, a firm has to pay a firing tax F_t when separation takes place. On the other

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[1]In the standard search and matching model, each firm hires one worker and can post at most one vacancy (Mortensen and Pissarides, 1994; Pissarides, 2000). Pissarides (2000, Ch.3) considers a model of large firms in which each firm can employ many workers. He shows that the model with large firms has the same implications as the standard model, assuming that wages are determined through bargaining at the individual level.

[2]I am grateful to the referee for his/her comments with respect to the treatment of the productivity growth rate.

hand, a worker receives an unemployment subsidy Z_t when he is unemployed.

The number of successful job matches per unit time is given by the matching function $\mathcal{M}(u_t, v_t)$, where u_t is the number of unemployed workers and v_t is the number of vacancies at time t. The matching function $\mathcal{M}(u, v)$ is continuous, twice differentiable, increasing in its arguments, and has constant returns to scale. Define $\theta_t \equiv v_t/u_t$ as the tightness of the labor market. The rate at which a firm with a vacancy is matched with a worker is $\mathcal{M}(u_t, v_t)/v_t = \mathcal{M}(1/\theta_t, 1) \equiv q(\theta_t)$. Similarly, the rate at which an unemployed worker is matched with a firm is $m(u_t, v_t)/u_t = \theta_t q(\theta_t)$. Since the matching function has constant returns to scale, $q(\theta_t)$ is decreasing in θ_t and $\theta_t q(\theta_t)$ is increasing in θ_t. I also make the standard Inada-type assumptions on $\mathcal{M}(u, v)$, which ensure that $\lim_{\theta \to \infty} q(\theta) = 0$, $\lim_{\theta \to 0} q(\theta) = \infty$, $\lim_{\theta \to \infty} \theta q(\theta) = 0$ and $\lim_{\theta \to 0} \theta q(\theta) = \infty$.

After a firm with a vacancy and an unemployed worker meet, the firm produces output and pays wages to its worker. Wages are chosen so as to share the surplus from the job match in fixed proportions. The worker's share is $\beta \in (0, 1)$.

2.1 The value functions

The values of firms and workers are described by a series of Bellman equations. I start with the firm's side. Let the value of a filled job be J_t and the value of a vacant job be V_t.

The value of a filled job satisfies

$$rJ_t = p_t - (1 + \tau)w_t + \delta(V_t - J_t - F_t) + \frac{dJ_t}{dt}. \tag{1}$$

A firm with a filled job revenues $p - (1 + \tau)w$, which is the productive output of the match minus the wage paid to the worker. The match may be destroyed by the exogenous shock at rate δ, in which case the firm loses its asset value of the filled job, pays the firing tax, and obtains the value of a vacant job. Finally, the asset value of a match is expected to change over time due to technological progress.

Because of the existence of the R&D investment cost, the expected profit of a new match is different from J_t, as defined in (1). Therefore, I introduce the notation J_t^n for the expected profit of a new match to the firm. Then, the value of a vacant job at time t is given by

$$rV_t = -\Gamma_t + q(\theta_t)[J_t^n - V_t - C_t(y_t)] + \frac{dV_t}{dt}. \tag{2}$$

Given the starting wage w_t^n, the initial value of an filled job satisfies

$$rJ_t^n = p_t - (1 + \tau)w_t^n + \delta(V_t - J_t^n - F_t) + \frac{dJ_t^n}{dt}. \tag{3}$$

I now turn to the worker's side. Let W_t denote the value for an employed worker at time t. It satisfies

$$rW_t = w_t + \delta(U_t - W_t) + \frac{dW_t}{dt}, \tag{4}$$

where U is the value of an unemployed worker. The value of an employed worker is determined by several factors. The worker receives the wage w. The match may be destroyed by the exogenous shock at rate δ, in which case the worker loses the current asset value and obtains the asset value of being unemployed. The asset value of a match is expected to change over time due to technological progress.

The value of an unemployed worker satisfies

$$rU_t = Z_t + \theta_t q(\theta_t)(W_t^n - U_t) + \frac{dU_t}{dt}, \tag{5}$$

where W^n is the value of an employed worker at the moment of job creation.

Given an initial wage w^n, the initial value of an employed worker satisfies

$$rW_t^n = w_t^n + \delta \left(U_t - W_t^n\right) + \frac{dW_t^n}{dt}. \tag{6}$$

The firm that has a job with value J_t at time t expects to make a capital gain of $dJ_t/dt = g\phi(y)J$ on it. The same holds for the value of an employed worker W_t and an unemployed worker U_t, where the capital gain is $g\phi(y)W$ and $g\phi(y)U$, respectively. But the value of a job V_t does not change because it is zero by the free entry condition.

I focus on the steady state. This corresponds to a balanced growth path where the economy grows at the rate of productivity growth $g\phi(y)$. To make the mode stationary, I assume that all exogenous variables grow at the rate of productivity growth.[3] Thus, I define three positive exogenous parameters γ, z, and F such that $\Gamma_t = p_t\gamma$, $Z_t = p_t z$, and $F_t = p_t F$. Furthermore, the cost function can be rewritten as $C_t(y) = p_t C(y)$.

Replacing the capital gain by its steady-state value, the above Bellman equations can be rewritten as follows:

$$(r - g\phi(y))J = p - w(1 + \tau) + \delta[V - J - pF], \tag{7}$$

$$(r - g\phi(y))V = -p\gamma + q(\theta)[J^n - V - pC(y)], \tag{8}$$

$$(r - g\phi(y))J^n = p - w^n(1 + \tau) + \delta[V - J^n - pF], \tag{9}$$

$$(r - g\phi(y))W = w + \delta[U - W], \tag{10}$$

$$(r - g\phi(y))U = pz + \theta q(\theta)[W^n - U], \tag{11}$$

and

$$(r - g\phi(y))W^n = w^n + \delta[U - W^n]. \tag{12}$$

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[3]In the literature, in order to ensure the existence of a balanced growth path, usually all the exogenous parameters are assumed to follow the pace of productivity growth. See, for example, Mortensen and Pissarides (1999) and Pissarides and Vallanti (2007).

