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Relative effects of labor taxes on employment and working hours: role of mechanisms shaping working hours

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Abstract High labor income taxes are one of the most important explanations advanced for the large decline of labor supply in Europe over the past 30 years. While in some countries the decline comes evenly from employment and hours per worker, in others it comes mostly from hours per worker, or predominantly from employment. This paper studies why labor taxes have different relative effects on employment and hours per worker. We show that different hour-shaping mechanisms are one of the underlying reasons. In the mechanism when hours per worker are bargained by matched job-worker pairs, a higher labor income tax would reduce both employment and hours per worker. As the worker's hour-bargaining share is larger, hours per worker are decreased by more and employment is decreased by less. In the mechanism when hours per worker are determined exclusively by the household, this goes to the case when the worker has a one-hundred percent hour bargaining power. In this situation, when the leisure utility is linear in hours, the effect on employment is zero and all negative effects are on hours per worker. At the other extreme, in the mechanism when hours per worker are effectively regulated, a higher labor tax only reduces employment with a zero effect on hours. We calibrate the model and show that the quantitative effects of Europe's increases in average effective tax rates in the past 30 years are consistent with the theoretical predictions.

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1 Introduction

One striking observation in the labor market is that, relative to the US, the labor supply in Europe declined by about 30 % from the early 1970s to the early 2000s. Prescott (2002, 2004, 2006) attributed high labor income taxes in Europe as one important determinant of declining labor supply in Europe.[1] Building upon previous work by Prescott (2002, 2004, 2006), recent studies by Ohanian et al. (2008), Rogerson (2008), Jacobs (2009), Rogerson and Wallenius (2009) and Krusell et al. (2010), among others, have uncovered that high labor income taxes in Europe are an important determinant of declining labor supply in Europe.[2]

Changes in labor supply come from changes in employment and hours worked per worker. The OECD data indicate that relative to the US, the decline in labor supply comes evenly from falling employment and hours worked per worker in countries like Belgium, France, Germany and the UK, but the decline comes mostly from decreasing hours worked per worker in countries like Ireland, Netherland and Norway and mainly from falling employment in countries like Australia, New Zealand and Turkey.[3] There are institutional differences that may explain the differences on the intensive vs. the extensive margin among OECD countries.[4] In the context of the institutional differences, the labor tax may provide one important explanation. Then, an interesting and important question arises: are there institutional settings where higher labor income taxes have a stronger negative effects on hours worked per worker,

[1] According to McDaniel (2007) and Rogerson (2008), in the early 1970s the average tax rate on labor income in Belgium, France, Germany, Italy, and the Netherlands was about 39 % which was higher than the 18 % average rate in the US. In the early 2000s, the average tax rate on labor in these European countries was about 51 % which was still much higher than the 22 % average rate in the US.

[2] Alesina et al. (2006) suggested that Prescott's results held true only under implausibly high labor supply elasticities. These authors and other recent contributors like Eugster et al. (2011), Giavazzi et al. (2013) and Azariadis et al. (2013) suggested an alternative explanation based on different leisure preferences between Europeans and Americans. Moreover, some economists argued Europe's low labor supply and high unemployment based on stronger labor unions (e.g., Alesina et al. 2006) and higher labor market regulations like generous unemployment compensation (e.g., Ljungqvist and Sargent 2007b, 2008a). There are also other explanations based on differences in entry costs (Fonseca et al. 2001), changes in technology and government (Rogerson 2006), and home production (Ngai and Pissarides 2008; Olovsson 2009). Since our paper focuses on the explanation based on high labor taxes in Europe, in order to simply the model we abstract from these alternative explanations.

[3] Available data in OECD countries indicate that in some countries, relative to the US, declining hours per person from the early 1970s to the early 2000s come essentially from decreasing hours per worker which accounts for more than 90 %. Conversely, in other countries, declining hours per person in the same period basically are from falling employment rates which also accounts for more than 90 %. See Appendix Table 6 for details.

[4] There is a recent literature that compares labor market adjustments on the intensive vs. the extensive margin in different institutional settings during the Great Recession (e.g. US vs. Germany) put forth by Merkl and Wesselbaum (2011) and Burda and Hunt (2011). Arpaia and Mourre (2012) reviewed related literature that analyzes the effect of institutional differences on labor market outcomes in OECD countries. Siebert (1997)

than on employment levels, and other settings where higher labor income taxes have a stronger negative effects on employment, than on hours worked per worker? The purpose of our paper is to study responses of hours per worker and responses of employment to increases in labor income taxes. We will show that different hours-shaping mechanisms is one of the underlying reasons leading to sometimes stronger adverse responses of hours worked per worker while at times stronger adverse responses of employment.

