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Abstract

Labor supply in Europe was declined by about 30% relative to the US over the past 3 decades. The decline comes from hours per worker and employment. This paper studies a matching model and the effects of labor taxes and unemployment benefits. Labor taxes decrease hours and employment, with overstated adverse effects on hours if extensive margins are not considered. Unemployment benefits decrease employment and increase hours, with understated adverse effects on employment if intensive margins are not considered. In baseline, labor taxes and unemployment benefits together explain about 75% of declining labor supply in Europe relative to the US.

Keywords: search, labor taxes, adverse labor markets, hours worked per worker and employment.

JEL classification: E24, E60, H20.

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1 Introduction

In the early 1970s, labor supply in Europe was roughly the same as that in the US. While labor supply remained to be unchanged in the US, it declined by about 30% in Europe relative to the US over the past 3 decades from the early 1970s to the early 2000s. Data indicates that declines in labor supply come from both hours worked per worker and employment rates. A growing body of literature has sought to understand reasons behind declining labor supply in Europe relative to the US. A number of papers pointed to adverse labor market institutions in Europe.[1] In particular, Europe has witnessed steadily higher labor taxes and more generous unemployment benefits than the US. There are two contrasting viewpoints concerning the effects of the two types of adverse labor market institutions on labor supply in Europe. First, Prescott (2002, 2004) and his followers attributed the large difference in hours worked per worker to higher labor income taxes in Europe.[2] Conversely, Ljungqvist and Sargent (2007, 2008a) and their followers accredited Europe's high unemployment rates to generous unemployment benefits: "*an important aspect of the European landscape that Prescott ignored: Government supplied non-employment benefits in the form of a replacement ratio times foregone labor income*" (Ljungqvist and Sargent, 2007, pp. 181-182).[3]

The former strand of research only differentiates working from leisure hours with neither employment nor unemployment. In contrast, the latter school of research distinguishes only employment from unemployment with neither working nor leisure hours. They do not analyze the effects on labor supply along both intensive and extensive margins. The purpose of this paper is to study a matching model so as to envisage the effects on labor supply along both intensive and extensive margins in one unified general equilibrium framework. We use the model to investigate and compare the relative effects of increases in labor income taxes and more generous unemployment benefits on hours worked per worker and employment rates and thus, labor supply.

Specifically, this paper studies a model that considers labor search within the neoclassical growth framework. There are a representative large household and a representative large firm. The large household decides consumption and savings and pools all resources for its members. These members include the employed who engage in work or leisure and the unemployed who undertake job search or leisure. The large firm creates and maintains vacancies. The firm rents capital and hires

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[1] See Nickell (1997), Blanchard and Wolfers (2000), and Blanchard and Giavazzi (2003) that underlined the role of adverse labor market institutions in Europe. There are also other kinds of explanation, like leisure references in Europe (Blanchard, 2004; Azariadis et al, 2013) and home production in Europe (Ngai and Pissarides, 2008).

[2] Other papers that have stressed the role of labor taxes in probing hours of work differences between Europe and the US include Ohanian *et al.* (2008), Rogerson (2008), Jacobs (2009) and Rogerson and Wallenius (2009).

[3] Other studies that have d underscored the role of unemployment benefits in understanding higher unemployment in Europe include Mortensen (1977), Layard et al. (1991), Mortensen and Pissarides (1999) and Garibaldi and Wasmer (2005).

labor to produce output by using a neoclassical technology that is concave in capital, employment and hours worked per worker. In the model, the unemployed choose search effort so as to equate the marginal cost of search and the marginal gain of employment from a successful match. The firm creates vacancies so as to equate the marginal cost of vacancies and the marginal benefit of employment from a successful match. Job seekers and vacancies are brought together by a matching technology. Upon a successful match, the wage and hours worked per worker are determined by the two sides of a match. We analyze the steady-state search equilibrium in terms of the optimal work-hour condition and the firm's vacancy-employment condition which link hours worked per worker to employment. We use these equilibrium conditions to investigate the relative effects of increases in labor income taxes and more generous unemployment benefits on hours worked per worker and employment/unemployment.

Our main results are summarized as follow. First, an increase in the labor tax decreases both hours worked per worker and employment rates in the long run because it increases the household's net marginal cost of working hours and decreases the firm's net marginal benefit of employment. If only an intensive margin is taken into account as is in Prescott (2002, 2004), the adverse effect on hours worked per worker is overstated as only the household's net marginal cost of working hours increases and the adverse effect on employment is neglected. Next, an increase in unemployment benefits decreases employment and increases hours worked per worker since it decreases the firm's net marginal benefit of employment but it also decreases search effort which in turn lowers the household's marginal cost of working hours. If only an extensive margin is taken into consideration as is in Ljungqvist and Sargent (2007, 2008a), the adverse effect on employment rates is understated as only the firm's net marginal benefit of employment falls and the positive effect on hours worked per worker is overlooked. Finally, by feeding into the model the data of increases in labor income taxes and unemployment benefits in Europe relative to the US, we find that an increase in labor income taxes has a more detrimental effect on hours worked per worker but has a less harmful effect on employment rates than an increase in unemployment benefits. In the baseline parameterization, these increases in labor taxes and unemployment benefits can account for about 75% of declining labor supply in Europe relative to the US over the past 30 years, with the fraction accounted for being increasing in the labor supply elasticity and decreasing in the labor's contribution in matching.

The closest paper to ours is Fang and Rogerson (2009) which have embedded working hours into the standard Pissarides matching model. In their model, the production of a worker-job pair is concave in working hours, with aggregate output simply summing over the number of jobs and thus linear in employment. Our paper may be thought of as an extension of the Fang and Rogerson (2009) model with three different perspectives. First, we consider labor search within the neoclassical growth framework with capital accumulation and leisure of the unemployed. By doing so, the unemployed are not necessarily better-off than the employed, as opposed to the standard Pissarides matching model. Secondly, we employ a representative large firm instead of a worker-job pair as in the standard search model. Thus, as opposed to linear aggregate production in employment in Fang and Rogerson (2009), in our model aggregate production is concave in employment which is consistent with a diminishing marginal product. Thirdly, we include unemployment benefits which are not analyzed by Fang and Rogerson (2009). In particular, we compare the relative effects of two types of adverse labor market institutions and find that labor taxes are more detrimental to hours worked per worker while unemployment benefits are more harmful to unemployment. The former results are consistent with Prescott (2002, 2004) who attributed Europe's lower working hours to higher labor taxes and the latter results lend support to Ljungqvist and Sargent (2007, 2008a) who accredited Europe's higher unemployment to generous unemployment benefits.

The remainder of this paper is organized as follow. In the next section, we document relevant data concerning differences in labor supply between Europe and the US. In Section 3, we set up a labor-search and neoclassical-growth model. In Section 4, we characterize the steady state equilibrium. Section 5 studies the effects of higher labor income taxes and more generous unemployment benefits. Finally, we offer some concluding remarks in Section 6.

2 Relevant Data

Before proceeding to the model, we briefly summarize the evidence concerning differences in labor supply (hours worked per person), employment rates and hours worked per worker in Europe relative to the US. Table 1 presents the data for eleven European countries (EU-11), along with Belgium, France, Germany, with the US data normalized at 100 in 1970-73 and 2000-03.[4] According to Table 1, in the early 1970s, hours worked per person in Germany were 30% and those in France were 9% higher than those in the US. Although hours worked per person in Belgium were lower than those in the US in the early 1970s, hours worked per person in the EU-11 on average were 9% higher than those in the US. In the early 2000s, however, hours worked per person in Belgium, France and Germany were 20%-30% and in the EU-11 were 19% lower than those in the US. These numbers indicate that, relative to the US, hours worked per person were dropped by 55% in Germany, 35% in France, 20% in Belgium and 28% on average in the EU-11 over the period from the early 1970s to the early 2000s.

[Insert Table 1 here]

The fall in hours worked per person comes from decreasing employment rates and hours worked per worker. First, Germany, France and the EU-11 had higher employment rates than the US

[4] To calculate the statistics, we employ the same method as those used in Prescott (2004) and Rogerson (2006).

in the early 1970s, while Belgium had a slightly smaller employment rate than the US in the early 1970s. In the early 2000s, all these European countries had lower employment rates than the US. Over the past 30 years from the early 1970s to the early 2000s, relative to the US, the employment rate was dropped by 12% in Belgium, 14% in France, 18% in Germany and 13% in the EU-11. Next, for hours worked per worker, in the early 1970s, Germany, France and the EU-11 had higher hours worked per worker than the US, while Belgium had about the same hours worked per worker as the US. In the early 2000s, these European countries all had lower hours worked per worker. Over the period from the early 1970s to the early 2000s, relative to the US, hours worked per worker were dropped by 11% in Belgium, 22% in France, 37% in Germany and 16% in the EU.