The amount of R&D investment y is chosen by the firm to maximize the present-discounted value of its expected income at the moment of job creation. Therefore, the optimal level of y satisfies

$$\frac{d}{dy}[J^n - V - pC(y)] = 0. \tag{13}$$

The wages are determined through the Nash bargaining between a firm and a worker over the share of expected future joint income. I assume that at the initial wage determination stage the cost of R&D is not "sunk" but "on the table". Under this assumption, the difference between the initial wage bargaining and subsequence renegotiation arise.[4] When a firm and a worker first meet and sign a contract, the payoff to the firm equals $J^n - V - pC(y)$ because the firm incurs R&D costs. Therefore, the initial wage is determined by the following equation

$$w^n = \arg\max \left[W^n - U\right]^\beta \left[J^n - V - pC(y)\right]^{1-\beta}.$$

Once the worker is employed, the firm will not pay the cost of R&D. In this case, however, if the firm fails to agree to a continuation wage, the firm will have to pay the firing cost pF. Thus, the continuing wage is chosen as

$$w = \arg\max[W - U]^\beta[J - V + pF]^{1-\beta}.$$

The solution to these optimization problems must satisfy the following first-order conditions

$$(1-\beta)[W^n - U] = \beta[J^n - V - pC(y)], \tag{14}$$

and

$$(1-\beta)[W - U] = \beta[J - V + pF], \tag{15}$$

respectively.

In equilibrium, all profit opportunities from new jobs are exploited. Thus, I have the following free entry condition

$$V = 0. \tag{16}$$

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[4] This wage determination mechanism is adopted in most of search and matching models. See Pissaires (2000, Ch.9) and Mortensen and Pissarides (1999). This study assumes that a firm chooses the level of R&D activity after bargaining the wage with its worker, but there are alterative timings of the R&D investment to be considered. The reverse timing is one of alternatives. Thus, a firm meets an unemployment worker and chooses the level of the R&D activity, and then bargains the wage. In this case, whether the cost of the R&D investment is sunk or not at the initial wage determination stage is crucial. If the cost is not sunk, although the timing is reversed, my analysis and the main results are not unchanged. On other hand, when the cost of the R&D investment is sunk at the initial wage determination stage, Equation (14) needs to be replaced by $(1-\beta)(W^n - U) = \beta(J^n - V)$. One can easily show that my analysis remains valid and the effects of labor market policies on labor market variables are qualitatively unchanged. However, the effects of labor market policies, such as a firing tax and an unemployment benefit, on the innovation become qualitatively ambiguous due to the hold-up problem.

The evolution of unemployment is given by the difference between the flow into unemployment and the flow out of it. Thus,

$$\dot{u} = \delta(1 - u) - \theta q(\theta)u.$$

In the steady-state, the unemployment rate is determined by

$$u = \frac{\delta}{\delta + \theta q(\theta)}. \tag{17}$$

3   Characterization of steady-state equilibrium

A steady-state equilibrium is a profile $\{u, \theta, y, w^n, w, J^n, J, V, W^n, W, U\}$ which satisfies the Bellman equations (7), (8), (9), (10), (11), and (12), the condition for the optimal level of R&D (13), the wage equations (14) and (15), the free entry condition (16), and the steady-state unemployment rate condition (17).

The free entry condition (16) together with the equation (8) yields

$$\frac{p\gamma}{q(\theta)} = J^n - pC(y). \tag{18}$$

From (11), (14), (16), and (18), the value of an unemployed worker can be rewritten as

$$(r - g\phi(y))U = pz + \frac{\beta\theta p\gamma}{1 - \beta}. \tag{19}$$

By substituting J^n and W^n given by equations (9) and (12) into (14) with the free entry condition (16), I obtain

$$w^n = \frac{1}{1 + \beta\tau}\left[\beta p(1 - \delta F) - \beta p(r + \delta - g\phi(y))C(y) + (1 - \beta)(r - g\phi(y))U\right].$$

Substituting the value of unemployment (19) into the above relation, I get an expression for the initial wage

$$w^n = \frac{p}{1 + \beta\tau}\left[\beta(1 - \delta F) - \beta(r + \delta - g\phi(y))C(y) + (1 - \beta)z + \beta\theta\gamma\right]. \tag{20}$$

One can derive the continuation wage in a similar manner as I did in obtaining the initial wage. By using equations (7), (10), (15), (16), and (19), the continuation wage is

$$w = \frac{p}{1 + \beta\tau}\left[\beta + (1 - \beta)z + \beta(r - g\phi(y))F + \beta\theta\gamma\right].$$

By substituting the starting wage (20) into (9) and by imposing the free entry condition $V = 0$, and by using the equation (18), I obtain

$$\frac{\gamma}{q(\theta)} = \frac{(1 - \beta)(1 - \delta F) - (1 + \tau)\left[(1 - \beta)z + \beta\theta\gamma\right]}{(r + \delta - g\phi(y))(1 + \beta\tau)} - \frac{(1 - \beta)}{(1 + \beta\tau)}C(y). \tag{21}$$

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This equation is referred as the job creation condition. The job creation condition (21) states that the expected vacancy cost, the left-hand side of (21), equals to the firm's share of the expected net surplus from a new job match, the right-hand side of (21).

Finally, using the equations (9), (16), and (20), the optimal condition for the R&D level (13) can be expressed as,

$$
\begin{aligned}
\frac{d}{dy}[J^n - V - pC(y)] &= \frac{p(1-\beta)}{(1+\beta\tau)} \left[\frac{g\phi'(y)\left\langle 1 - \delta F - (1+\tau)\left(z + \frac{\beta\theta\gamma}{1-\beta}\right)\right\rangle}{(r+\delta-g\phi(y))^2} - C_y(y) \right] \\
&= 0
\end{aligned}
\tag{22}
$$

which can be summarized as

$$
\frac{g\phi'(y)\left[1 - \delta F - (1+\tau)\left(z + \frac{\beta\theta\gamma}{1-\beta}\right)\right]}{(r+\delta-g\phi(y))^2} = C_y(y).
\tag{23}
$$

The left-hand side of equation (23) is the marginal benefit of investment in R&D. I denote this term by $B(y)$. Equation (23) states that in the equilibrium the optimal level of R&D activities is such that the marginal benefit of investment in R&D is equal to the marginal cost of it.

The second order condition for the determination of the optimal R&D level is given by

$$
\frac{d^2}{dy^2}[J^n - V - pC(y)] = \frac{p(1-\beta)}{(1+\beta\tau)}[B_y(y) - C_{yy}(y)] < 0,
$$

which implies

$$
B_y(y) - C_{yy}(y) < 0.
$$

The system of equations (21) and (23) determine the endogenous variables θ and y. Given θ, equation (17) determines the steady-state equilibrium unemployment rate.

