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RELATIVE EFFECTS OF LABOUR TAXES AND UNEMPLOYMENT BENEFITS ON HOURS WORKED PER WORKER AND EMPLOYMENT

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Abstract. Over the past 3 decades, labour supply in Europe has declined by approximately 30% relative to the USA. The decline comes from hours per worker and employment. The present paper uses a matching model to study the effects of labour taxes and unemployment benefits. Labour 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 the baseline parameterization, labour taxes and unemployment benefits together explain approximately 75% of the declining labour supply in Europe relative to the USA.

1. INTRODUCTION

In the early 1970s, the labour supply in Europe was roughly the same as that in the USA. Whereas the labour supply remained unchanged in the USA, it declined by approximately 30% in Europe relative to the USA from the early 1970s to the early 2000s. Data indicates that the decline in the labour supply comes from both hours worked per worker and employment rates. A growing body of literature has sought to understand the reasons behind the declining labour supply in Europe relative to the USA. A number of papers point to adverse labour market institutions in Europe.[1] In particular, Europe has witnessed steadily higher labour taxes and more generous unemployment benefits than the USA. There are two contrasting viewpoints concerning the effects of the two types of adverse labour market institutions on the labour supply in Europe. First, Prescott (2002, 2004) and his followers attribute the large difference in hours worked per worker to higher labour income taxes in Europe.[2]

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[1] See Nickell (1997), Blanchard and Wolfers (2000) and Blanchard and Giavazzi (2003), who underline the role of adverse labour market institutions in Europe. There are also other explanations, including 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 labour taxes in probing hours of work differences between Europe and the USA include Ohanian *et al*. (2008), Rogerson (2008), Jacobs (2009) and Rogerson and Wallenius (2009).

Conversely, Ljungqvist and Sargent (2007, 2008a) and their followers accredit 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. 181–2).[3]

The former strand of research only differentiates working from leisure hours with neither employment nor unemployment considered. In contrast, the latter school of research distinguishes only employment from unemployment with neither working nor leisure hours taken into consideration. They do not analyse the effects on labour supply along both intensive and extensive margins. The purpose of the present paper is to study a matching model so as to envisage the effects on labour 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 labour income taxes and more generous unemployment benefits on hours worked per worker and employment rates and thus, labour supply.

Specifically, this paper studies a model that considers labour search within the neoclassical growth framework. The model includes a representative large household and a representative large firm. The large household decides on 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 labour 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 analyse 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 labour income taxes and more generous unemployment benefits on hours worked per worker and employment/unemployment.

Our main results are summarized as follows. First, an increase in the labour 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

[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).

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 because 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 for increases in labour income taxes and unemployment benefits in Europe relative to the USA, we find that an increase in labour 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 labour taxes and unemployment benefits account for approximately 75% of declining labour supply in Europe relative to the USA over the past 30 years, with the fraction accounted for being increasing in the labour supply elasticity and decreasing in the labour's contribution in matching.

The closest paper to ours is Fang and Rogerson (2009), in which working hours are embedded 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, is 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 labour 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 case in the standard Pissarides matching model. Second, we employ a representative large firm instead of a worker–job pair as in the standard search model. Thus, in contrast 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. Third, we include unemployment benefits, which are not analysed by Fang and Rogerson (2009). In particular, we compare the relative effects of two types of adverse labour market institutions and find that labour 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 attributes Europe's reduced working hours to higher labour taxes and the latter results lend support to Ljungqvist and Sargent (2007, 2008a), who accredit 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 labour supply between Europe and the USA. In Section 3, we set up a labour search and neoclassical growth model. In Section 4, we characterize the steady state equilibrium. Section 5 studies the effects of higher labour 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 labour supply (hours worked per person), employment rates and hours worked per worker in Europe relative to the USA. Table 1 presents the data for 11 European countries (EU-11), along with Belgium, France and Germany, with the US data normalized at 100 in 1970–1973 and 2000–2003.[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 USA. Although hours worked per person in Belgium were lower than those in the USA in the early 1970s, hours worked per person in the EU-11 on average were 9% higher than those in the USA. 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 USA. These numbers indicate that, relative to the USA, hours worked per person 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.