To this end, we study a labor search model with variable employment and hours that is based on Fang and Rogerson (2009) which, to our knowledge, is the only search model that considers both unemployment and work hours.[5] Our main departure is to allow for separate bargaining powers for hours and wage. First, in the existing literature, work hours may be determined by both sides of a match, the worker alone and the government regulation. These mechanisms have been employed in studies by Fang and Rogerson (2009), Prescott (2004) and Marimon and Zilibotti (2000), respectively. These mechanisms capture some real-world institutions. Sometimes we see that a trade union negotiates with the employer about the working conditions including hours, overtime and health and safety, some other times, a worker alone deciding the numbers of work hours. Moreover, we also see that the government regulates minimum daily rest periods and a maximal number of work hours per week. It is interesting to see how these different institutional settings affect the magnitude of responses of hours and responses of employment to changes in labor taxes. Second, our assumption of separate bargaining powers for hours and wage is mainly justified by institutional facts. For example, according to Manning (1987, p. 125), “in the US, strikes at contract renegotiations about mandatory issues are legal, but strikes about permissive issues in the course of contracts are not.” The wage is in the list of mandatory issues on which employers have to bargain with the union, while the employment and work hours belong to the list of permissive issues.[6]

Our model has a representative large household that comprises a continuum of members, who are either employed or unemployed. Employed members choose between work and leisure hours, while unemployed members search for jobs and also enjoy leisure. There is a representative firm which pays costs to create job vacancies. Unfilled jobs and job seekers meet through a matching technology. Hours worked per worker are determined by one of the three mechanisms. They may be bargained by a matched job-worker pair, decided by the worker, or regulated by the authority. Using different

Footnote 4 continued
offered a nice survey concerning comparative institutional factors at the root of unemployment in Europe. See also Acemoglu (2001) that found that the institutional factors of minimum wages and unemployment benefits shift the composition of employment toward high-wage jobs, which, if it operates in the European labor market, may suggest that institutional factors may dominate market forces (employers exercising their bargaining power under unemployment).

5 Fang and Rogerson (2009) is based on the model of Andolfatto (1996) by abstracting from capital.

6 See also Walque et al. (2009) which formalized different bargaining powers for hours bargaining and wage bargaining.

hour-shaping mechanisms, we investigate the magnitude of responses of hours and responses of employment to changes in labor taxes in a steady state.[7] Employment and hours in a steady state are determined by two conditions. The labor demand is a firm's free entry condition which equalizes the marginal cost and the marginal gain of employment whereas the labor supply condition, which comes from the worker's bargaining hour, equates the marginal cost and benefit of hours worked per worker. The effects of different hour-shaping mechanisms mainly work via their effects on the labor supply condition.

Our main findings are summarized as follows. First, when hours worked per worker are bargained by a matched job-worker pair, a higher labor tax decreases both the employment and hours with the relative responses of hours and employment depending on the hour bargaining power. As the worker's hour bargaining power increases, hours per worker are decreased by more and employment is decreased by less. Second, when hours per worker are determined by the worker by trading off between leisure and consumption, this degenerates to the case where the worker has one-hundred percent of hour-bargaining power. In this case, the effect of labor taxes on hours per worker is the largest and that on employment is the smallest. In extremis, where the leisure utility is linear in hours, the negative effect is completely on hours per worker without reducing employment. At the other extreme, where hours per worker are effectively regulated, labor taxes only lower employment without reducing hours. Finally, we also carry out a simulation analysis.

While the effects of labor taxes along different margins of labor supply have been studied in Saez (2002), Laroque (2005) and Lehmann et al. (2014), the latter is the closest paper to ours, in exploring the effects of progressive labor income taxes along the intensive and the participation margin. Lehmann et al. (2014) have found that a rise in the average labor tax rate decreased employment rates and participation rates and increased unemployment rates.[8] Yet, they did not study the effects of labor taxes on the distribution of effects between employment and hours; nor did they explore how the distribution of effects is affected by different hour bargaining powers. Next, Saez (2002) and Laroque (2005) are less closely related to our paper as they both focus on optimal taxes and transfers. While Saez (2002) analyzed optimal income tax-transfers for low incomes in a model with labor supply responses along either the intensive margin or the participation margin (work or not), Laroque (2005) studied the optimal tax-subsidy schedules in an economy with labor supply responses only along

[7] While the first hour-shaping mechanism has been taken up by Fang and Rogerson (2009), the second and the third were used by Prescott (2004) and Marimon and Zilibotti (2000), respectively. Fang and Rogerson (2009) set up a matching model of labor supply and examined the effects of tax and transfer policies on the employment and the hour margins of labor supply. Marimon and Zilibotti (2000) envisaged employment and distributional effects of regulating (reducing) working time in a general equilibrium model with search-matching frictions. While Fang and Rogerson (2009) and Marimon and Zilibotti (2000) studied labor search models, Prescott (2004) analyzed a neoclassical growth model. Prescott (2004) and Marimon and Zilibotti (2000) considered capital adjustment, whereas there is no capital in Fang and Rogerson (2009).