4 The effects of labor market policies

In this section, I analyze the effects of labor market policies on unemployment and R&D activities. The model has three labor market policy parameters: the firing tax F, the payroll tax τ, and the unemployment subsidy z. I perform comparative static exercise by totally differentiating (17), (21), and (23) with respect to endogenous variables and exogenous policy parameters. In Appendix, I present the formal derivation of the comparative statics results.

I begin by analyzing the effects of the employment protection on unemployment and R&D activities.

Proposition 1 *An increase in the firing cost F reduces both the level of R&D activities y and labor market tightness θ: dy/dF < 0 and dθ/dF < 0. Then, the unemployment rate increases: du/dF > 0 .*

Since the firm has to pay the firing tax when the job is destroyed, an increase in the firing tax reduces the value of a filled job. The lower value of a filled job discourages a firm to invest in R&D. Furthermore, firms are discouraged to open vacancies. Thus, labor market tightness decreases, leading to higher unemployment.

[Figure 1 around here]

[Figure 2 around here]

This result is consistent with recent cross country experience. In Figure 1 and Figure 2, R&D intensities and average unemployment rates are plotted against the OECD overall employment protection legislation (EPL) index.[5] The correlation coefficient between R&D intensity and EPL index is -0.361 and the correlation coefficient between the unemployment rate and EPL index is 0.198. Thus, R&D intensity is negatively correlated with the employment protection and the unemployment rate is positively correlated with the employment protection. Although cross country comparisons constitute the most naïve evidence, this empirical evidence confirms the implication of the model.

Next I analyze the effects of the payroll tax rate.

Proposition 2 *An increase in the payroll tax rate τ reduces labor market tightness θ and increases the unemployment rate u: dθ/dτ < 0 and du/dτ > 0. However, the sign of the effect on the level of R&D activities is ambiguous.*

Since a higher payroll tax decreases the profit of a firm, the expected value of a filled job also decreases. The lower expected value of a filled job reduces job creation. This leads to lower labor market tightness, resulting in higher unemployment. The effect of the payroll tax on the level of R&D activities is ambiguous. This ambiguity is due to a lower workers' outside option from lower labor market tightness. Since a higher payroll tax reduces labor market tightness, employed workers have worse outside opportunities and so accept lower wages. This increases the value of a filled job, and firms are encouraged to invest in R&D activities. However, a higher payroll tax directly reduces the value of a filled job, discouraging firms from investing in R&D activities. Since the overall effect of the payroll tax on the level of R&D activities is determined by these two opposite effects, it is qualitatively ambiguous.

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[5]The specific countries and the data associated with each are reported in Appendix.

[Figure 3 around here]

[Figure 4 around here]

Similar to the case of the firing tax, scatter diagram of R&D intensities and unemployment rates against the tax wedge is reported in Figure 3 and 4, respectively.[6] Figure 3 shows that the correlation between R&D intensities and the tax wedge is essentially zero, while Figure 4 shows that the correlation between unemployment rates and the tax wedge is positively correlated, which is consistent with the implication of the model.

The implications of my model for the effects of the firing tax and the payroll tax on unemployment and the innovation level are the same to those of Mortensen (2005). However, the underlying mechanisms are different. In the Mortensen model, technological progress is assumed to be embodied and the creative destruction effect plays an important role. Thus, labor market policies affect unemployment and the level of R&D through the job destruction side. In contrast, in my model, technological progress is assumed to be disembodied and the capitalization effect plays an important role. Thus, policy interventions to labor market affect unemployment and innovation through the job creation side.

I now turn to examine the effects of the unemployment subsidy on unemployment and the level of R&D activities.

Proposition 3 *An increase in the unemployment insurance benefits z reduces the level of R&D activities y and labor market tightness θ: $dy/dz < 0$ and $d\theta/dz < 0$. Then, the unemployment rate u increases: $du/dz > 0$.*

The effects of the unemployment subsidy on the level of R&D activities and labor market outcome are basically the same as the case in the firing tax. The higher unemployment subsidy increases the worker's wage and thus reduces the expected value of a filled job. This leads to the lower level of R&D activities and lower labor market tightness, resulting in higher unemployment.

[Figure 5 around here]

[Figure 6 around here]

R&D intensities and average unemployment rates are plotted against the OECD summary measure of unemployment benefits in Figure 5 and 6. Figure 5 shows that R&D intensities and unemployment benefits are negatively correlated. This result is consistent with the prediction of the model. In contrast, Figure 6 shows that the correlation between unemployment rates and

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[6]I use the tax wedge estimated by the Eurostat.

unemployment benefits is essentially zero, which is not consistent with the model. However, the impact of unemployment benefits on the rate of unemployment has been controversial in the empirical literature (Atkinson and Micklewright, 1991; Holmlund, 1998). Furthermore, cross country comparisons of these kind constitutes the most naïve evidence. Therefore, more evidence would be necessary to conclude the effect of the generosity of unemployment benefits on the unemployment rate.

Propositions 1, 2, and 3 suggest that labor market policies that protect workers have an important role in determining the level of R&D activities. Thus, the model provides an explanation of the relationship between R&D activities and labor market policies which is reported by several empirical studies.

Lastly, I examine the effect of a change in the technological progress rate g on R&D intensity and unemployment.

Proposition 4 *An increase in the technological growth rate g increases both the level of R&D activities y and labor market tightness θ:$dy/dg > 0$ and $d\theta/dg > 0$. Then, the unemployment rate u decreases: $du/dg < 0$.*

Faster growth raises the returns to job creation, thus firms are encouraged to post more vacancies and to invest in R&D activities. This leads to higher job finding rate of unemployed workers, resulting in lower unemployment. This result is basically the same as in the standard matching model with disembodied technological progress developed by Pissarides (2000). This is because we may view the model of Pissarides (2000) as a special case of my model where the level of R&D intensity is fixed. Recent empirical studies find a negative impact of growth on unemployment (Bruno and Sachs, 1985; Ball and Moffitt, 2001; Muscatelli and Tirelli, 2001; Staiger et al., 2001; Tripier, 2006; Pissarides and Vallanti, 2007). The implication of Proposition 4 is consistent with empirical evidence.

5 Conclusion

Recently, several empirical studies demonstrate that labor market policies affect R&D activities. However, there has not been much theoretical investigation into the effects of labor market policies on R&D activities. This paper develops a search and matching model in which a firm's R&D decision is endogenously determined. I analyze the effects of labor market policies, such as a firing tax, a payroll tax, and an unemployment subsidy, on R&D activity and unemployment.