To summarize the data, over the past 30 years from the early 1970s to the early 2000s, hours worked per person in the EU-11 on average were declined by 28% relative to the US. The decline in labor supply is from both decreasing hours worked per worker and falling employment rates.

3 The Model

The economy is populated by the representative large household and the representative large firm. As in Andolfatto (1996) and Fang and Rogerson (2009), we adopt the assumption of the large household setup. Family members in a larger household pool all resources regardless of their labor market status which assures perfect consumption insurance. The large household comprises a continuum of members (of measure one), who are either employed or unemployed. Like Fang and Rogerson (2009), the employed engage in work or leisure and obtain a wage when working. Yet, unlike Fang and Rogerson (2009), the unemployed take on job search or leisure and the cost of job search is foregone leisure. Also, unlike these authors, there is a large firm. The large firm creates and maintains multiple vacancies and rents capital and hires labor to produce goods using a technology that is concave in employment. The job finding and recruitment rates are endogenous, depending on the masses of both matching parties. Unfilled vacancies and job seekers are met bilaterally through the matching technology. Filled vacancies and employed workers are separated at an exogenous rate. Finally, there is a fiscal authority that levies taxes and offers unemployment benefits.

3.1 Households

The representative household has a unified preference and pools all resources for its members. In a period t, a fraction e_t of the members is employed and the remaining fraction $(1-e_t)$ is unemployed. Given a fixed time endowment normalized at unity, each employed member allocates a fraction l_t of the total time to work and the remaining fraction $(1-l_t)$ to leisure. Unemployed members devote a fraction s_t of their time to job search and the remaining fraction $(1-s_t)$ to leisure. From the household's perspective, the employment changes according to

$$e_{t+1} - e_t = \mu_t\left(s_t(1-e_t)\right) - \psi e_t, \tag{1}$$

where $s_t(1\text{-}e_t)$ is an aggregate search made by the unemployed, μ_t is the effective job finding rate and ψ is the (exogenous) job separation rate. Thus, the change in employment ($e_{t+1}-e_t$) is equal to the inflow of unemployed workers into the employment pool ($\mu_t s_t(1-e_t)$) net of the outflow as a result of separation (ψe_t).

Denote c_t as consumption and k_t as capital with δ the depreciation rate. Further, denote by w_t and r_t the wage rate and the interest rate, respectively. Let the profit be π_t, unemployment benefits be b, the labor income tax rate be τ and the lump-sum tax per household be T_t. The household's budget constraint is

$$c_t + \left[k_{t+1} - (1-\delta)k_t\right] + T_t = r_t k_t + (1-\tau)w_t e_t l_t + b(1-e_t) + \pi_t. \tag{2}$$

The large household has four sources of income: capital rental, after-tax wage earned by employed members, the compensation received by unemployed members, and profits remitted from firms. It allocates income to consumption, investment and lump-sum taxes. The household obtains utility from consumption and leisure. Following Andolfatto (1996), the utility of an employed member is $u(c_t) + \chi_1 V(1-l_t)$ and the utility of a unemployed member is $u(c_t) + \chi_2 V(1-s_t)$, where χ_1 and χ_2 are the degree of leisure utilities for an employed and a unemployed member, respectively. We assume that u and V exhibit the standard concavity property of positive and decreasing marginal utilities.[5] If $\chi_2 V(1-s_t) \le \chi_1 V(1-l_t)$, an unemployed member is not better-off than an employed member, as opposed to the standard Pissarides matching model adopted in Fang and Rogerson (2009). The utility of the large household is the sum across all household members and thus $u(c_t) + e_t\chi_1 V(1-l_t) + (1-e_t)\chi_2 V(1-s_t)$.

The household's optimal control problem is written as the following Bellman equation,

$$U(k_t, e_t) = \max_{k_{t+1}, s_t}\left[u(c_t) + e_t\chi_1 V(1-l_t) + (1-e_t)\chi_2 V(1-s_t) + \frac{1}{1+\rho}U(k_{t+1}, e_{t+1})\right], \tag{3}$$

subject to the constraints (1) and (2), where $\rho>0$ is the time preference rate.

The first-order conditions with respect to k_{t+1} and s_t and the Benveniste-Scheinkman conditions for k_t and e_t are, respectively,

$$u'(c_t) = \frac{1}{1+\rho}U_k\left(k_{t+1}, e_{t+1}\right), \tag{4a}$$

$$\chi_2 V'(1-s_t) = \frac{\mu_t}{1+\rho}U_e\left(k_{t+1}, e_{t+1}\right). \tag{4b}$$

[5] For simplicity, we use the same form of the leisure utility for employed and unemployed members in the household. Results are the same if different forms are used.

$$U_k(k_t, e_t) = u'(c_t)(1-\delta + r_t), \tag{4c}$$

$$U_e(k_t, e_t) = u'(c_t)\left[(1-\tau)w_t l_t - b\right] + \chi_1 V(1-l_t) - \chi_2 V(1-s_t) + \frac{1}{1+\rho} U_e(k_{t+1}, e_{t+1})(1-\psi - s_t\mu_t). \tag{4d}$$

While (4a) is standard, (4b) equates the marginal cost of search effort in terms of foregone leisure to the expected marginal gain of employment from a successful match in the next period. The last two conditions are the representative household's marginal gain of capital and employment, respectively, in the beginning of the period. Forwarding (4c) by one period and substituting it into (4a) gives the following standard Euler equation

$$u'(c_t) = \frac{1}{1+\rho} u'(c_{t+1})(1-\delta + r_{t+1}). \tag{5}$$

3.2 Firms

The representative large firm has filled jobs and unfilled jobs. For filled jobs, the large firm decides how much to produce and there are profits. The large firm also decides the number of new vacancies (unfilled jobs) and searches for unemployed workers if unfilled jobs are created.

For filled jobs, the representative large firm rents capital and hires labor in order to produce a single final good y_t. The production technology is neoclassical, given by the following function.

$$y_t = A k_t^{\alpha} (e_t l_t)^{1-\alpha}, \tag{6}$$

where $A>0$ is a productivity parameter and $\alpha \in (0, 1)$ is the share of capital. The production function is concave in employment, as opposed to that in the standard Pissarides matching model adopted by Fang and Rogerson (2009) wherein aggregate production is linear in employment.

From the firm's perspective, employment is increased by the inflow of employees and decreased by the outflow due to separation.

$$e_{t+1} - e_t = \eta_t v_t - \psi e_t, \tag{7}$$

where η_t is the (endogenous) recruitment rate and v_t is (endogenously) created vacancies.

The large firm also creates new vacancies. There are costs of creating and maintaining vacancies. We assume the following quadratic cost function: $\Lambda(v_t) = \lambda_0 v_t + \lambda_1 v_t^2$, where $\lambda_0>0$, $\lambda_1>0$. Hence, firm's flow profits in t equal the output net of the costs of labor, capital, and vacancy creation; i.e.,

$$\pi_t = A k_t^{\alpha} (e_t l_t)^{1-\alpha} - w_t e_t l_t - r_t k_t - \Lambda(v_t). \tag{8a}$$

The representative large firm chooses capital and vacancies in order to maximize the discounted sum of flow profits. The Bellman equation associated with the firm is

$$\Pi(e_t) = \max_{k_t, v_t} \left[\pi_t + \frac{1}{1+r_t} \Pi(e_{t+1}) \right], \tag{8b}$$

subject to constraint (7).

The first-order conditions with respect to k_t and v_t and the Benveniste-Scheinkman condition for e_t are, respectively,

$$\alpha A(\frac{k_t}{e_t l_t})^{\alpha-1} = r_t, \tag{9a}$$

$$\lambda_0 + 2\lambda_1 v_t = \frac{\eta_t}{1+r_t}\Pi_e(e_{t+1}), \tag{9b}$$

$$\Pi_e(e_t) = [(1-\alpha)A(\frac{k_t}{e_t l_t})^{\alpha} - w_t]l_t + \frac{1-\psi}{1+r_t}\Pi_e(e_{t+1}). \tag{9c}$$

Capital is determined by the marginal product of capital equal the rental rate in (9a). (9b) is the vacancy-employment condition which equates a firm's marginal cost of vacancies in this period to the expected marginal benefit of employment/recruitment from a successful match in the next period. Notice that the condition is also like an entry condition in the Pissarides model wherein the benefit of a new entry (vacancy) is equal to the cost of a new entry. A firm's marginal benefit of employment in (9c) is the sum of the marginal product of labor net of the wage rate multiplied by hours worked per worker and the discounted future marginal benefit.