[8] They also found that a rise in labor tax progressivity decreased unemployment rates and in-work effort but increased participation rates provided that the unemployment rate was inefficiently high.

the participation margin.[9] Our paper is different from these two studies in that we analyze the distribution effects of labor taxes on employment and hours and explore how the distribution effects are affected by different hour bargaining powers.

The remainder of this paper is as follows. In Sect. 2, we set up a labor search model without capital adjustment. In Sect. 3, we study the relative effects of higher labor taxes on employment and hour worked per worker under different hour-shaping mechanisms, and then we quantify the effects. Finally, we offer some concluding remarks in Sect. 4.

2 A simple labor search model

Our simple model embeds the labor supply into a standard Pissarides labor search framework. The labor supply model allows for a distinction between working hours and leisure, whereas the Pissarides labor search framework, between the employment status and the unemployment status.

2.1 Environment

Time is discrete. In the beginning of a period, matched jobs and workers produce goods. When some jobs are destroyed, the detached worker enters the unemployment pool, but the destroyed job is gone. If the firm chooses to create a job, there is a cost of creation and maintenance in each period. Firms with job vacancies search for workers. In the same time, detached worker searches for jobs. Job offers and job seekers are matched with different probabilities. If a vacant job and a job seeker meet, the matched pair bargains over the wage and the hour. With the wage and the hour determined by the Nash bargaining procedure, the agreement is reached by both parties. Then, the unemployed workers become employed and the vacant jobs are filled in the end of the period. The matched pairs start to produce in the next period.

Following Andolfatto (1996) and Fang and Rogerson (2009), the economy is populated by a continuum of identical infinitely-lived large households. The adoption of the large household as a decision-making unit avoids the unnecessary complexities involved in tracking the distribution of the employed and the unemployed. The large household comprises a continuum of members (of measure one), who are either (1) employed, by engaging in work or leisure, or (2) unemployed, by searching jobs or enjoying leisure. Job search is costless, but a job vacancy needs a cost for creation and maintenance. A vacant job and a job seeker meet bilaterally through a matching technology. The job finding and recruitment rates are endogenous, depending on the masses of both matching parties. In every period, filled jobs and employed workers are separated at an exogenous rate. Finally, the fiscal author-

[9] Saez (2002) discovered that the optimal transfer program was characterized by a classical negative income tax program when labor supply are along the intensive margin and by a earned income tax credit when behavioral responses are concentrated along the extensive margin. Laroque (2005) uncovered that, given an income guarantee, a feasible allocation was second-best optimal if and only if the associated taxes are lower than the Laffer bound, determined by the joint distribution of the agents' productivities and work opportunity costs.

ity levies labor income taxes and transfers the tax revenue to households in a lump sum.

Members of the representative large household are homogeneous, equally contribute to, and enjoy, family resources. In period t, a fraction e_t of the members is employed and the remaining fraction is unemployed. Given a fixed time endowment normalized at unity, each employed member allocates a fraction h_t of the total time to work and the remaining fraction to leisure. From the household's perspective, the employment evolves according to the following process

$$e_{t+1} = p_t(1 - e_t) + (1 - \lambda)e_t, \tag{1}$$

where p_t denotes the (endogenous) job finding rate and λ is the (exogenous) job separation rate. Thus, the change in employment $(e_{t+1} - e_t)$ is equal to the inflow of workers into the employment pool $(p_t(1 - e_t))$ net of the outflow as a result of separation (λe_t).