The model demonstrates that these policy interventions to the labor market discourage firms from opening new jobs, leading to higher unemployment. Furthermore, increases in the firing

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cost and the unemployment benefit reduce the value of having a filled job, therefore discouraging firms from investing in R&D. The effect of an increase in the payroll tax on the level of R&D activities is qualitatively ambiguous due to a lower workers' outside option from lower labor market tightness.

References

[1] Aghion, P., Howitt, P., 1994. Growth and unemployment. Review of Economic Studies 61, 477-494.

[2] Aghion, P., Howitt, P., 1998. Endogenous Growth Theory. MIT Press, Cambridge, MA.

[3] Atkinson, A. B., Micklewright, J., 1991. Unemployment compensation and the labor market transition: A critical review. Journal of Economic Literature 29 (4), 1679–1727.

[4] Ball, L., Moffitt, R., 2002. Productivity Growth and the Phillips Curve. In Krueger,A. B, and R. Solow. (Eds.), The Roaring Nineties: Can Full Employment be Sustained?. Russell Sage Foundation, New York.

[5] Bruno, M. and J. D. Sachs., 1985. Economics of Worldwide Stagflation. Harvard University Press, Cambridge, MA.

[6] Chen, B. L., Mo, J. P., Wang, P., 2002. Market frictions, technology adoption and economic growth. Journal of Economic Dynamics & Control 26, 1927-1954.

[7] Diamond, P. 1982. Wage Determination and Efficiency in Search Equilibrium. Review of Economic Studies 49, 217-227.

[8] Holmlund, B., 1998. Unemployment insurance in theory and practice. Scandinavian Journal of Economics 100 (1), 113–141.

[9] Mortensen, D. T. 1982. Property Rights and Efficiency in Matching, Racing and Related Games. American Economic Review 72, 968-79.

[10] Mortensen, D. T. 2005. Growth, Unemployment and Labor Market Policy. European Economic Association (April-May 2005) 3, 236-258.

[11] Mortensen, D. T., Pissarides, C. A., 1994. Job creation and job destruction in the theory of unemployment. Review of Economic Studies 61, 397-415.

[12] Mortensen, D. T., Pissarides, C. A., 1998. Technological progress, job creation, and job destruction. Review of Economic Dynamics 1, 733-753.

[13] Mortensen, D. T., Pissarides, C. A., 1999. Job reallocation and employment fluctuations. In: Woodford, M., Taylor, J. B. (Eds.), Handbook of Macroeconomics, Vol. 1. Elsevier Science, Amsterdam, 1171-1227.

[14] Muscatelli, V. A., Tirelli, P., 2001. Unemployment and Growth: Some Empirical Evidence from Structural Time Series Models. Applied Economics 33, 1083-1088.

[15] Nicoletti, G., Bassanini, A., Jean, S., Ernst, E., Santiago, P., Swaim, P. 2002. Product and Labour Market Interactions in OECD Countries (December 14, 2001). OECD Economics Department Working Papers No. 312.

[16] OECD. 2002. OECD Employment Outlook 2002: Paris.

[17] Pissarides, C. A., 2000. Equilibrium Unemployment Theory, second ed. MIT Press, Cambridge, MA.

[18] Pissarides, C. A., Vallanti, G., 2007. The Impact of TFP Growth on Steady-State Unemployment. International Economic Review 48, 607-640.

[19] Postel-Vinay, F., 2002. The dynamics of technological unemployment. International Economic Review 43, 737-760.

[20] Staiger, D., Stock, J., Watson, M., 2001. Prices, Wages and the U.S. NAIRU in the 1990s. In Krueger, A. B, and Solow, R. (Eds.), The Roaring '90s: Can Full Employment Be Sustained. Russell Sage and Century Fund, New York, 3–60.

[21] Tripier, F., 2006. Sticky prices, fair wages, and the co-movements of unemployment and labor productivity growth. Journal of Economic Dynamics & Control 30, 2749-2774.

Appendix

Table 1: Descriptive statistics

Country	R&D intensity	Unemployment rate	Tax wedge	EPL index*	Unemployment benefit**
Austria	1.8	4.1	42.0	2.3	31
Belgium	1.9	8.4	50.2	2.5	40
Bulgaria	0.7	15.9	37.0		
Cyprus	0.3	4.2	17.2		
Czech Republic	1.1	7.9	41.6	2.1	
Denmark	2.1	6.0	40.5	1.5	57
Estonia	0.7	10.7	39.2		
Finland	2.8	11.9	42.0	2.1	35
France	2.2	10.3	43.7	2.5	39
Germany	2.3	8.2	47.3	2.6	28
Greece	0.6	10.0	34.7	3.5	14
Hungary	0.8	7.1	46.7	1.7	
Ireland	1.2	8.8	20.5	1.1	32
Italy	1.1	10.0	43.8	3.4	26
Japan	3.0	4.0	21.2	2.3	10
Latvia	0.4	12.6	41.1		
Lithuania	0.6	13.9	40.2		
Luxembourg	1.7	2.9	29.7		
Netherlands	1.9	4.5	39.9	2.2	52
Norway	1.7	3.9	34.7	2.6	39
Poland	0.6	15.9	42.3	2.0	
Portugal	0.7	5.7	31.7	3.7	39
Romania	0.4	6.5	43.2		
Slovakia	0.9	17.4	40.2		
Slovenia	1.5	6.7	40.6		
Spain	0.9	14.4	34.8	3.1	37
Sweden	3.6	7.3	48.0	2.6	26
Turkey	0.5	9.2	41.1	3.5	
United Kingdom	1.9	6.9	28.3	0.9	17
United State	2.6	5.5	27.8	0.7	13

Source: Eurostat Structural Indicators (1992-2004) Averages.

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    **OECD Benefits and Wages. I use the gross replacement rate as a measure of unemployment benefit and the data are averages of 1993-2003.