It is straightforward to rewrite (9a) as

$$q_t \equiv \frac{k_t}{e_t l_t} = (\frac{\alpha A}{r_t})^{\frac{1}{1-\alpha}}. \tag{9d}$$

Thus, the market effective capital-labor ratio, denoted by q, is decreasing in the rental rate.

3.3 Labor Matching and Bargaining

The labor market exhibits search frictions with aggregate flow matches depending on the masses of job seekers and vacancies. Following Diamond (1982), we assume pair-wise random matching. The matching technology takes the constant-returns form:[6] $M_t = m\left(s_t(1-e_t)\right)^{\gamma}\left(v_t\right)^{1-\gamma}$, where m>0 measures the degree of matching efficacy and $\gamma\in(0, 1)$ the contribution of job seekers in matching. Aggregate search and recruitment behave like two inputs in the matching function and the output is the aggregate matched pair M_t. The matching function facilitates the endogenous determination of job finding rates and recruitment rates. As in Andolfatto (1996), since s_t is search effort per job seeker, aggregate search effort by job seekers is $s_t(1- e_t)$.

[6] In a survey of micro foundations underlying the matching function and its empirical success, Petrongolo and Pissarides (2001) referred to the matching function as a useful modeling device for building labor market frictions into equilibrium macroeconomic models of wages, employment, and unemployment that occupies the same place in the macroeconomist's tool kit as other aggregate functions such as the production function. See also Lubik (2012).

A job seeker's surplus acquired from a successful match is evaluated by its augmenting value from employment U_e in (4d), whereas a vacant job's surplus of a successful match is gauged by its incremental value from recruit Π_e in (9c). In a frictionless Walrasian world, taking the wage as given, the household maximizes U_e and the firm maximizes Π_e in order to decide their supply of and demand for labor. There is implicitly an auctioneer in the labor market which sets an equilibrium wage so as to equate labor supply to labor demand. In a frictional labor market, however, there is no auctioneer and a job seeker would meet at most one unfilled job one time and similarly, an unfilled job would meet at most one job seeker one time. This creates a bilateral monopoly.

Following conventional wisdom, the wage rate is determined by a matched worker-job pair through a cooperative bargaining game. Like Fang and Rogerson (2009), an employed worker does not devote all the time endowment to work and thus the pair of a successful match also bargains over working hours. In the game, the following joint surplus is maximized: $[U_e(k_t, e_t)]^{\beta}[\Pi_e(e_t)]^{1-\beta}$, where $\beta \in (0,\ 1)$ measures a labor's bargaining power. In solving the bargaining problem, the worker-job pair treats matching rates (μ_t and η_t), the beginning-of-period level of employment (e_t), and the market interest rate (r_t) as given. The worker also takes as given the wage and working hours of all others. The first-order conditions are

$$\frac{\beta}{U_e(k_t, e_t)} \frac{dU_e(k_t, e_t)}{dw_t} = -\frac{1-\beta}{\Pi_e(e_t)} \frac{d\Pi_e(e_t)}{dw_t}, \tag{10a}$$

$$\frac{\beta}{U_e(k_t, e_t)} \frac{dU_e(k_t, e_t)}{dl_t} = -\frac{1-\beta}{\Pi_e(e_t)} \frac{d\Pi_e(e_t)}{dl_t}. \tag{10b}$$

3.4 The Government

The government's behavior is passive; it levies labor income and lump-sum taxes and offers unemployment benefits. The government budget constraint is

$$T_t + \tau w_t e_t l_t = b(1 - e_t). \tag{11}$$

In order to isolate the effects of policy changes carried out later, we include lump-sum taxes T_t. When the labor tax rate τ is changed, with unemployment benefits b being held unchanged, lump-sum taxes/subsidies T will change accordingly in order to balance the budget. Similarly, when unemployment benefits are increased, with the labor tax rate being held constant, lump-sum taxes will adjust to balance the budget.

4 Equilibrium

A search equilibrium is a tuple of individual quantity variables, $\{e_t, l_t, s_t, v_t, c_t, k_t, y_t\}$, a pair of aggregate quantities, $\{M_t, T_t\}$, a pair of matching rates, $\{\mu_t, \eta_t\}$, and a pair of prices, $\{w_t, r_t\}$, such that:

(i) all households and firms optimize; (ii) all employment evolutions hold, (iii) labor-market matching and wage and hours bargaining conditions are met; (iv) the government budget is balanced; and (v) the goods market clears.

4.1 Steady State

A steady state is search equilibrium when all variables do not change over time. First, in a steady state the Euler equation in (5) gives the following interest rate: $r = \rho + \delta$. Substituting the rate into (9d) yields the effective capital-labor ratio: $q = (\frac{\alpha A}{\rho+\delta})^{\frac{1}{1-\alpha}}$, which is constant in a steady state.

Next, if we use the household's budget (2) and the firm's flow profit (8a), along with the government's budget (11), the goods market clearing condition in a steady state is

$$y = c + \delta k + \Lambda(v). \tag{12}$$

Moreover, in a steady state the labor market must satisfy the following matching relationships (Beveridge curve) given by

$$m\big(s(1-e)\big)^{\gamma}(v)^{1-\gamma} = \mu\big(s(1-e)\big) = \eta v = \psi e. \tag{13}$$

Thus, the number of successful job matches equals the employment inflow from the household side, $\mu(s(1-e))$, the employment inflow from the firm side, ηv, and is equal to the employment outflow in a steady state. These relationships enable us to solve matching rates and equilibrium vacancies as functions of e and s.

$$\mu = \frac{\psi e}{s(1-e)} \equiv \mu(\underset{+}{e},\underset{-}{s}), \tag{14a}$$

$$v = \left[\frac{\psi e}{m\big(s(1-e)\big)^{\gamma}}\right]^{\frac{1}{1-\gamma}} \equiv v(\underset{+}{e},\underset{-}{s}), \tag{14b}$$

$$\eta = \frac{\psi e}{v(e,s)} = \left[m\left(\frac{s(1-e)}{\psi e}\right)^{\gamma}\right]^{\frac{1}{1-\gamma}} \equiv \eta(\underset{-}{e},\underset{+}{s}). \tag{14c}$$

Thus, the effective job finding rate and the equilibrium vacancy are positively related to employment and negatively related to search effort, while the recruitment rate is negatively related to employment and positively related to search effort.

In a steady state, the household's surplus accrued from a successful match in (4d) is

$$U_e = \frac{1+\rho}{\rho+\psi+s\mu}\left\{u'(c)\big((1-\tau)wl-b\big)+\left[\chi_1 V(1-l)-\chi_2 V(1-s)\right]\right\}. \tag{15}$$

Moreover, using $r = \rho + \delta$, the firm's surplus accrued from a successful match in (9c) is

$$\Pi_e = \frac{1+\rho+\delta}{\rho+\delta+\psi}\left(MPL - w\right)l, \tag{16}$$

where $MPL \equiv (1-\alpha)Aq^{\alpha}$ denotes the marginal product of labor which is constant.

Following Andolfatto (1996), the parametric forms are used for utility.

$$u(c) = \ln c \quad \text{and} \quad V(1-x) = \frac{(1-x)^{1-\sigma}}{1-\sigma}, \text{ where } x = l,\ s,$$

in which $\sigma>0$ is the reciprocal of the elasticity of leisure.[7] These forms are consistent with the balanced growth path.

We are ready to derive equilibrium conditions in a steady state. First, by using the effective capital-labor ratio and (14b), (12) gives the following consumption

$$c = (Aq^{\alpha} - \delta q)el - \Lambda(v(e,s)) \equiv c(\underset{+}{e}, \underset{+}{l}, \underset{+}{s}), \tag{17}$$

which is increasing in employment, hours worked per worker and search effort. Intuitively, an increase in employment raises output net of depreciation but also increases the vacancy creation cost. In general, the increase in output net of depreciation is larger than the increase in the vacancy creation cost, and thus consumption increases.[8] Hours worked per worker increase output net of depreciation and thus, consumption. Moreover, larger search effort reduces the vacancy creation cost which increases disposable income and thus, consumption.