Denote w_t and τ as the wage rate and the income tax rate, respectively. The household receives after-tax wage income, profits Π_t, and lump-sum transfers T_t and spends on consumption c_t. Thus, the large household's budget constraint is

$$c_t = (1 - \tau)w_t e_t h_t + \Pi_t + T_t. \tag{2}$$

The household seeks to maximize the total utility of its members. The household's periodic utility depends on consumption and leisure and takes a separable form (King and Rebelo 1999). To relate leisure to working hours h_t, we posit the leisure utility $1 - g(h_t)$, where $g(h_t)$ is the disutility function from working. The disutility function is assumed to be weakly concave in work time with the level of disutility normalized to zero at zero working hour; i.e., $g(0) = 0$, $g'(h) > 0$ and $g''(h) \geq 0$. Thus, the leisure of an unemployed worker is $1 - g(0) = 1$. By aggregating all members in the large household, the leisure utility of the large household is $e_t[1 - g(h_t)] + (1 - e_t) \cdot 1 = 1 - e_t g(h_t)$. Then, the large household's utility is $u(c_t) + [1 - e_t g(h_t)]$,[10] where $u' > 0 > u''$.

Let $U(e_t)$ denote the lifetime value of the household in period t when the state is e_t. Denote as $\rho > 0$ the time preference rate. The Bellman equation of the household's optimal control problem is

$$U(e_t) = \max\left[\{u(c_t) + [1 - e_t g(h_t)]\} + \frac{1}{1+\rho}U(e_{t+1})\right], \tag{3}$$

subject to constraints (1) and (2).

[10] An example is the separable utility $u(c_t) - g(h_t)$ used in Fang and Rogerson (2009) wherein taking an average over all members in the large household gives $e_t[u(c_t) - g(h_t)] + (1 - e_t)[u(c_t) - g(0)] = u(c_t) - e_t g(h_t)$.

The effect of changes in the employment rate e_t on total household utility is[11]

$$U_e(e_t) = \left[u'(c_t)(1-\tau)w_t h_t - g(h_t)\right] + \frac{1}{1+\rho} U_e(e_{t+1})(1-\lambda-p_t). \quad (4)$$

The unit of production is a matched job-worker pair. Following Fang and Rogerson (2009), a matched job-worker pair produces output with a technology of a decreasing return given by[12]

$$y_t = f(h_t),\ f'(h_t) > 0 > f''(h_t).$$

The value of an individual job to a firm is independent of the number of jobs the firm already has. We assume that the vacancy creation cost is a one-time up front cost ϕ in units of output.[13] When a firm with an unfilled job matches with an unemployed worker, it has two options: (1) to accept the worker and fill the job, or (2) to reject the worker and retain the unfilled job into the next period. Denote π_{vt} and π_{et} as the lifetime value of an unfilled job and a filled job, respectively. If a job is filled in period t, its lifetime value is the flow value in t, $(f(h_t) - w_t h_t)$, plus the discounted future value when the match is not separated given as follows.

$$\pi_{et} = [f(h_t) - w_t h_t] + \frac{1}{1+r_t}(1-\lambda)\pi_{e(t+1)}, \quad (5a)$$

where r_t is the interest rate. Conversely, if a job is not filled in period t, its lifetime value is the discounted weighted average of finding a worker to fill the job and remaining unfilled given as follows.

$$\pi_{vt} = \frac{1}{1+r_t}\left[q_{t+1}\pi_{e(t+1)} + (1-q_{t+1})\pi_{v(t+1)}\right], \quad (5b)$$

where q_t is the recruitment rate which is taken as given by a firm with an unfilled job but is endogenously determined in equilibrium.

Denote v_t as the number of vacant jobs. Then, from the firms' perspective, the employment is increased by the inflow $(q_t v_t)$ and decreased by the outflow (λe_t),

$$e_{t+1} - e_t = q_t v_t - \lambda e_t. \quad (6)$$

In each period t, unemployed workers $(1-e_t)$ and unfilled jobs v_t meet each other through the Diamond (1982) type pair-wise random matching function $M_t = M(1 -$

[11] Working hours may be bargained by the two sides of a successful match, completely determined by the household, or regulated by the authority. Details will be offered in Sect. 3 below.

[12] To ease analysis, we present a model without capital adjustment. In the Appendix, we present a model with capital accumulation and the production function $y_t = f(k_t, h_t)$, $f_x > 0 > f_{xx}$, where $x = k, h$.

[13] The sufficient condition for any equilibrium with positive employment is that the vacancy creation cost be not too large. The surplus from a match is always positive under our assumptions on the functions u and f.

e_t,v_t). We assume that this function is of constant returns and is increasing and strictly concave in the two inputs. As is standard, we adopt the following Cobb–Douglas form.

$$M_t = m(1 - e_t)^{\gamma} (v_t)^{1-\gamma}, \tag{7}$$

where $m > 0$ is the degree of matching efficacy and $\gamma \in (0, 1)$ the contribution of labor search.