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 USA in the early 1970s, while Belgium had a slightly smaller employment rate than the USA in the early 1970s. In the early 2000s, all these European countries had lower employment rates than the USA. Over the past 30 years from the early 1970s to the early 2000s, relative to the USA, the employment rate 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 greater hours worked per worker than the USA, while Belgium had approximately the same hours worked per worker as the USA. 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 USA, hours worked per worker 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 declined by 28% relative to the USA. The decline in labour supply is from both decreasing hours worked per worker and falling employment rates.

3. THE MODEL

In the model applied in the present study, the economy is populated by a representative large household and a 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 labour market status, which assures perfect consumption

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

Table 1. Hours and employment in the EU relative to the USA, 1970–1973 and 2000–2003

	Hours worked per person			Employment rate			Hours worked per worker		
	1970–1973	2000–2003	Difference	1970–1973	2000–2003	Difference	1970–1973	2000–2003	Difference
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 (43.42%)	107.99	91.57	–16.42 (56.58%)
USA	100	100	0	100	100	0	100	100	0

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. All US values are normalized to 100 in 1970–1973 and 2000–2003. All EU data in 1970–1973 and 2000–2003 are normalized to the US values in the respective period. EU-11 includes Belgium, Denmark, Finland, France, Germany, Ireland, Italy, the 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. 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).

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 engage in job search or leisure and the cost of job search is foregone leisure. In addition, unlike these authors, there is a large firm in the model. The large firm creates and maintains multiple vacancies and rents capital and hires labour 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 $s_t(1–e_t)$ 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. Furthermore, 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 labour 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 an 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 an unemployed member, respectively. We assume that u and V exhibit the standard concavity property of positive and decreasing marginal utilities.[5] If $\chi_2 V(1-s_t) \leq \chi_1 V(1-l_t)$, 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:

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

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,

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

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

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

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

While equation (4a) is standard, equation (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 equation (4c) by one period and substituting it into equation (4a) gives the following standard Euler equation:

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

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

[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.

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 labour in order to produce a single final good y_t. The production technology is neoclassical, given by the following function:

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

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 labour, capital and vacancy creation; that is,

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

The representative large firm chooses capital and vacancies 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,

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

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

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

Capital is determined by the marginal product of capital equal to the rental rate in equation (9a). Equation (9b) is the vacancy–employment condition that 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 equation (9c) is the sum of the marginal product of labour net of the wage rate multiplied by hours worked per worker and the discounted future marginal benefit.

It is straightforward to rewrite equation (9a) as:

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

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

3.3. *Labour matching and bargaining*

The labour market exhibits search frictions with aggregate flow matches depending on the masses of job seekers and vacancies. Following Diamond (1982), we assume pairwise random matching. The matching technology takes the constant-returns form:[6] $M_t = m(s_t(1 - e_t))^{\gamma}(v_t)^{1-\gamma}$, 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), because s_t is search effort per job seeker, aggregate search effort by job seekers is $s_t(1 - e_t)$.

A job seeker's surplus acquired from a successful match is evaluated by its augmenting value from employment U_e in equation (4d), whereas a vacant job's surplus of a successful match is gauged by its incremental value from recruit Π_e in equation (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 determine their supply of and demand for labour. There is implicitly an auctioneer in the labour market who sets an equilibrium wage so as to equate labour supply to labour demand. In a frictional labour 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.