Proof of Proposition 1

By totally differentiating equations (21) and (23) with respect to endogenous variables and the exogenous variables F, I obtain

$$\begin{pmatrix} -\frac{\gamma q'(\theta)}{q(\theta)^2} + \frac{(1+\tau)\beta\gamma}{(r+\delta-g\phi(y))(1+\beta\tau)} & 0 \\ -\frac{g\phi'(y)(1+\tau)\frac{\beta\gamma}{1-\beta}}{(r+\delta-g\phi(y))^2} & B_y(y) - C_{yy}(y) \end{pmatrix} \begin{pmatrix} \frac{d\theta}{dF} \\ \frac{dy}{dF} \end{pmatrix} = \begin{pmatrix} -\frac{(1-\beta)\delta}{(1+\beta\tau)(r+\delta-g\phi(y))} \\ \frac{g\phi'(y)\delta}{(r+\delta-g\phi(y))^2} \end{pmatrix},$$

where the determinant for the left hand side coefficient matrix is given by

$$\Delta = \left[-\frac{\gamma q'(\theta)}{q(\theta)^2} + \frac{(1+\tau)\beta\gamma}{(r+\delta-g\phi(y))(1+\beta\tau)} \right] (B_y - C_{yy}) < 0.$$

Then, the comparative static result can be stated as

$$\frac{d\theta}{dF} = -\frac{1}{\Delta} \frac{(B_y - C_{yy})(1-\beta)\delta}{(1+\beta\tau)(r+\delta-g\phi(y))} < 0,$$

and

$$\frac{dy}{dF} = -\frac{1}{\Delta} \frac{\gamma q'(\theta)}{q(\theta)^2} \frac{g\phi'(y)\delta}{(r+\delta-g\phi(y))^2} < 0.$$

The effect on the unemployment rate can be obtained by totally differentiating equation (17) and using above results. Thus, I have

$$\frac{du}{dF} = -\frac{[\theta q(\theta)]' u}{\delta + \theta q(\theta)} \cdot \frac{d\theta}{dF} > 0.$$

∎

Proof of Proposition 2

By totally differentiating equations (21) and (23) with respect to endogenous variables and the exogenous variables τ, I obtain

$$\begin{pmatrix} -\frac{\gamma q'(\theta)}{q(\theta)^2} + \frac{(1+\tau)\beta\gamma}{(r+\delta-g\phi(y))(1+\beta\tau)} & 0 \\ -\frac{g\phi'(y)(1+\tau)\frac{\beta\gamma}{1-\beta}}{(r+\delta-g\phi(y))^2} & B_y(y) - C_{yy}(y) \end{pmatrix} \begin{pmatrix} \frac{d\theta}{d\tau} \\ \frac{dy}{d\tau} \end{pmatrix} = \begin{pmatrix} -\frac{1-\beta}{r+\delta-g\phi(y)}\left(z + \frac{\beta\theta\gamma}{(1-\beta)}\right) - \frac{\gamma\beta}{q(\theta)} \\ \frac{g\phi'(y)}{(r+\delta-g\phi(y))^2}\left(z + \frac{\beta\theta\gamma}{1-\beta}\right) \end{pmatrix},$$

where the determinant for the left hand side coefficient matrix is given by

$$\Delta = \left[-\frac{\gamma q'(\theta)}{q(\theta)^2} + \frac{(1+\tau)\beta\gamma}{(r+\delta-g\phi(y))(1+\beta\tau)} \right] (B_y - C_{yy}) < 0.$$

Then, the comparative static result can be stated as

$$\frac{d\theta}{d\tau} = -\frac{1}{\Delta} \left[B_y - C_{yy} \right] \left[\frac{1-\beta}{r+\delta-g\phi(y)} \left(z + \frac{\beta\theta\gamma}{1-\beta} \right) + \frac{\gamma\beta}{q(\theta)} \right] < 0$$

and

$$\frac{dy}{d\tau} = -\frac{1}{\Delta} \cdot \frac{g\phi'(y)\gamma}{q(\theta)(r+\delta-g\phi(y))^2} \left\{ -\frac{(1+\tau)\beta}{1-\beta}\gamma\beta - \frac{q'(\theta)}{q(\theta)} (1+\beta\tau) \left(z + \frac{\beta\theta\gamma}{1-\beta} \right) \right\}.$$

In the above relation, the first term of bracket in RHS is negative and the second term is positive. Therefore, the effect on the level of R&D intensity is ambiguous. Again, the effect on the unemployment rate can be obtained by totally differentiating equation (17) and using above results. Thus,

$$\frac{du}{d\tau} = -\frac{[\theta q(\theta)]' u}{\delta + \theta q(\theta)} \cdot \frac{d\theta}{d\tau} > 0.$$

∎

Proof of Proposition 3

By totally differentiating equations (21) and (23) with respect to endogenous variables and the exogenous variables z, I obtain

$$\begin{pmatrix} -\frac{\gamma q'(\theta)}{q(\theta)^2} + \frac{(1+\tau)\beta\gamma}{(r+\delta-g\phi(y))(1+\beta\tau)} & 0 \\ -\frac{g\phi'(y)(1+\tau)\frac{\beta\gamma}{1-\beta}}{(r+\delta-g\phi(y))^2} & B_y(y) - C_{yy}(y) \end{pmatrix} \begin{pmatrix} \frac{d\theta}{dz} \\ \frac{dy}{dz} \end{pmatrix} = \begin{pmatrix} \frac{-(1+\tau)(1-\beta)}{(r+\delta-g\phi(y))(1+\beta\tau)} \\ \frac{g\phi'(y)(1+\tau)}{(r+\delta-g\phi(y))^2} \end{pmatrix},$$

where the determinant for the left hand side coefficient matrix is given by

$$\Delta = \left[-\frac{\gamma q'(\theta)}{q(\theta)^2} + \frac{(1+\tau)\beta\gamma}{(r+\delta-g\phi(y))(1+\beta\tau)} \right] (B_y - C_{yy}) < 0.$$

Then, the comparative static result can be stated as

$$\frac{d\theta}{dz} = -\frac{1}{\Delta} (B_y - C_{yy}) \frac{(1+\tau)(1-\beta)}{(r+\delta-g\phi(y))(1+\beta\tau)} < 0,$$

and

$$\frac{dy}{dz} = -\frac{1}{\Delta} \frac{\gamma q'(\theta)}{q(\theta)^2} \frac{g\phi'(y)(1+\tau)}{(r+\delta-g\phi(y))^2} < 0.$$

The effect on the unemployment rate can be obtained by totally differentiating equation (17) and using above results. Thus, I have

$$\frac{du}{dz} = -\frac{[\theta q(\theta)]' u}{\delta + \theta q(\theta)} \cdot \frac{d\theta}{dz} > 0.$$