After a successful match, the effective wage is determined by maximizing the joint surplus

$$\max_{w_t} \; [U_e(e_t)]^{\beta} \, [\pi_{et} - \pi_{vt}]^{1-\beta} ,$$

where the worker's surplus is the increase in total household utility when employed (U_e), the firm's surplus is the increase in the lifetime value from a vacant to a filled job ($\pi_e - \pi_v$), and $\beta \in (0, 1)$ is the worker's bargaining power.[14] In the bargaining problem, the job-worker pair treats matching rates (p_t and q_t), the beginning-of-period employment (e_t), the bargains of all other household members in the current period, and all future bargains as given. The first-order condition of the bargaining problem is

$$\frac{\beta}{U_e(e_t)} \frac{\partial U_e(e_t)}{\partial w_t} = -\frac{1-\beta}{\pi_{et} - \pi_{vt}} \left(\frac{\partial \pi_{et}}{\partial w_t} - \frac{\partial \pi_{vt}}{\partial w_t} \right), \tag{8}$$

where $\frac{\partial U_e(e_t)}{\partial w_t} = u'(c_t)(1-\tau)h_t$,[15] $\frac{\partial \pi_{et}}{\partial w_t} = -h_t$ and $\frac{\partial \pi_{vt}}{\partial w_t} = 0$.

Finally, there is a passive government which levies the labor income tax to finance transfers. The balance of the government budget is

$$\tau w_t e_t h_t = T_t. \tag{9}$$

As noted in Rogerson (2006) and Ljungqvist and Sargent (2007a, 2008b), the effects of the labor income tax on the labor supply may depend on the way of using the tax revenue. In order to isolate the effects of increases in labor taxes from different ways of government spending, we assume that the tax revenue is transferred to households in a lump-sum fashion.

2.2 Equilibrium

A search equilibrium is a tuple of individual quantity variables $\{e_t, h_t, v_t, c_t, y_t\}$, a pair of aggregate quantities $\{M_t, T_t\}$, a pair of matching rates $\{p_t, q_t\}$, and wage rates $\{w_t\}$, such that: (1) households optimize; (2) firms freely enter; (3) employment

[14] Under the Hosios (1990) rule and thus $\beta = \gamma$, the bargaining is efficient. The results in our paper hold no matter whether the bargaining is efficient or not.

[15] The household takes profits and future values as given when bargaining over current values. An individual worker also takes all other members' bargains in the current period as given. See Fang and Rogerson (2009).

evolutions hold; (4) labor-market matching and wage bargaining conditions are met; (5) the government budget is balanced; and (6) the goods market clears.

A steady state is search equilibrium when all variables do not change over time. In a steady state, $e_{t+1} = e_t = e$ and the interest rate r is equal to the time preference rate ρ. Moreover, the labor market satisfies the following matching relationships (Beveridge curve) $p(1-e) = qv = m(1-e)^{\gamma}(v)^{1-\gamma} = \lambda e$. In the appendix, we use these relationships to solve the two matching rates and the vacant jobs as functions of e, with $p'(e) > 0, q'(e) < 0$, and $v'(e) > 0$. Intuitively, more employment e decreases job seekers. Thus, the job finding rate is increasing in employment and the recruitment rate is decreasing in employment. Moreover, while vacant jobs are directly negatively related to employment, they are also positively related to the job finding rate and negatively related to the recruitment rate. More employment raises the job finding rate and reduces the recruitment rate and these indirect effects on vacant jobs dominate the direct effect of employment. As a result, more employment also increases vacant jobs.

Aggregate output is ey and total profits are $\Pi = e(y - wh - \phi\lambda)$, with the profits being remitted to the household. If we use (2) and (9), the goods market clearing condition is $c = e[f(h) - \phi\lambda] \equiv c(e, h)$, where positive consumption requires $f(h) - \phi\lambda > 0$. Differentiation gives $c_e = f(h) - \phi\lambda > 0$, $c_h = ef'(h) > 0$, $c_\phi = -\lambda e < 0$ and $c_\lambda = -\phi e < 0$. Note that when a job is separated, the worker enters the unemployment pool, but the destroyed job is gone. If the firm chooses to create a job, the cost of creation and maintenance is ϕ in each period. Following existing wisdom such as Fang and Rogerson (2009), we have assumed that the cost of a vacant job is not a one-shot cost of creating a job; it is the cost of creating and maintaining a job in each period. As the job separation rate is λ, in the steady state the firms create and maintain λe vacant jobs in each period. Thus, the net output is equal to the output minus the cost of job creation and maintenance which is $\phi\lambda e$.