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

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 worker'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 behaviour is passive; it levies labour income and lump-sum taxes and offers unemployment benefits. The government budget constraint is

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

To isolate the effects of policy changes carried out later, we include lump-sum taxes, T_t. When the labour tax rate τ is changed, with unemployment benefits b being held unchanged, lump-sum taxes/subsidies T will change accordingly to balance the budget. Similarly, when unemployment benefits are increased, with the labour 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) labour-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 equation (9d) yields the effective capital–labour ratio: $q = \left(\frac{\alpha A}{\rho + \delta}\right)^{\frac{1}{1-\alpha}}$, which is constant in a steady state.

Next, if we use the household's budget (equation 2) and the firm's flow profit (equation 8a), along with the government's budget (equation 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 labour market must satisfy the following matching relationships (Beveridge curve) given by

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

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:

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

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

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

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 equation (4d) is

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

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

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

where $MPL \equiv (1-\alpha)Aq^a$ denotes the marginal product of labour, which is constant.

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

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

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–labour ratio and equation (14b), equation (12) gives the following consumption:

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

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 equations (15) and (16), we rewrite equation (10a) as

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

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

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

[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) make a similar assumption of $c_e > 0$.

where $\underset{+\ +\ +}{MRS^e(e, l, s)} \equiv \left[\frac{\chi_2(1-s)^{1-\sigma} - \chi_1(1-l)^{1-\sigma}}{1-\sigma}\right] \underset{+\ +\ +}{c(e, l, s)}$ is the difference of the marginal rate of substitution (MRS) for leisure and consumption between unemployment and employment (i.e. 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 labour and the reservation wage; the reservation wage is the sum of unemployment benefits and losses in leisure utilities from unemployment to employment. As the marginal product of labour 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 equation (18). First, all other things being equal, a higher employment e raises the bargained wage because it increases consumption, which increases the reservation wage.[9] Second, greater working hours, l, has an ambiguous effect on the bargained wage. In the special case of $b = 0$, greater working hours raises the bargained wage because 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 greater working hours may reduce the wage. Third, 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, therefore, 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 labour income taxes (τ) and higher unemployment benefits (b) both increase the reservation wage. Thus, the bargained wage is increasing in labour income taxes and unemployment benefits.

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

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

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 the unique search effort level as the marginal benefit of search effort is decreasing in search effort and the marginal cost is increasing in it. Moreover, higher employment increases the marginal cost of search effort but has an ambiguous effects on the marginal benefit and, thus,

9 To save space, all algebra below is delegated to the Appendix.

has a negative or an ambiguous effect on search effort. Furthermore, greater working hours increases the marginal cost of search effort and decreases the marginal benefit and, therefore, decreases search effort. Finally, labour 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*

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 equation (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 equation (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 labour, 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 labour is constant, this condition determines a unique level of hours worked per worker. To characterize hours worked per worker, it is clear that employment and search effort both increase the marginal cost of working hours due to higher consumption. Moreover, a higher labour tax also increases the marginal cost of working hours due to a lower post-tax wage rate. Thus, employment, search effort and labour taxes all decrease hours worked per worker. With the search effort in equation (20), the condition above gives the following optimal working hours:

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

In the relationship above, although l and e also exert indirect effects via search effort S in equation (20) that may offset the direct effect on the net marginal cost

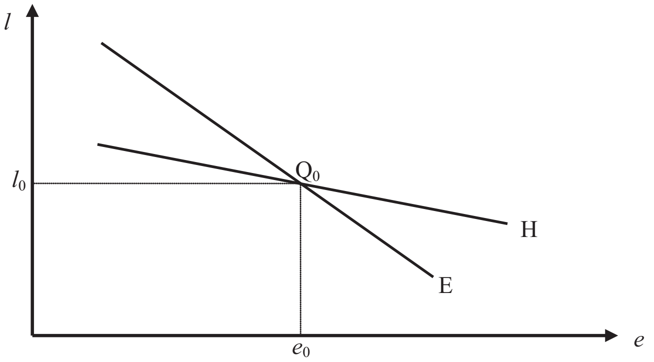

Figure 1. Steady state

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).