Next, by using (15) and (16), we rewrite (10a) as

$$\beta(1-\tau)l\left[(1-\tau)wl - b + \left(\tfrac{\chi_1(1-l)^{1-\sigma} - \chi_2(1-s)^{1-\sigma}}{1-\sigma}\right)c\right]^{-1} = 1 - \beta\left[MPL - w\right]^{-1},$$

where the left-hand side of the equation is the household's marginal benefit of wage and is decreasing in the wage, while the right-hand side of the equation is the firm's marginal cost of wage and is increasing in the wage. With the use of (17), the condition above gives the following bargained wage

$$w = \beta MPL + (1-\beta)\left[\frac{b + MRS^{e}(e,l,s)}{(1-\tau)l}\right] \equiv W(\underset{+}{e}, \underset{?}{l}, \underset{+}{s}; \underset{+}{\tau}, \underset{+}{b}), \tag{18}$$

where $MRS^{e}(\underset{+}{e}, \underset{+}{l}, \underset{+}{s}) \equiv \left[\tfrac{\chi_2(1-s)^{1-\sigma} - \chi_1(1-l)^{1-\sigma}}{1-\sigma}\right] c(\underset{+}{e}, \underset{+}{l}, \underset{+}{s})$ is the difference of the marginal rate of substitution (MRS) for leisure and consumption between unemployment and employment; thus, the loss in leisure utilities in the consumption term from unemployment to employment. The bargained wage is a weighted average of the marginal product of labor and the reservation wage; the reservation wage is the sum of unemployment benefits and losses in leisure utilities from unemployment to employment.

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[7] For simplicity, we use the same elasticity of leisure for the employed and the unemployed. Allowing elasticity of leisure of the unemployed to be different from that of the employed will not change the results.

[8] Fang and Rogerson (2009) made a similar assumption of $c_e>0$.

As the marginal product of labor is constant in a steady state, policy changes affect the steady-state bargained wage via their effects on the reservation wage.

We characterize the bargained wage in (18). First, with all other things being equal, a higher employment e raises the bargained wage since it increases consumption which increases the reservation wage.[9] Secondly, a larger working hour l has an ambiguous effect on the bargained wage. In the special case of b=0, a larger working hour raises the bargained wage since it increases losses in leisure utilities in the consumption term per hour (MRS^e/l). However, when unemployment benefits are large, the offsetting effect from unemployment benefits is substantial and a larger working hour may reduce the wage. Thirdly, higher search effort s increases consumption which decreases the marginal utility of consumption and thus increases losses in leisure utilities in the consumption term from unemployment to employment and thus the wage, but it may also decrease the marginal utility of leisure and hence losses in leisure utilities from unemployment to employment and thus the wage. As the positive effect dominates, higher search effort increases the bargained wage. Finally, higher labor income taxes (τ) and higher unemployment benefits (b) both increase the reservation wage. Thus, the bargained wage is increasing in labor income taxes and unemployment benefits.

Moreover, by using the equilibrium interest rate, (14a)-(14c) and (15)-(18), we rewrite an unemployed member's optimal search effort condition in (4b) as

$$\underbrace{\frac{\mu(e,s)}{\rho+\psi+s\mu(e,s)}\beta\left[(1-\tau)MPL\cdot l-b-MRS^e(e,l,s)\right]}_{\substack{\| \\ MB^s(\underset{-}{e},\underset{-}{l},\underset{-}{s};\underset{-}{\tau},\underset{-}{b})}} = \underbrace{\chi_2\frac{c(e,l,s)}{(1-s)^{\sigma}}}_{\substack{\| \\ MRS^s(\underset{+}{e},\underset{+}{l},\underset{+}{s})}}, \tag{19}$$

which equates an unemployed member's discounted (after-tax) marginal benefit from a successful match, denoted as MB^s, to the marginal cost of search which is an unemployed member's MRS between leisure and consumption, denoted as MRS^s. It is clear that the condition gives unique search effort as higher search effort decreases the marginal benefit of search effort and increases the marginal cost. Moreover, higher employment increases the marginal cost of search effort but has an ambiguous effects on the marginal benefit and thus has a negative or an ambiguous effect on search effort. Further, a higher working hour increases the marginal cost of search effort and decreases the marginal benefit and thus decreases search effort. Finally, labor taxes and unemployment benefits both decrease the marginal benefit of search effort and thus decrease search effort. Therefore, the condition gives the following optimal search effort.

$$s = S(\underset{-or\,?}{e},\underset{-}{l};\underset{-}{\tau},\underset{-}{b}). \tag{20}$$

4.2 Simplified Steady-state Equilibrium Conditions

[9] To save the space, all algebra below is delegated in the Appendix.

Now, we simplify equilibrium conditions in a steady state in terms of employment and hours worked per worker. First, we rewrite the optimal working hour condition in (10b) as

$$\beta\left[(1-\tau)w-\chi_1(1-l)^{-\sigma}c\right]\left[(1-\tau)wl-b+\left(\frac{\chi_1(1-l)^{1-\sigma}-\chi_2(1-s)^{1-\sigma}}{1-\sigma}\right)c\right]^{-1}=-\frac{1-\beta}{l}$$

Substituting (18) into the condition above and rearranging terms yields

$$\frac{MRS^l(\overset{+}{e},\overset{+}{l},\overset{+}{s})}{(1-\tau)}=MPL, \tag{21}$$

where $MRS^l(e,l,s)\equiv\chi_1(1-l)^{-\sigma}c(e,l,s)$ is an employed member's MRS between leisure hours and consumption. The left-hand side is the marginal cost of working hours. The right-hand side is the marginal product of labor which is the marginal benefit of working hours. As the marginal cost of working hours is increasing in working hours and the marginal product of labor is constant, this condition determines a unique hour worked per worker. To characterize hours worked per worker, it is clear to see that employment and search effort both increase the marginal cost of working hours due to higher consumption. Moreover, a higher labor tax also increases the marginal cost of working hours due to a lower post-tax wage rate. Thus, employment, search effort and labor taxes all decrease hours worked per worker. With the search effort in (20), the condition above gives the following optimal working hour.

$$l=L(\underset{-}{e},\underset{-}{S}(\underset{-or?}{e},\underset{-}{l};\underset{-}{\tau},\underset{-}{b});\underset{-}{\tau}).$$

In the relationship above, although l and e also exert indirect effects via search effort S in (20) that may offset the direct effect on the net marginal cost of working hours, we find that these indirect effects are dominated by the direct effects. Thus, the working hour function above is written as

$$l=\tilde{L}(\underset{-}{e};\underset{-}{\tau},\underset{+}{b}), \tag{22}$$

which is negatively sloping in the (e, l) plane. See Figure 1 wherein the hour locus is referred to as Locus H (Hours).

[Insert Figure 1 here]

Next, by using the equilibrium interest rate, (14a)-(14c), and (15)-(18), we can rewrite the firm's vacancy-employment condition in (9b) as

$$\underbrace{\frac{\eta(e,s)}{\rho+\delta+\psi}(1-\beta)\left(MPL\cdot l-\frac{b+MRS^e(e,l,s)}{1-\tau}\right)}_{\substack{\parallel\\ MB^v(\underset{-}{e},\underset{-}{l},\underset{?}{s})}}=\underbrace{\lambda_0+2\lambda_1 v(e,s)}_{\substack{\parallel\\ MC^v(\underset{+}{e},\underset{-}{s})}}. \tag{23}$$

The condition equates a firm's discounted marginal benefit of employment from a successful match, denoted as MB^v, to the marginal cost of vacancy, denoted as MC^v. It is clear that the firm's marginal benefit of employment is decreasing in employment and the marginal cost is increasing in employment. Thus, this condition determines unique employment. To characterize the employment function, it is clear that a higher working hour decreases the firm's marginal benefit of employment and thus decreases employment. Moreover, higher search effort decreases the marginal cost but has an ambiguous effect on the marginal benefit. Thus, higher search effort may increase or have an ambiguous effect on employment. Further, higher taxes, more generous unemployment benefits and larger vacancy creation costs all decrease the firm's net marginal benefit of employment and thus decrease employment. Therefore, the condition above gives the following employment function.

$$e = E(\underset{-}{l}, \underset{+or?}{S}(\underset{-or?}{e}, \underset{-}{l}; \underset{-}{\tau}, \underset{-}{b}); \underset{-}{\tau}, \underset{-}{b}, \underset{-}{\lambda_0}).$$

In the employment function above, l and e exert indirect ambiguous effects via search effort S on the firm's net marginal benefit of employment. Yet, it is easy to show the direct effects of l and e always dominate these indirect effects. Accordingly, we obtain the following employment function

$$e = \tilde{E}(\underset{-}{l}; \underset{-}{\tau}, \underset{-}{b}, \underset{-}{\lambda_0}), \tag{24}$$

which is negatively sloping in the (e, l) plane. See Figure 1 wherein the employment locus is referred to as Locus E (Employment).

Thus, the steady state is determined by the interaction of Loci H and E. By exploring the effects of a higher cost of vacancy creation, it is clear that Locus H needs to be always flatter than Locus E in order to satisfy the Correspondence Principle (Samuelson, 1948).[10] As Locus H is flatter than Locus E, this implies that the two curves have at most one intersection. See Q_0 in Figure 1. The two loci determine steady-state employment (e_0) and hours worked per worker (l_0), and thus labor supply ($e_0 l_0$).