In the Appendix, we use (4) to derive the change in total household utility in a steady state $U_e(e)$ and (5a) to derive the value of a filled job in a steady state π_e. Moreover, in a steady state, the free-entry condition implies that a firm will create vacant jobs until the value of an unfilled job equal to the cost: $\pi_v = \phi$. We must note that, due to the setup that the value of an individual job to a firm is independent of the number of jobs the firm already has, employment does not affect these three values above. By using these three values, the first-order condition of the wage bargaining in (8) gives

$$\beta \left[\frac{1+\rho}{\rho+\lambda+p} \left(wh - \frac{g(h)}{u'(c)} \frac{1}{(1-\tau)} \right) \right]^{-1} = (1-\beta) \left[\frac{1+\rho}{\rho+\lambda} (f(h) - wh) - \phi \right]^{-1}. \tag{10}$$

In (10), the left-hand side is the marginal benefit of the household, referred to as MB_w, which is decreasing in the wage rate. The right-hand side of (10) is the marginal cost of the firm, referred to as MC_w, which is increasing in the wage. Thus, given e and h, there is a unique bargained wage in equilibrium. See E_0 in Fig. 1.

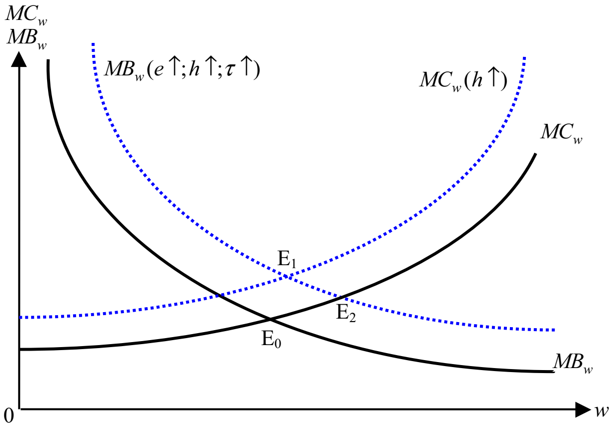

Fig. 1 Equilibrium wage

Rearranging terms in (10) and using the relationship $c = c(e, h)$ give the bargained wage as a function of e and h,

$$w = w\left(\underset{(+)}{e}, \underset{(+)}{h}; \underset{(+)}{\tau}\right) \equiv \beta \frac{(\rho + \lambda + p)}{\rho + \lambda + \beta p}[AP(h)] + (1 - \beta)\frac{(\rho + \lambda)}{\rho + \lambda + \beta p} \left[\frac{MRS(c(e, h), 1 - eg(h))}{1 - \tau} \frac{g(h)}{h}\right], \tag{11}$$

where $MRS(c(e, h), 1 - eg(h)) \equiv \frac{1}{u'(c)}$ is the marginal rate of substitution between consumption and leisure and $AP(h) = \frac{1}{h}[f(h) - \frac{\rho+\lambda}{1+\rho}\phi]$ is a worker's average output of hours net of the vacancy creation cost. The wage is the weighted average of the net average product (the value of working hours) and the marginal utility of leisure in terms of the marginal utility of consumption (the value of leisure hours).[16]

In equilibrium, as both sides of a match agree upon the wage set through the Nash bargaining process, a vacant job is filled by a job seeker. On the one hand, the value of a filled job π_e is $(+\frac{\rho}{q})$ times of the value of a vacant job π_v=ϕ. On the other hand, the wage of employment in (11) is a weighted average of the average product and the value of leisure hours which is larger than the value of outside option of the unemployed. Thus, by agreeing upon the bargained wage, both sides of a match are better off.

To characterize the bargained wage, it is easy to see from Fig. 1 that a higher employment level e does not affect the MC_w locus, since employment does not affect the values of a filled job and an unfilled job in a steady state. Yet, a higher employment level e shifts the MB_w locus upward. The reasons are that the large household has higher

[16] We note that a low-skilled worker is different from the case of β going to 0. Unless AP is zero, it is difficult to justify the case of β going to 0 in that a worker would not accept a job offer if he/she is paid only a wage equal to the value of leisure hours.