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

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

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 a unique employment level. To characterize the employment function, it is clear that greater working hours 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. Furthermore, 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 that 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 flatter than Locus E in each intersection.[10] As Locus H is always 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, labour supply (e_0l_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 labour income and is used to make a lump-sum transfer; and a benefit to the unemployed which is proportional to labour income as financed by a lump-sum tax. While the former policy is stressed by Prescott (2002, 2004) in explaining lower hours worked per worker in Europe than the USA, the latter policy is emphasized by Ljungqvist and Sargent (2007, 2008a) in accounting for higher unemployment rates in Europe than the USA. We start with the analysis of increases in labour 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 labour taxes*

First, we analyse the effects of increases in the labour 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 labour supply is (e_0l_0).

When the labour 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 labour tax

[10] 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.

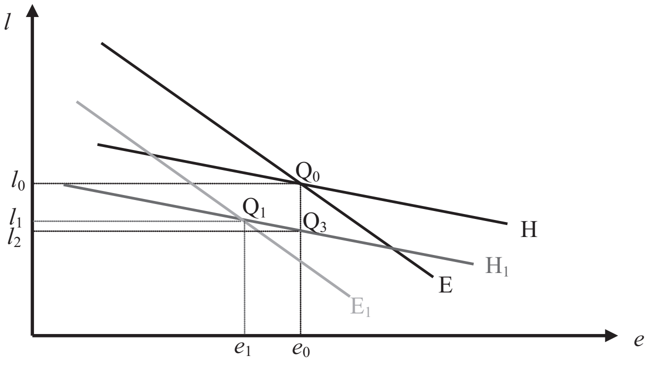

Figure 2. Long-run effects of higher wage taxes (τ)

rate yields direct effects to decrease working hours in both Loci H and E. However, in Locus H, a higher labour 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 labour 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 labour 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 analyse the effects of increases in unemployment benefits (higher b). Suppose that the initial steady state is at Q_0 in Figure 3.

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

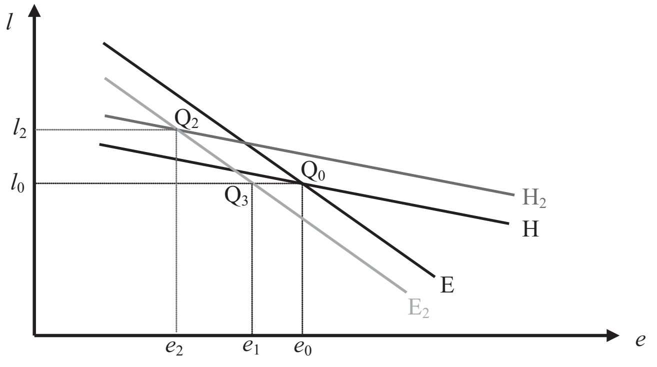

Figure 3. Long-run effects of higher unemployment benefits (b)

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 labour taxes and unemployment benefits on labour 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 compensation. We are particularly interested in how tax rates and unemployment compensation differences between Europe and the USA lead to large differences in hours worked per worker and employment and, thus, labour supply. To this end, we use the data for increases in labour income taxes and unemployment benefits in Europe relative to the USA 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 labour supply. Notice that when there are increases in tax rates and unemployment compensation, in the steady state the wage also changes because the wage is affected by hours of work and employment.

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 $\delta = 0.02$ and the quarterly time preference rate to $\rho = 0.01$. 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 approximately one-third and we follow Prescott (2004) to use the value $\alpha = 0.3224$. With the values of A and α, we compute the effective capital–labour ratio as $q = \left(\frac{\alpha A}{\rho + \delta}\right)^{\frac{1}{1-\alpha}} = 33.2622$, which, in turn, gives $MPL = 2.0973$ and, via equation (6), the quarterly capital–output ratio $k/y = 10.7467$, which is consistent with a capital–output ratio of 2.5–3.0 in annual data.