5 Policy Analysis

Although the simplicity of our model confines the breadth of the policies that can be envisaged, two policies of pervasive interest can be studied within our model: a tax on the employed which is proportional to labor income and is used to make a lump-sum transfer; and a benefit to the unemployed which is proportional to labor income as financed by a lump-sum tax. While the former policy has been stressed by Prescott (2002, 2004) in explaining lower hours worked per worker in Europe than the US, the latter policy has been emphasized by Ljungqvist and Sargent (2007, 2008a)

[10] According to the Correspondence Principle, a higher cost of vacancy creation λ_0 shifts the employment locus down without shifting the hour locus; should the employment locus be less steep than the hour locus, employment would be increased, not decreased, which is inconsistent.

in accounting for higher unemployment rates in Europe than the US. We start with the analysis of increases in labor income taxes, followed by increases in unemployment benefits. The comparative-static analysis is delegated in the Appendix. Here, we offer graphical illustrations.

5.1 Effects of Labor Taxes

First, we analyze the effects of increases in the labor tax rate (higher τ). Suppose that the initial steady state is at Q_0 in Figure 2. Thus, the initial hour worked per worker is l_0, initial employment is e_0, initial unemployment is (1-e_0) and initial labor supply is (e_0l_0).

[Insert Figure 2 here]

When the labor tax rate (τ) is increased, the household's net marginal cost of working hours increases and thus working hours are decreased; the firm's net marginal benefit of employment is decreased and thus employment is decreased. Then, Loci H is shifted to Locus H_1 and Locus E is shifted to Locus E_1 in Figure 2. Moreover, with given employment levels, Locus E_1 is shifted downward more than that of Locus H_1. The reasons are that a higher labor tax rate yields direct effects to decrease working hours in both Loci H and E. However, in Locus H, a higher labor tax rate also generates an offsetting effect via decreasing search effort which reduces the net marginal cost of working hours and thus increases working hours. Hence, Locus H_1 is shifted downward less than Locus E_1. The new steady state is at Q_1 in Figure 2. As a result, hours worked per worker l_1 and employment e_1 are lower than their initial levels l_0 and e_0, respectively. Accordingly, hours worked per person (e_1l_1) are lower than the initial level (e_0l_0).

Note that in Prescott (2002, 2004), there is only an intensive margin (i.e., work hours and leisure hours) and not an extensive margin (i.e., employment and unemployment). The equilibrium condition in Prescott (2002, 2004) may be thought of as involving only Locus H without Locus E, with the initial steady state Q_0 being determined by Locus H and the initial employment level e_0 in Figure 2. In this case, a higher labor tax rate (τ) shifts Locus H downward to Locus H_1. The new steady state is at Q_3. Thus, compared to the case with both intensive and extensive margins, hours worked per worker here are reduced by more to the level $l_2<l_1$. Therefore, without an extensive margin in Prescott (2002, 2004), as the adverse effect on employment is not taken into account, the adverse effects on hours worked per worker are overstated. To summarize the results,

Proposition 1 *An increase in labor taxes decreases both hours worked per worker and employment. With fixed employment, the adverse effect on hours worked per person is overstated.*

5.2 Effects of Unemployment Benefits

Next, we analyze the effects of increases in unemployment benefits (higher b). Suppose that the initial steady state is at Q_0 in Figure 3.

[Insert Figures 3 here]

When unemployment benefits are increased, the firm's net marginal benefit of employment is decreased. With given work hours, employment decreases and thus the Locus E is shifted leftward to Locus E_2 in Figure 3. Moreover, more generous unemployment benefits also decrease search effort which reduces the household's marginal cost of working hours. With given employment, hours worked per worker increase and thus Locus H is shifted upward to Locus H_2. The new steady state is at Q_2 in Figure 3. As a result, employment is lower but hours worked per worker are higher.

In Ljungqvist and Sargent (2007, 2008a), there is only an extensive margin and not an intensive margin (i.e., fixed working hours). The equilibrium condition in Ljungqvist and Sargent (2007, 2008a) may be interpreted as involving only Locus E without Locus H, with the initial steady state Q_0 being determined by Locus E and the initial work-hour level l_0 in Figure 3. In this case, more generous unemployment benefits only shift Loci E downward to Loci E_2, and thus the new steady state is at Q_3. Compared to the case with both intensive and extensive margins, employment here is reduced by less to the level $e_1 > e_2$. Therefore, without an intensive margin in Ljungqvist and Sargent (2007, 2008a), as the positive effect on hours worked per worker is not taken into account, the adverse effect on employment is understated. To summarize the results,

Proposition 2 *An increase in unemployment benefits decreases employment and increases hours worked per worker. With fixed hours worked per worker, the adverse effect on employment is understated.*

5.3 Quantitative Analysis

We now quantify the effects of increases in labor taxes and unemployment benefits on labor supply. First, we calibrate our model in a steady state to the US economy. Then, we quantify the effects of changes in tax rate differences and unemployment compensations. We are particularly interested in how tax rates and unemployment compensation differences between Europe and the US lead to large differences in hours worked per worker and employment and thus labor supply. To this end, we use the data of increases in labor income taxes and unemployment benefits in Europe relative to the US in the early 2000s and quantify the effects.[11] With other things being equal and thus holding other parameters constant, we can compare the effects of tax rate differences with the effects of unemployment compensation differences on hours of work and employment, and thus the labor supply. Notice that when there are increases tax rates and unemployment compensations, in the steady state the wage also changes because the wage is affected by hours of work and employment.

[11] In a life-cycle model, Rogerson and Wallenius (2009) also calibrated their model to the US economy and analyzed the effects of tax rate differences between Europe and the US on differences in hours of work per worker.

We calibrate parameters and variables at a quarterly frequency. With the annual depreciation rate of capital in the range of 6%-8% and the annual time preference rate of 4%, we follow Ljungqvist and Sargent (2008b) to set the quarterly capital depreciation rate to δ=0.02 and the quarterly time preference rate to ρ=0.01. The data gives the steady-state interest rate at r=0.03. The coefficient of technology is normalized to A=1. The capital share is about one-third and we follow Prescott (2004) to use the value α=0.3224. With the values of A and α, we compute the effective capital-labor ratio as $q = (\frac{\alpha A}{\rho+\delta})^{\frac{1}{1-\alpha}} = 33.2622$, which in turn gives MPL=2.0973 and, via (6), the quarterly capital-output ratio k/y=10.7467 which is consistent with a capital-output ratio of 2.5-3 in annual data.

The fraction of employment in the working-age population is about 75% (cf. Kydland and Prescott 1991) and thus we set e=0.75. The fraction of time allocated to the market (el) is 25% as pointed out by Prescott (2006). This implies l=0.3333. For the average fraction of time spent to search, we follow Andolfatto (1996) to set s=0.5×l=0.1667. According to Shimer (2005), the monthly job finding rate is 0.45. We go along this rate and translate it into a quarterly value of $s\mu$=1-(1-0.45)^3=0.8336, implying μ=5.0016. We employ (13) to compute the quarterly separation rate as a fraction of employment at ψ=($s\mu$(1-e))/e=0.2779. Moreover, we follow Shimer (2005) by normalizing the steady-state ratio of vacancies to searching workers to one (v/(1-e)=1) which implies the vacancy at v=0.25 in a steady state. Then, we utilize (13) to calibrate η=($s\mu$(1-e))/v=0.8336.

By setting the consumption-output ratio at c/y=0.67 and normalizing λ_1=1, we use (17) to calibrate the coefficient of vacancy costs λ_0=0.1061. We compute the wage at w=1.4257 from (18). In accordance with Prescott (2004), unemployment benefits are 0.319 times forgone labor income, and hence we calibrate b=0.319×w×l which gives b=0.1516. Based on the data in McDaniel (2007), Rogerson (2008) used the labor taxes in Belgium, France, Germany, Italy, and the Netherlands to represent the tax in Europe.[12] We follow this method and calculate the population-weighted average effective tax rate on labor income for these five countries. We find that the average effective tax rate in years 1970-73 is 0.3982 which leads us to set the benchmark labor tax rate to τ=0.4, a rate similar to that of the US as noted in Prescott (2004).