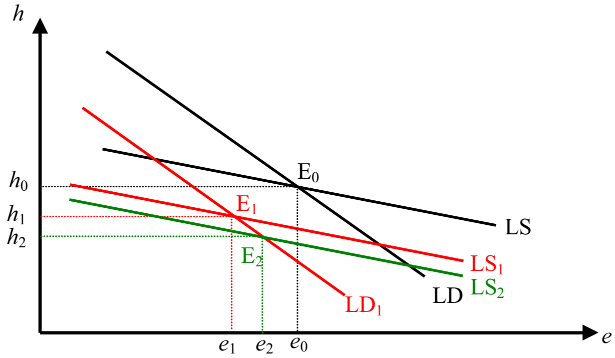

Fig. 2 Steady state and effects of higher wage taxes when the supply of hours is bargained by job-worker pairs

output and thus, higher consumption which increases the marginal rate of substitution between consumption and leisure. As a result of a higher opportunity cost of leisure in terms of consumption, the reservation wage of a worker is increased. Thus, the firm needs to pay a higher wage. Next, a longer hour h shifts both the MB_w and MC_w loci upward and has an ambiguous effect on the wage. Since the utility function implies that the value of leisure is greater for unemployed members than for employed members,[17] near the steady state it is harder to ask employed workers to work more hours. Thus, the MB_w locus is shifted more, so the bargained wage is increasing in h. Finally, a higher labor tax rate reduces a worker's after-tax wage and shifts the MB_w locus upward and the firm needs to pay a higher wage rate.

Finally, by using (11), (5b) the firm's free-entry condition $\pi_v = \phi$ is written as

$$\Omega\left(\underset{(-)}{e}, \underset{(-)}{h}; \underset{(-)}{\tau}\right) \equiv \frac{q(e)}{\rho + q(e)} \frac{1+\rho}{\rho+\lambda} [f(h) - w(e, h; \tau)h] - \phi = 0. \qquad (12)$$

In (12), the marginal cost of a vacant job is constant at ϕ while the marginal benefit is decreasing in employment e. Thus, with given hours (12) gives a unique employment level. It is easy to see that a longer work hour h increases the output and thus the marginal benefit, but a longer work hour also increases the labor cost and reduces the marginal benefit. As the effect on the labor cost dominates, the marginal benefit is decreasing in h (see "Appendix"). Thus (12) is downward-sloping in the $h - e$ space, referred to as the **firm's labor demand** (**LD**) curve in Fig. 2, indicating a trade-off between e and h from the firm perspective. The net marginal benefit of vacancies is decreasing in τ as a higher labor tax increases the bargained wage and pushes up the labor cost.

In addition to the labor demand condition, we need the worker's supply of hours in order to solve employment and hours in a steady state. Three kinds of mechanisms are studied in the next section.

[17] This is a property in search and match models; see, for example, Cheron and Langot (2004).

3 Effects of labor taxes on employment and working hours

In this section, we explore the relative magnitude of responses of hours and responses of employment to changes in labor taxes. We start with the mechanism when hours worked per worker are bargained by a matched job-worker pair. Then, we envisage the mechanism when the household chooses hours worked per worker. This case turns out to be an extreme event when the worker has a one-hundred percent hour bargaining power. Finally, we study the mechanism in the other extreme when hours worked per worker are regulated.

As the curvature of the leisure utility affects relative effects, to ease analysis we use the form

$$g(h) = \bar{g}h^{1+\varepsilon}, \quad \bar{g} > 0, \quad \varepsilon \geq 0. \tag{13}$$

The form satisfies $g(0) = 0$, $g'(h) > 0$ and $g''(h) \geq 0$, wherein $1/\varepsilon$ is the hour supply elasticity. Then, the leisure utility of an employed worker is $1 - \bar{g}e_t h_t^{1+\varepsilon}$ and is weakly convex in hours. In the limit when $\varepsilon = 0$ and thus the hour supply elasticity is infinite, then $g'(h) = \bar{g}$, and the leisure utility $1 - \bar{g}e_t h_t$ is linear in both employment and hours per worker.

3.1 Hours bargained by job-worker pairs

Now, we analyze the case when hours worked per worker are bargained by a matched job-worker pair.[18] The hour bargaining leads to

$$-\frac{\beta_h}{U_e(e_t)}\frac{\partial U_e(e_t)}{\partial h_t} = \frac{1-\beta_h}{\pi_{et}-\pi_{vt}}\left(\frac{\partial \pi_{et}}{\partial h_t} - \frac{\partial \pi_{vt}}{\partial h_t}\right), \tag{14a}$$

where $\frac{\partial U_e(e_t)}{\partial h_t} = u'(c_t)(1-\tau)w_t - g'(h_t)$,[19] $\frac{\partial \pi_{et}}{\partial h_t} = f'(h_t) - w_t$ and $\frac{\partial \pi_{vt}}{\partial h_t} = 0$. We denote the worker's hour bargaining power in (14a) asβ_h, which may or may not be equal to the worker's wage bargaining power β in (11).