The fraction of employment in the working-age population is approximately 75% (see Kydland and Prescott, 1991) and, therefore, 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 $s = 0.5 \times l = 0.1667$. 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 $\mu = 5.0016$. We employ equation (13) to compute the quarterly separation rate as a fraction of employment at $\psi = (s\mu(1\text{-}e))/e = 0.2779$. 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 equation (13) to calibrate $\eta = (s\mu(1 - e))/v = 0.8336$.

By setting the consumption–output ratio at $c/y = 0.67$ and normalizing $\lambda_1 = 1$, we use equation (17) to calibrate the coefficient of vacancy costs $\lambda_0 = 0.1061$. We compute the wage at $w = 1.4257$ from equation (18). In accordance with Prescott (2004), unemployment benefits are 0.319 times forgone labour income, and, hence, we calibrate $b = 0.319 \times w \times l$, which gives $b = 0.1516$. Based on the data in McDaniel (2007), Rogerson (2008) use the labour 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 labour income for these five countries. We find that the average effective tax rate

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

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

Table 2. Benchmark parameter values and calibration

		Quarterly
Benchmark parameters and observables		
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	$v/(1\text{-}e)$	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 labour income	τ	0.4000
Labour supply elasticity	LSE	0.6500
Calibration		
Rate of return of capital	r	0.0300
Effective capital–labour ratio	q	33.2622
Marginal product of labour	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
Labour searcher's bargaining power	β	0.7183
Labour searcher's share in matching technology	γ	0.7183
Coefficient of matching efficacy	m	3.0193

in years 1970–1973 is 0.3982, which leads us to set the benchmark labour tax rate to $\tau = 0.4$, a rate similar to that of the USA, as noted in Prescott (2004).

Finally, for the utility function adopted here, the labour supply elasticity is $LSE = (1 - l)/(\sigma l)$. The LSE estimated in MaCurdy (1981) ranges from 0.1 to 0.5 for men and is likely higher for women, while Andolfatto (1996) set $LSE = 1$. For the present purposes, we choose an intermediate value: $LSE = 0.65$, which implies $\sigma = 3.0769$. Given this value, equation (21) is solved for $\chi_1 = 0.6971$ and equation (19) is solved for $\chi_2 = 1.6813$.[13] We obtain the bargaining share $\beta = 0.7183$ from equation (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 worker'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.

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

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%

Now, we quantify the effects of increases in tax rates and unemployment benefits. We start by measuring the increase in labour taxes and unemployment benefits in Europe relative to the USA in the early 2000s. For labour taxes, based on McDaniel (2007), we calculate the population-weighted average effective tax rate on labour income in the five European countries under concern in 2000–2003 and obtain the tax rate 0.5168. With the data that the effective labour tax rate increased a little bit in the USA in the past 30 years,[14] this indicates an increase in labour tax rates of approximately 30% in Europe relative to the USA from that in 1970–1973. 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 considered and 50% in the USA in the late 1990s. These data suggest that unemployment benefits in Europe are roughly 40% higher than in the USA. 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.

First, the quantitative effects of increases in the labour income tax are in the first row of Table 3. The results indicate that when the labour 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, labour 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 of 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 of 1.13%. As a result, labour supply is decreased by 5.2%.

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

[14] Based on the data in McDaniel (2007), the effective labour tax rate (on household income and payroll) in the USA increased from 0.1775 in 1970–1973 to 0.22475 in 2000–2003.

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%

Parameter values are the same as in Table 2 except for $\mu = 1.8$, $\eta = 0.3$, $\chi_2 = 1.7849$, $b = 0.1392$, $\beta = \gamma = 0.7009$ and $m = 1.0533$.