∎

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Proof of Proposition 4

By totally differentiating equations (21) and (23) with respect to endogenous variables and the exogenous variables g, I obtain

$$
\begin{pmatrix}
-\frac{\gamma q'(\theta)}{q(\theta)^2} + \frac{(1+\tau)\beta\gamma}{(r+\delta-g\phi(y))(1+\beta\tau)} & 0 \\
-\frac{g\phi'(y)(1+\tau)\frac{\beta\gamma}{1-\beta}}{(r+\delta-g\phi(y))^2} & B_y(y) - C_{yy}(y)
\end{pmatrix}
\begin{pmatrix}
\frac{d\theta}{dg} \\
\frac{dy}{dg}
\end{pmatrix}
=
\begin{pmatrix}
\frac{\phi(y)\{(1-\beta)(1-\delta F)-(1+\tau)[(1-\beta)z+\beta\theta\gamma]\}}{(r+\delta-g\phi(y))^2(1+\beta\tau)} \\
-\frac{\phi'(y)(r+\delta+g\phi(y))\left[1-\delta F-(1+\tau)\left(z+\frac{\beta\theta\gamma}{1-\beta}\right)\right]}{(r+\delta-g\phi(y))^3}
\end{pmatrix},
$$

where the determinant for the left hand side coefficient matrix is given by

$$
\Delta = \left[-\frac{\gamma q'(\theta)}{q(\theta)^2} + \frac{(1+\tau)\beta\gamma}{(r+\delta-g\phi(y))(1+\beta\tau)} \right] (B_y - C_{yy}) < 0.
$$

Then, the comparative static result can be stated as

$$
\frac{d\theta}{dg} = \frac{1}{\Delta}(B_y - C_{yy})\frac{\phi(y)\Omega}{(r+\delta-g\phi(y))^2(1+\beta\tau)} > 0,
$$

and

$$
\begin{aligned}
\frac{dy}{dg} &= \frac{1}{\Delta}\left\{ \frac{g\phi'(y)(1+\tau)\beta\gamma\phi(y)\frac{\Omega}{1-\beta}}{(r+\delta-g\phi(y))^4(1+\beta\tau)} - \left[-\frac{\gamma q'(\theta)}{q(\theta)^2} + \frac{(1+\tau)\beta\gamma}{(r+\delta-g\phi(y))(1+\beta\tau)} \right]\frac{\phi'(y)(r+\delta+g\phi(y))\frac{\Omega}{1-\beta}}{(r+\delta-g\phi(y))^3} \right\} \\
&= \frac{1}{\Delta}\left\{ -\frac{(1+\tau)\beta\gamma\phi'(y)(r+\delta)\Omega}{(r+\delta-g\phi(y))^4(1+\beta\tau)(1-\beta)} + \frac{\gamma q'(\theta)}{q(\theta)^2}\frac{\phi'(y)(r+\delta+g\phi(y))\Omega}{(r+\delta-g\phi(y))^3(1-\beta)} \right\} > 0,
\end{aligned}
$$

where

$$
\Omega \equiv (1-\beta)(1-\delta F) - (1+\tau)\left[(1-\beta)z + \beta\theta\gamma\right] > 0.
$$

The effect on the unemployment rate can be obtained by totally differentiating equation (17) and using above results. Thus, I have

$$
\frac{du}{dg} = -\frac{[\theta q(\theta)]'u}{\delta + \theta q(\theta)} \cdot \frac{d\theta}{dg} < 0.
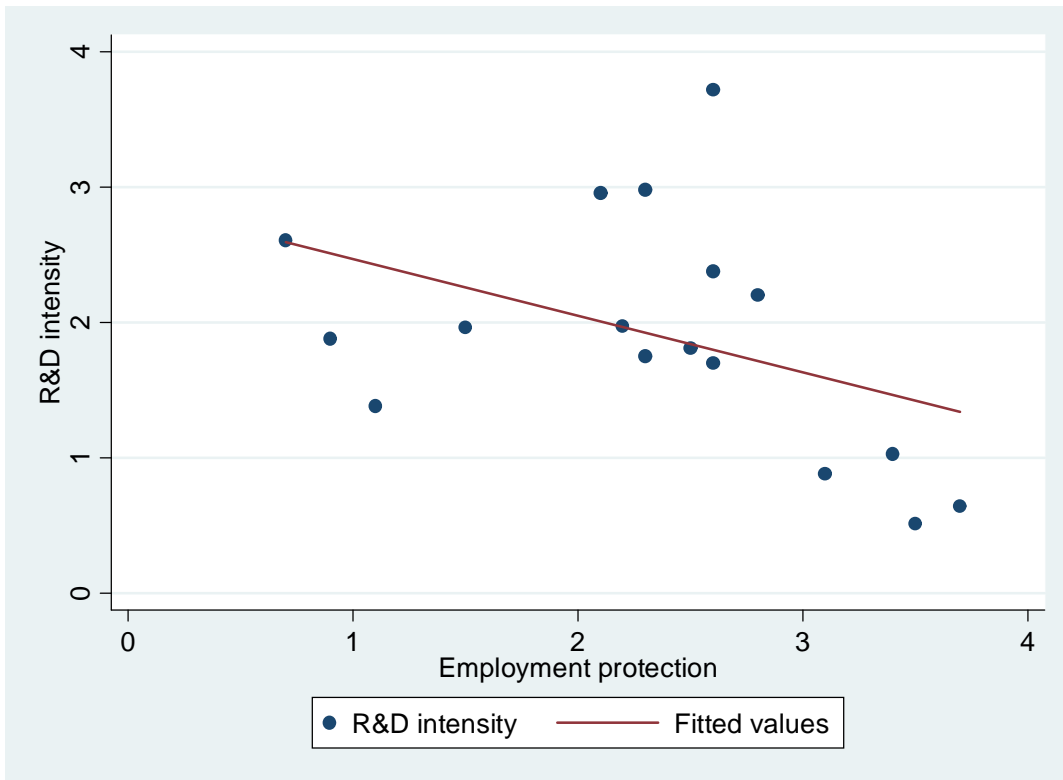$$