Finally, for the utility function adopted here, the labor supply elasticity is LSE=(1-l)/(σl). The LSE estimated in MaCurdy (1981) ranged from 0.1 to 0.5 for men and is likely higher for women, while Andolfatto (1996) set LSE=1. For present purposes, we choose an intermediate value: LSE=0.65, which implies σ=3.0769. Given this value, (21) is solved for χ_1=0.6971 and (19) is solved

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[12] McDaniel (2007) calculated a series of average tax rates on consumption, investment, labor and capital using national account statistics in 15 OECD countries. The data has been used by Rogerson (2008) and Ohanian *et al.* (2008).

for χ_2=1.6813.[13] We obtain the bargaining share β=0.7183 from (23), which is close to the value of 0.72 used by Shimer (2005). Assuming that Hosios' rule holds (Hosios, 1990), a search worker's contribution in matching is pinned down by the labor's share in the wage bargaining, $\gamma=\beta$. Then, from matching relationships we calibrate m=3.0193. The parameter values, observables and calibrated values are listed in Table 2. Under the benchmark parameter values, we obtain a unique steady state.

[Insert Table 2 here]

Now, we quantify the effects of increases in tax rates and unemployment benefits. We start by measuring the increase in labor taxes and unemployment benefits in Europe relative to the US in the early 2000s. For labor taxes, based on McDaniel (2007), we calculate the population-weighted average effective tax rate on labor income in the five European countries under concern in 2000-03 and obtain the tax rate 0.5168. With the data that the effective labor tax rate increased a little bit in the US in the past 30 years,[14] this indicates an increase of labor tax rates by about 30% in Europe relative to the US from that in 1970-73. Next, based on the data in OECD (1999, Table 2.2), the population-weighted average unemployment payment rate is 69.72% in the five European countries under concern and 50% in the US in the late 1990s. These data suggest that unemployment benefits in Europe are roughly 40% higher than the US. Given the data, we quantify the effects of increases in the value of τ by 30% and the value of b by 40% from their baselines. In each exercise, the government budget is balanced by adjusting lump-sum taxes or transfers. Quantitative results are illustrated in Table 3.

[Insert Table 3 here]

First, the quantitative effects of increases in the labor income tax are in the first row of Table 3. The results indicate that when the labor income tax rate is increased by 30%, hours worked per worker are decreased from 0.333 to 0.310 which means a drop by 6.85%. The employment rate is decreased from 0.75 to 0.708 which indicates a decrease by 5.55%; thus, the unemployment rate is increased by 5.55%. As a result, labor supply is decreased by 12.02%. Next, the quantitative effects of increases in unemployment benefits are reported in the second row of Table 3. The results suggest that when unemployment benefits are increased by 40%, the employment rate is decreased from 0.75 to 0.703, which is a decrease by 6.26%; thus, the unemployment rate is increased by 6.26%. Hours worked per worker grow slightly from 0.333 to 0.337, which is an increase by 1.13%. As a result, labor supply is decreased by 5.2%.

Our foregoing results indicate that a 30% increase in labor income taxes in Europe relative to the US has a large adverse effect on hours worked per worker, which is consistent with the claim

[13] These parameter values indicate that the employed are better off than the unemployed.

[14] Based on the data in McDaniel (2007), the effective labor tax rate (on household income and payroll) in the US increased from 0.1775 in 1970-73 to 0.22475 in 2000-03.

made by Prescott (2002, 2004). Yet, there is also a substantial adverse effect on employment rates. Moreover, our results suggest that a 40% increase in unemployment benefits has a large adverse effect on employment which is consistent with the argument made by Ljungqvist and Sargent (2007, 2008a). These quantitative effects imply that a 30% increase in labor income taxes has a more detrimental effect on hours worked per worker but has a less harmful effect on employment than a 40% increase in unemployment benefits.

To see the combined effects of these two adverse labor market institutions, we increase the labor income tax and unemployment benefits at the same time, with the effects shown in the last row of Table 3. The results reveal that the employment rate is decreased from 0.75 to 0.609, which indicates a large drop by 18.73%. Hours worked per worker are decreased from 0.333 to 0.323, which implies a decrease by 3.08%. As a result, these two adverse labor market institutions decrease labor supply by 21.23%. Compared to the data of a decrease by 28.23% in the EU-11 relative to the US over the past 30 years in Table 1, our quantitative results suggest that higher labor income taxes and more generous unemployment benefits in the EU than the US both can account for about 75% of the declining labor supply in the EU relative to the US over the past 30 years from the early 1970s to the early 2000s.

Finally, we investigate the robustness of the foregoing quantitative results by carrying out three types of sensitivity analysis. First, in the baseline we calibrate the quarterly separation rate to target the monthly job-find rate of 0.45 in the data documented by Shimer (2005). This gives a quarterly separation rate of 0.2779 which is larger than the rate of 0.1 documented by Shimer (2005). Alternatively, we may calibrate the quarterly job-find rate to target the quarterly separation rate of ψ=0.1. This gives a quarterly job-find rate of 0.3 which is lower than the quarterly job-find rate of 0.8336 in the data documented by Shimer (2005). In the new calibration, parameter values remain the same as those in Table 2 except for the values of μ, η, χ_2, b, β, γ and m=1.0533. The effects of increases tax rates and unemployment compensations are illustrated in Table 4. It is clear to see that the effects are about the same as those in Table 3.

Next, we vary the *LSE* by increasing its value to 1 and decreasing its value to 0.5.[15] Moreover, we envisage whether or not the results are robust when the Hosios' rule does not hold. In this exercise, we fix the labor's bargaining share at β=0.7183 and vary the labor's contribution in matching γ to take alternative values {0.235, 0.54, 0.72} used by Hall (2005), Hall and Milgrom (2008) and Shimer (2005), respectively. In the sensitivity analysis of varying the *LSE*, we recalibrate the model and find that all parameter values are the same as those in Table 2 except for the values of σ, χ_1, χ_2, m and β. In the sensitivity analysis of deviating from the Hosios' rule, we recalibrate the model and find

[15] The value of LSE cannot be smaller than 0.5 as then the calibrated value of χ_2 is negative.

that all parameter values are the same as those in Table 2 except for the value of *m*. Overall, we find that our foregoing results are robust in that an increase in the labor tax reduces both hours worked per worker and employment rates, and an increase in unemployment benefits lowers employment rates with a small increase in hours worked per worker. The quantitative results indicate that the two adverse labor market institutions explain declining labor supply by more when the labor supply elasticity is larger and the labor's contribution in search γ is smaller.[16]

6. Concluding Remarks

Over the past 30 years from the early 1970s to the early 2000s, labor supply in Europe was declined by about 30% relative to the US. The decline in labor supply comes from hours worked per worker and employment rates. Europe has witnessed steadily higher labor taxes and more generous government-supplied unemployment benefits than the US. Some studies attributed declining hours worked per worker in Europe relative to the US to higher labor taxes, while other studies accredited high unemployment rates in Europe to more generous unemployment benefits. This paper studies a model that consider labor search within the neoclassical growth framework so as to investigate the effects on labor supply along both intensive and extensive margins in one unified general equilibrium framework. We use the model to envisage and compare the relative effects of increases in labor taxes and more generous unemployment benefits on hours worked per worker and employment rates.

We find that an increase in the labor tax decreases hours worked per worker and employment rates with an overstated adverse effect on hours worked per worker if employment is fixed as is in Prescott (2002, 2004). Moreover, more generous unemployment benefits decrease employment rates and increase hours worked per worker, with an understated adverse effect on employment rates if hours worked per worker are fixed as are in Ljungqvist and Sargent (2007, 2008a). In the baseline parameterization, we find that increases in labor taxes and unemployment benefits together explain about 75% of declining labor supply in Europe relative to the US over the past 3 decades, with the fraction accounted for being increasing in the labor supply elasticity and decreasing in the labor's contribution in matching.

Finally, our model has a limitation. The labor force is fixed in our model wherein people who are not employed are treated as the unemployed who are entitled to unemployment benefits. In reality, the labor force is variable and people may be out of the labor force. An extension of our research is to compare the effects of labor taxes and unemployment benefits on employment rates and hours worked per worker in a context with an endogenous labor force. In particular, male labor force participation had declined and female labor force participation had risen over the period under study.

[16] Labor supply is decreased by 30.14% when *LSE*=1 and by 12.74% when *LSE*=0.5. Moreover, labor supply is decreased by 36.1% when γ=0.235, by 24.12% when γ=0.54 and by 21.21% when γ=0.72.

The aggregate effects may be different between Europe and the US which suggest an alternative mechanism.