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 labour 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 labour market institutions, we increase the labour 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 of 18.73%. Hours worked per worker are decreased from 0.333 to 0.323, which implies a decrease of 3.08%. As a result, these two adverse labour market institutions decrease labour supply by 21.23%. Compared to the data showing a decrease of 28.23% in the EU-11 relative to the USA over the past 30 years in Table 1, our quantitative results suggest that higher labour income taxes and more generous unemployment benefits in the EU than the USA both account for approximately 75% of the declining labour 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 $\psi = 0.1$. 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 approximately 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 consider whether or not the results are robust when Hosios'

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

rule does not hold. In this exercise, we fix the worker's bargaining share at $\beta = 0.7183$ and vary the worker'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 involving 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 involving deviating from Hosios' rule, we recalibrate the model and find 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 labour 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 labour market institutions explain declining labour supply by more when the labour supply elasticity is larger and labour's contribution in search γ is smaller.[16]

6. CONCLUDING REMARKS

From the early 1970s to the early 2000s, the labour supply in Europe declined by approximately 30% relative to the USA. The decline in the labour supply comes from hours worked per worker and employment rates. Europe has witnessed steadily higher labour taxes and more generous government-supplied unemployment benefits than the USA. Some studies attribute declining hours worked per worker in Europe relative to the US to higher labour taxes, while other studies accredit high unemployment rates in Europe to more generous unemployment benefits. The present paper studies a model that considers labour search within the neoclassical growth framework so as to investigate the effects on labour 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 labour taxes and more generous unemployment benefits on hours worked per worker and employment rates.

We find that an increase in the labour 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 they are in Ljungqvist and Sargent (2007, 2008a). In the baseline parameterization, we find that increases in labour taxes and unemployment benefits together explain approximately 75% of declining labour supply in Europe relative to the USA over the past 3 decades, with the fraction accounted for being increasing in the labour supply elasticity and decreasing in worker's contribution in matching.

[16] Labour supply is decreased by 30.14% when $LSE = 1$ and by 12.74% when $LSE = 0.5$. Moreover, labour supply is decreased by 36.1% when $\gamma = 0.235$, by 24.12% when $\gamma = 0.54$ and by 21.21% when $\gamma = 0.72$.

Finally, our model has a limitation. The labour 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 labour force is variable and some people may be out of the labour force. An extension of our research is to compare the effects of labour taxes and unemployment benefits on employment rates and hours worked per worker in a context with an endogenous labour force. In particular, male labour force participation had declined and female labour force participation had risen over the period under study. The aggregate effects may be different between Europe and the USA, suggesting an alternative mechanism.

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MATHEMATICAL APPENDIX

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

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

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

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

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

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

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

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 $X \equiv \dfrac{\chi_2(1-s)^{1-\sigma} - \chi_1(1-l)^{1-\sigma}}{1-\sigma} > 0$.

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

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

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

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

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

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

$$MB_l^s = -\frac{\mu}{\rho+\psi+s\mu}\beta Xc_l < 0, \tag{A2f}$$

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

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

$$MB_b^s = -\frac{\mu}{\rho+\psi+s\mu}\beta < 0. \tag{A2i}$$

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

$$MRS_e^l de + MRS_l^l dl + MRS_s^l ds + MPL d\tau = 0, \tag{A3a}$$

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

[18] If the worker devoted more effort in searching, it would increase his or her 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.

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

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

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

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

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

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

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

5. The slope of Loci E and H.
   The signs of $l = \tilde{L}(e; \tau, b)$ in equation (22) and $e = \tilde{E}(l; \tau, b, \lambda_0)$ in equation (24) in the (e, l) plan is derived as follows. By substituting equation (A2a), we rewrite equations (A3a) and (A4a) as follows:

$$\tilde{L}_e de + \tilde{L}_l dl = \tilde{L}_\tau d\tau + \tilde{L}_b db, \quad \text{(A5a)}$$

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

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; that is, $\frac{de}{d\lambda_0} < 0$. Let $D \equiv \tilde{L}_e\tilde{E}_l - \tilde{L}_l\tilde{E}_e$ denote the determinant of the Jacobean matrix in equations (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 $D > 0$. Therefore, the two curves have, at most one, intersection.

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