∎

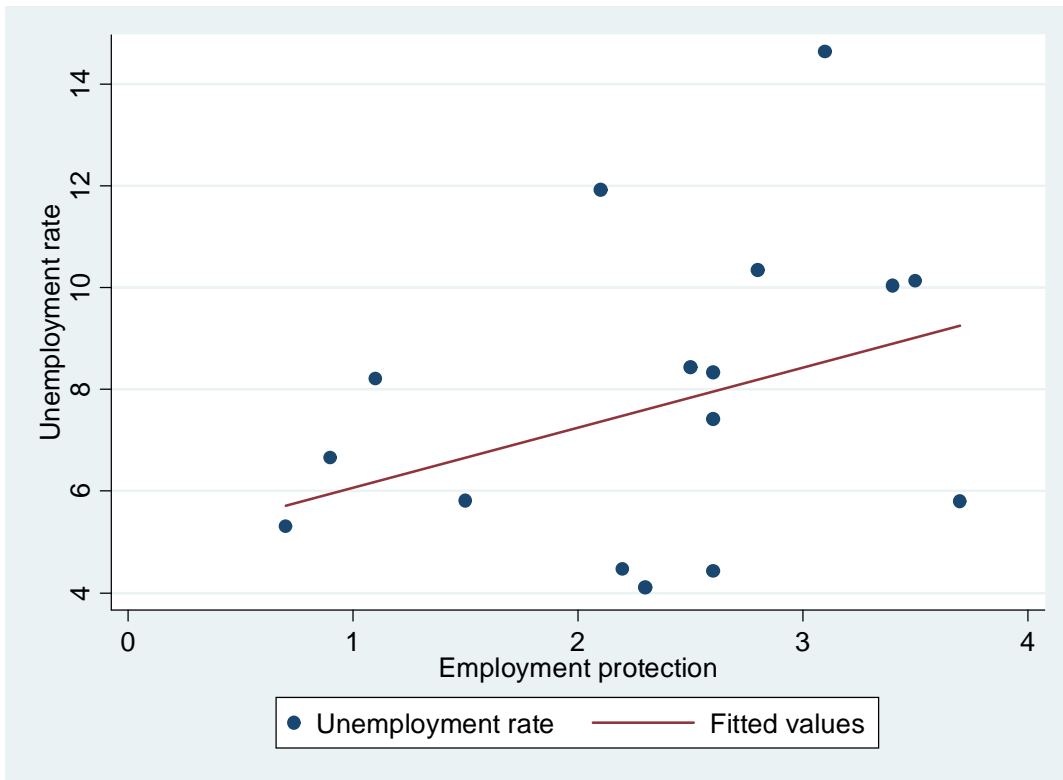Figure 1: R&D intensity vs. EPL (Correlation = -0.361)

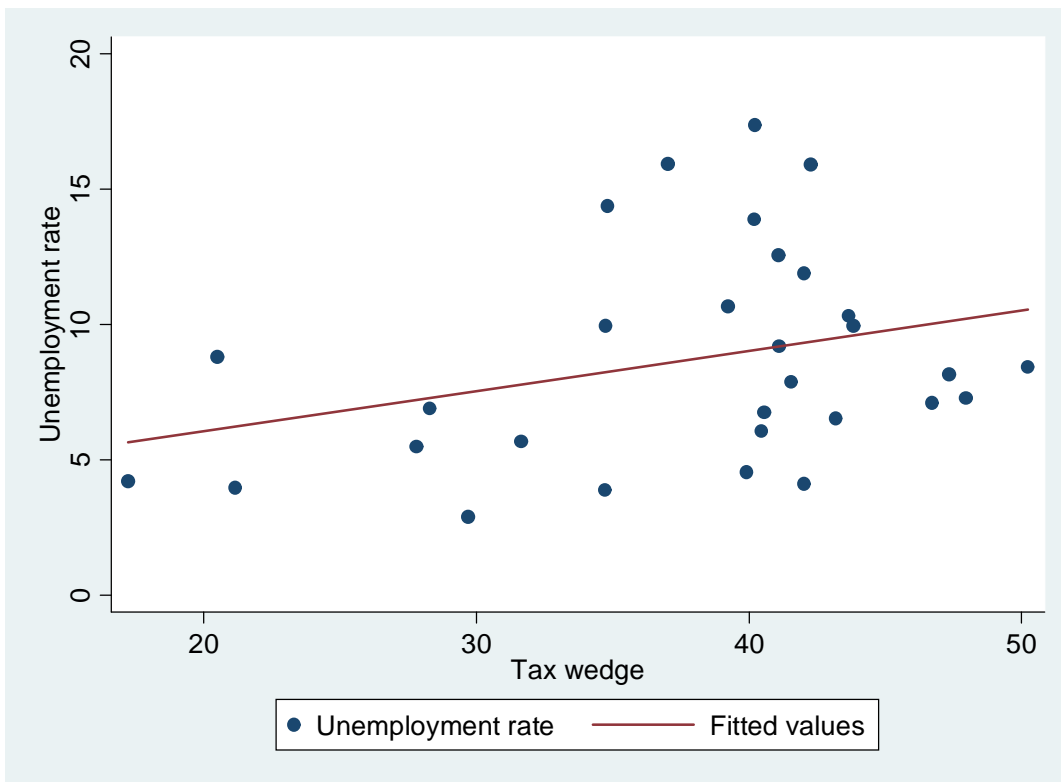Figure 2: The unemployment rate vs. EPL (Correlation = 0.198)

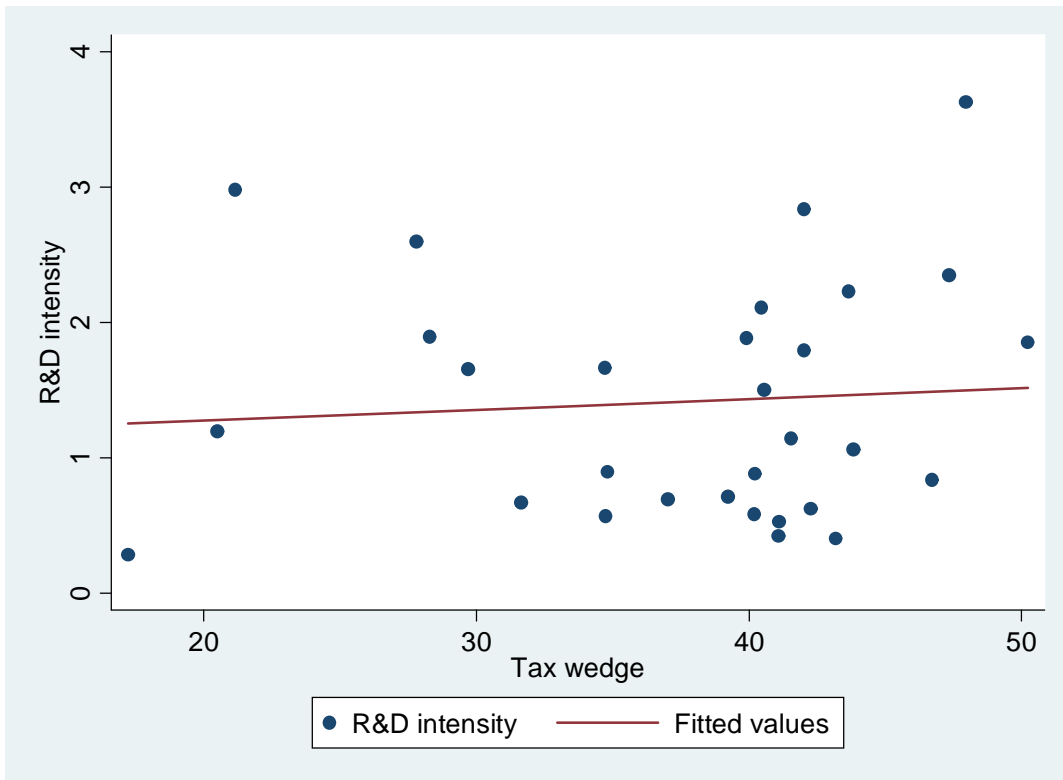Figure 3: R&D intensity vs. tax wedge (Correlation = 0.075)