Mathematical Appendix

1. The wage equation.

The relationship $w = W(\underset{+}{e}, \underset{?}{l}, \underset{+}{s}; \underset{+}{\tau}, \underset{+}{b})$ in (18) can be derived as follows.

$$W_e = \frac{(1-\beta)}{(1-\tau)l} MRS_e^e > 0, \tag{A1a}$$

$$W_l = \frac{(1-\beta)}{(1-\tau)l}\left[MRS_l^e - \frac{MRS^e}{l} - \frac{b}{l}\right] \gtrless 0,\text{[17]} \text{ if } b \text{ is } \begin{matrix}\text{small}\\ \text{large}\end{matrix}, \tag{A1b}$$

$$W_s = \frac{(1-\beta)}{(1-\tau)l} MRS_s^e > 0, \tag{A1c}$$

$$W_\tau = (1-\beta)\left[\frac{b + MRS^e}{(1-\tau)^2 l}\right] > 0, \tag{A1d}$$

$$W_b = \frac{(1-\beta)}{(1-\tau)l} > 0, \tag{A1e}$$

where $MRS_e^e = Xc_e > 0,$ $MRS_l^e = MRS^l + Xc_l > 0,$ $MRS_s^e = -MRS^s + Xc_s > 0,$ [18] and $X \equiv \frac{\chi_2(1-s)^{1-\sigma} - \chi_1(1-l)^{1-\sigma}}{1-\sigma} > 0.$

2. The search effort equation.

The relationship $s = S(\underset{-or?}{e} \underset{-}{l},; \underset{-}{\tau}, \underset{-}{b})$ in (20) is derived as follows.

$$\left(MRS_s^s - MB_s^s\right)ds = \left(-MRS_e^s + MB_e^s\right)de + \left(-MRS_l^s + MB_l^s\right)dl + MB_\tau^s d\tau + MB_b^s db, \tag{A2a}$$

where
$$MRS_e^s = \chi_2 (1-s)^{-\sigma} c_e > 0, \tag{A2b}$$

$$MRS_l^s = \chi_2 (1-s)^{-\sigma} c_l > 0, \tag{A2c}$$

$$MRS_s^s = \chi_2 (1-s)^{-\sigma} c_s + \sigma\chi_2 (1-s)^{-\sigma-1} c > 0, \tag{A2d}$$

$$MB_e^s = \frac{(\rho+\psi)\mu_e}{(\rho+\psi+s\mu)^2}\beta\left[(1-\tau)MPL\cdot l - b - MRS^e\right] - \frac{\mu}{\rho+\psi+s\mu}\beta MRS_e^e < 0,\text{[19]} \tag{A2e}$$

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[17] Due to $MRS_{ll}^e > 0,$ $MRS_l^e - \frac{MRS^e}{l} > 0.$

[18] If the worker devoted more effort in searching, it would increase his outside option or reservation wage. Hence, we suppose $MRS_s^e > 0.$

[19] We assume that the direct effect dominates in order to ensure the diminishing marginal benefit.

$$MB_l^s = -\frac{\mu}{\rho+\psi+s\mu}\beta X c_l < 0\,, \quad \text{(A2f)}$$

$$MB_s^s = \frac{\mu_s}{(\rho+\psi+s\mu)}\beta\left[(1-\tau)MPL\cdot l - b - MRS^e\right] - \frac{\mu}{\rho+\psi+s\mu}\beta MRS_s^e < 0\,, \quad \text{(A2g)}$$

$$MB_\tau^s = -\frac{\mu}{\rho+\psi+s\mu}\beta MPLl < 0\,, \quad \text{(A2h)}$$

$$MB_b^s = -\frac{\mu}{\rho+\psi+s\mu}\beta < 0. \quad \text{(A2i)}$$

3. The hour equation

The relationship $l = L(\underset{-}{e}, \underset{-}{s}; \underset{-}{\tau})$ in (22) is derived as follows.

$$MRS_e^l de + MRS_l^l dl + MRS_s^l ds + MPLd\tau = 0, \quad \text{(A3a)}$$

where $MRS_e^l = \chi_1 (1-l)^{-\sigma} c_e > 0\,,$ (A3b)

$$MRS_l^l = \chi_1 (1-l)^{-\sigma} c_l + \sigma\chi_1 (1-l)^{-\sigma-1} c > 0\,, \quad \text{(A3c)}$$

$$MRS_s^l = \chi_1 (1-l)^{-\sigma} c_s > 0\,. \quad \text{(A3d)}$$

4. The employment equation

The relationship $e = E(\underset{-}{l}, \underset{+or?}{s}; \underset{-}{\tau}, \underset{-}{b}, \underset{-}{\lambda_0}) = 0$ is derived as follows.

$$\left(MB_e^v - 2\lambda_1 v_e\right)de + MB_l^v dl + \left(MB_s^v - 2\lambda_1 v_s\right)ds + MB_\tau^v d\tau + MB_b^v db + MB_\beta^v d\beta - d\lambda_0 = 0, \quad \text{(A4a)}$$

where $MB_e^v = \frac{(1-\beta)}{\rho+\delta+\psi}\left[\eta_e\left(MPL\cdot l - \frac{b+MRS^e}{1-\tau}\right) - \eta\frac{MRS_e^e}{1-\tau}\right] < 0\,,$ (A4b)

$$MB_l^v = \frac{\eta(1-\beta)}{\rho+\delta+\psi}\left[MPL - \frac{MRS_l^e}{1-\tau}\right] = -\frac{\eta(1-\beta)}{\rho+\delta+\psi}\frac{Xc_l}{1-\tau} < 0\,, \quad \text{(A4c)}$$

$$MB_s^v = \frac{(1-\beta)}{\rho+\delta+\psi}\left[\eta_s\left(MPL\cdot l - \frac{b+MRS^e}{1-\tau}\right) - \eta\frac{MRS_s^e}{1-\tau}\right] > (<)0, \quad \text{(A4d)}$$

$$MB_\tau^v = -\frac{\eta(1-\beta)}{\rho+\delta+\psi}\frac{b+MRS^e}{(1-\tau)^2} < 0\,, \quad \text{(A4e)}$$

$$MB_b^v = -\frac{\eta}{\rho+\delta+\psi}\frac{(1-\beta)}{1-\tau} < 0. \quad \text{(A4f).}$$

5. **The slope of Loci E and H.**

The signs of $l = \tilde{L}(\underset{-}{e}; \underset{-}{\tau}, \underset{-}{b})$ in (22) and $e = \tilde{E}(\underset{-}{l}; \underset{-}{\tau}, \underset{-}{b}, \underset{-}{\lambda_0})$ in (24) in the (*e*, *l*) plan is derived as follows. By substituting (A2a), we rewrite (A3a) and (A4a) as follows.

$$\tilde{L}_e de + \tilde{L}_l dl = \tilde{L}_\tau d\tau + \tilde{L}_b db, \tag{A5a}$$

$$\tilde{E}_e de + \tilde{E}_l dl = \tilde{E}_\tau d\tau + \tilde{E}_b db + d\lambda_0, \tag{A5b}$$

where $\tilde{L}_e \equiv MRS_e^l - MRS_s^l \frac{MRS_e^s - MB_e^s}{MRS_s^s - MB_s^s} > 0$,

$$\tilde{L}_l \equiv MRS_l^l - MRS_s^l \frac{MRS_l^s - MB_l^s}{MRS_s^s - MB_s^s} > 0,$$

$$\tilde{L}_\tau \equiv -MPL - MRS_s^l \frac{MB_\tau^s}{MRS_s^s - MB_s^s} < 0,$$

$$\tilde{L}_b \equiv -MRS_s^l \frac{MB_b^s}{MRS_s^s - MB_s^s} > 0,$$

$$\tilde{L}_\beta \equiv -MRS_s^l \frac{MB_\beta^s}{MRS_s^s - MB_s^s} < 0,$$

$$\tilde{E}_e \equiv \left(MB_e^v - 2\lambda_1 v_e\right) - \left(MB_s^v - 2\lambda_1 v_s\right) \frac{MRS_e^s - MB_e^s}{MRS_s^s - MB_s^s} < 0,$$

$$\tilde{E}_l \equiv MB_l^v - \left(MB_s^v - 2\lambda_1 v_s\right) \frac{MRS_l^s - MB_l^s}{MRS_s^s - MB_s^s} < 0,$$

$$\tilde{E}_\tau \equiv -MB_\tau^v - \left(MB_s^v - 2\lambda_1 v_s\right) \frac{MB_\tau^s}{MRS_s^s - MB_s^s} > 0,$$

$$\tilde{E}_b \equiv -MB_b^v - \left(MB_s^v - 2\lambda_1 v_s\right) \frac{MB_b^s}{MRS_s^s - MB_s^s} > 0.$$ [20]

Thus, Loci E and H are both negatively sloping in the (*e*, *l*) plane.