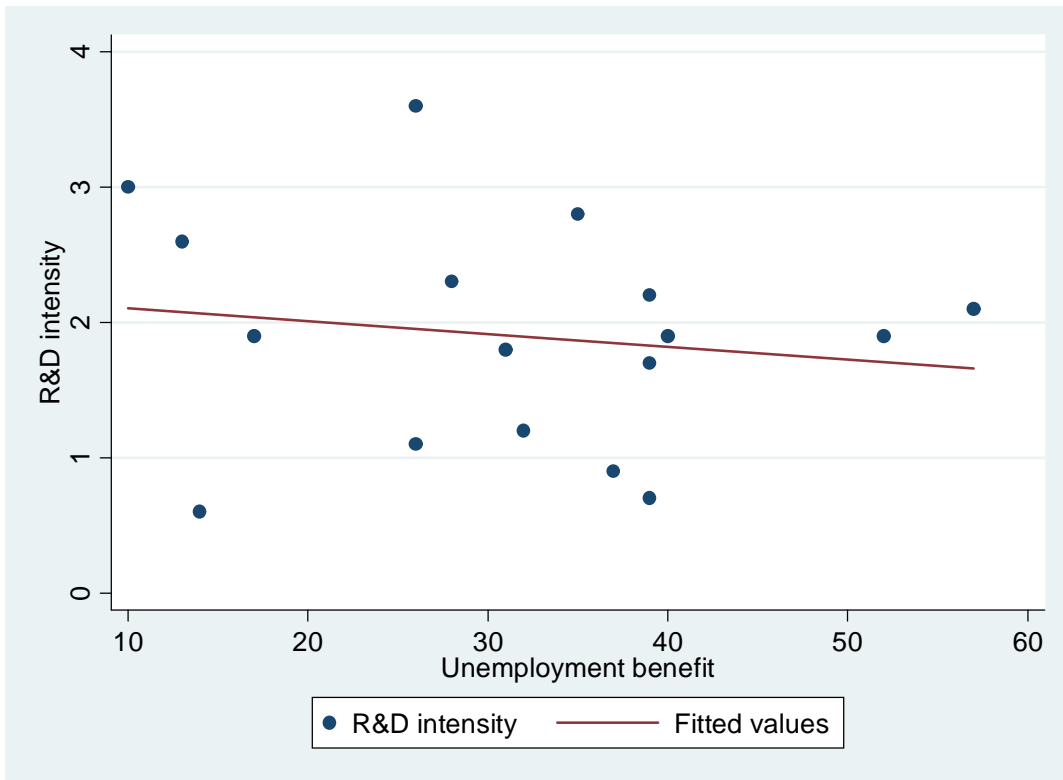Figure 4: Unemployment rate vs. tax wedge (Correlation = 0.310)

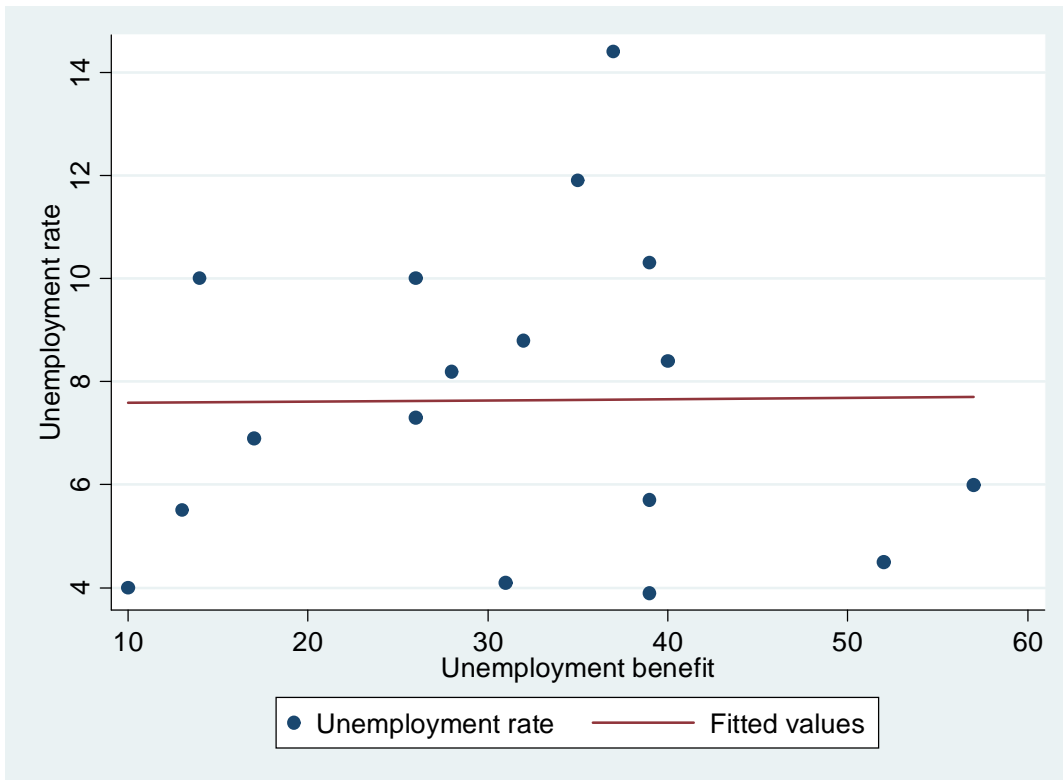Figure 5: R&D intensity vs. unemployment benefit (Correlation = -0.150)

Figure 6: The unemployment rate vs. unemployment benefit (Correlation = 0.010)