Moreover, a standard result is that a higher unit cost of vacancy creation λ_0 leads to less vacancies and thus less employment, i.e. $\frac{de}{d\lambda_0} < 0$. Let $D \equiv \tilde{L}_e \tilde{E}_l - \tilde{L}_l \tilde{E}_e$ denote the determinant of the Jacobean matrix in (A5a)-(A5b). Straightforward calculation gives $\frac{de}{d\lambda_0} = -\frac{\tilde{L}_l}{D} < 0$, which requires $-\frac{\tilde{L}_e}{\tilde{L}_l} > -\frac{\tilde{E}_e}{\tilde{E}_l}$ and *D*>0, according to the Correspondence Principle (Samuelson 1948). Therefore, the two curves have at most one intersection.

[20] We assumed that the direct effects of all these derivatives dominated the indirect effects resulted from the changes of searching effort.

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Table 1: Hours and Employment in the EU Relative to the US, 1970-73 and 2000-2003.

	Hours worked per person			Employment rate			Hours worked per worker		
	70-73	00-03	diff.	70-73	00-03	diff.	70-73	00-03	diff.
Belgium	92.86	72.5	-20.36	95.44	83.65	-11.79	97.29	86.7	-10.59
France	109.63	74.87	-34.76	103.36	89.52	-13.84	106.07	83.65	-22.42
Germany	132.79	77.42	-55.37	107.91	90.34	-17.57	123.04	85.7	-37.34
EU-11	109.63	81.4	-28.23	101.51	88.91	-12.60	107.99	91.57	-16.42
						(43.42%)			(56.58%)
United States	100	100	0	100	100	0	100	100	0

Note: 1. The hours worked per person are the total hours worked divided by the number of the population aged 15-64; the employment rate is the number of the employed divided by the number of the population aged 15-64; the hours worked per worker are the total hours worked divided by the number of the employed.

2. All US values are normalized to 100 in 1970-73 and 2000-03. All EU data in 1970-73 and 2000-03 are normalized to the U.S. values in the respective period. EU-11 includes Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Spain, Sweden and the UK. We use the population of a country as the weight of the country in calculating the data for the EU-11.

3. Numbers in parenthesis are the composition of differences in hours worked per person in EU-11 into employment and hours worked per worker.

Sources: Data on total numbers of hours worked and total numbers of the employed are taken from OECD (2010a), whereas data on total numbers of the population aged 15-64 are taken from OECD (2010b).

Table 2 Benchmark parameter values and calibration

Benchmark Parameters and Observables		quarterly
physical capital's depreciation rate	δ	0.0200
time preference rate	ρ	0.0100
aggregate consumption-aggregate output ratio	c/y	0.6700
capital's share	α	0.3224
job finding rate per job seeker	$s\mu$	0.8336
fraction of employment	e	0.7500
vacancy-searching worker ratio	$v/(1-e)$	1.0000
coefficient of goods technology	A	1.0000
coefficient of the cost of vacancy creation and management	λ_1	1.0000
fraction of time devote to work of the employed	el	0.2500
effective tax rate on labor income	τ	0.4000
labor supply elasticity	LSE	0.6500
Calibration		
rate of return of capital	r	0.0300
effective capital-labor ratio	q	33.2622
marginal product of labor	MPL	2.0973
capital-output ratio	k/y	10.7467
hours worked per worker	l	0.3333
fraction of time spend on search of the unemployed	s	0.1667
effective job finding rate	μ	5.0016
job separation rate	ψ	0.2779
vacancy creation	v	0.2500
employee recruitment rate	η	0.8336
coefficient of the cost of vacancy creation and management	λ_0	0.1061
equilibrium wage	w	1.4257
unemployment compensation	b	0.1516
inverse of intertemporal elasticity of substitution of leisure	σ	3.0769
utility weight of leisure for the employed	χ_1	0.6971
utility weight of leisure for the unemployed	χ_2	1.6813
labor searcher's bargaining power	β	0.7183
labor searcher's share in matching technology	γ	0.7183
coefficient of matching efficacy	m	3.0193

Table 3: Quantitative Results

	el		*e*		*l*	
Benchmark	**0.25000**	**100%**	**0.75000**	**100%**	**0.33333**	**100%**
$\tau \uparrow$ 30%	0.21996	-12.02%	0.70841	-5.55%	0.31050	-6.85%
$b \uparrow$ 40%	0.23699	-5.20%	0.70302	-6.26%	0.33710	1.13%
$\tau \uparrow$ 30% and $b \uparrow$ 40%	0.19691	-21.23%	0.60953	-18.73%	0.32306	-3.08%

Table 4: Quantitative Results when ψ=0.1

	el		*e*		*l*	
Benchmark	**0.25000**	**100%**	**0.75000**	**100%**	**0.33333**	**100%**
$\tau \uparrow$ 30%	0.22181	-11.28%	0.71557	-4.59%	0.30998	-7.01%
$b \uparrow$ 40%	0.23950	-4.20%	0.71228	-5.03%	0.33624	0.87%
$\tau \uparrow$ 30% and $b \uparrow$ 40%	0.20493	-18.03%	0.64472	-14.04%	0.31786	-4.64%

Note: parameter values are the same as in Table 2 except for μ=1.8, η=0.3, χ_2=1.7849, b=0.1392, β=γ=0.7009 and m=1.0533.

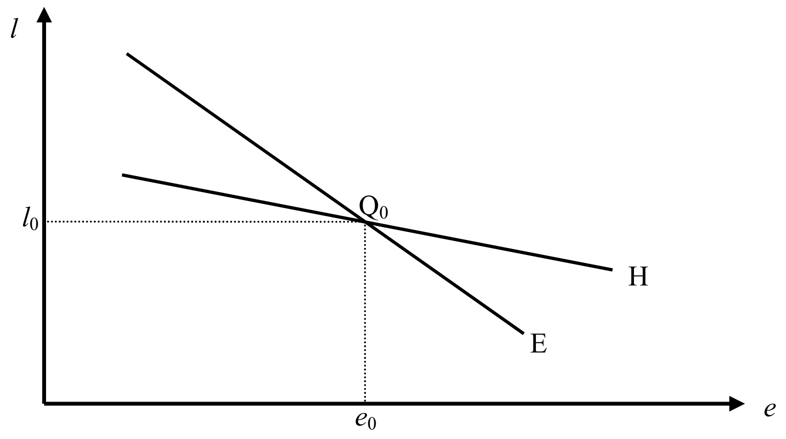

Figure 1: Steady state

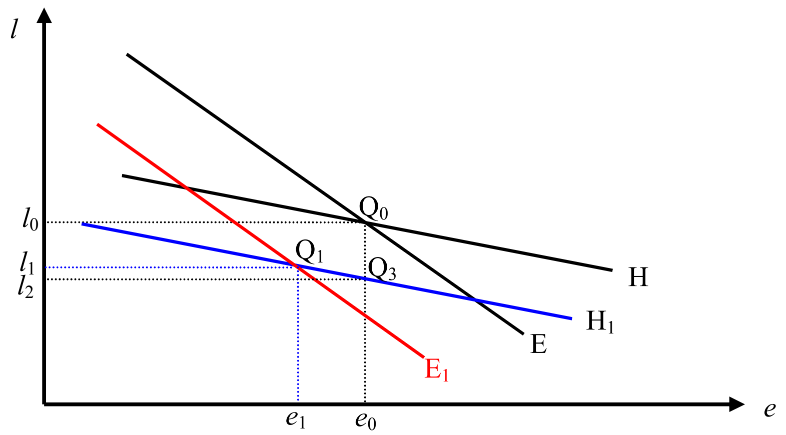

Figure 2: Long-run effects of higher wage taxes (τ)

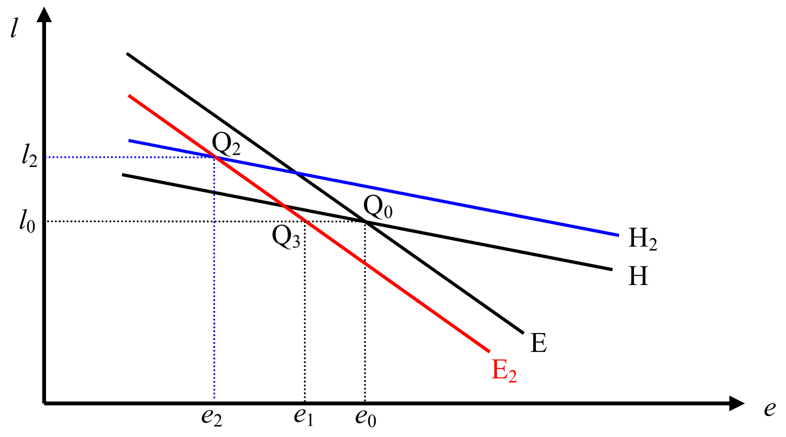

Figure 3: Long-run effects of higher unemployment benefits (b)

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