In (14a), the left-hand side is the change in the household's marginal utility which is the marginal cost of working an additional hour. The right-hand side is changes in the firm's marginal gain from an additional hour. In steady state, Eq. (14a) becomes

[18] Rocheteau (2002), Fang and Rogerson (2009) and Shimer (2008), among others used bargaining to determine hours worked per worker.

[19] To obtain the expression, we follow Fang and Rogerson (2009, p. 1158) and consider the case with finite family members. Let E_t denote the number of members that are employed in period t. In the bargaining over hours, we take the derivatives of $U(E_t) - U(E_t - 1)$ with respect to the current hours of the Eth worker, taking as given the hours of all other $(E_t - 1)$ workers in the family. Thus, working hours of the Eth worker only enter into the current period utility in $U(E_t)$ and do not enter into $U(E_t - 1)$. Therefore, if the Eth worker works one more hour, consumption is increased by the unit of $(1-\tau)w_t$ while leisure is decreased by $g'(h_t)$ which would change the value of $U(E_t)$ by $u'(c_t)(1-\tau)w_t - g'(h_t)$.

$$-\beta_h \frac{u'(c)(1-\tau)w - g'(h)}{\frac{1+\rho}{\rho+\lambda+p}\left[u'(c)(1-\tau)wh - g(h)\right]} = (1-\beta_h)\frac{f'(h) - w}{\frac{1+\rho}{\rho+\lambda}(f(h) - wh) - \phi}. \tag{14b}$$

Substituting the bargained wage rate in (11) into (14b) and rearranging terms yields

$$\begin{aligned}\Gamma(e, h; \tau) \equiv\ & MRS(c(e,h), 1-eg(h))g'(h) - \frac{\beta}{\beta_h}\frac{1-\beta_h}{1-\beta}(1-\tau)MP(h) \\ & -\frac{\beta_h - \beta}{\beta_h(1-\beta)}(1-\tau)w(e,h) = 0,\end{aligned} \tag{15a}$$

where $MP(h) \equiv f'(h)$ is the marginal product of hours per worker.

To start, consider the case when $\beta_h = \beta$ and thus the worker's share in the hour bargaining is the same as that in the wage bargaining. Thus (15a) is

$$\Gamma\left(\underset{(+)}{e}, \underset{(+)}{h}; \underset{(+)}{\tau}\right) = MRS(c(e,h), 1-eg(h)) \cdot g'(h) - (1-\tau)MP(h) = 0. \tag{15b}$$

Then, hours worked per worker are determined by the marginal cost of hours $MRS \cdot g'$ equal to the after-tax marginal gain of hours. Eq. (15b) is referred to as the **worker's labor supply** (**LS**) curve. In (15b), given employment, the net marginal cost of labor supply is increasing in hours ($\partial\Gamma/\partial h > 0$) as longer hours increase the marginal cost but decrease the marginal gain. Moreover, the net marginal cost of labor supply is increasing in employment ($\partial\Gamma/\partial e > 0$). The reason is that higher employment augments the marginal cost, as resulted from higher pooled consumption and lower pooled leisure in the large household which increases the marginal utility of leisure relative to the marginal utility of consumption (see "Appendix 5"). Therefore, the LS curve is downward-sloping in the $h - e$ space, indicating an underlying trade-off between e and h from the household perspective.

The LS curve (15b) and the LD curve (12) together determine e and h in steady state. Although both the LD and the LS curves are downward-sloping in the $h - e$ space, in the Appendix we have shown that the LS curve is always flatter than the LD curve at any point of intersection, implying that there is at most one intersection. See E_0 in Fig. 2. Their relative slopes reflect the fact that labor demand (labor supply) is more (less) elastic on the extensive relative to the intensive margin.

Once we determine the unique pair of hours (h_0) and employment (e_0) in a steady state, we can use other conditions to solve for other variables. In particular, the product of employment and hours per worker gives working hours per person ($e_0 h_0$).

We now analyze the effect of an increase in labor taxes. Holding employment fixed, the magnitude of the responses of hours per worker to changes in labor taxes in both LD and LS curves are derived by differentiating (12) and (15a) with respect to h and τ. The comparative-static results are

$$\left.\frac{dh}{d\tau}\right|_{LD} = -\frac{\Omega_\tau}{\Omega_h}, \tag{16a}$$

$$\left.\frac{dh}{d\tau}\right|_{LS} = -\frac{\Gamma_\tau}{\Gamma_h}, \tag{16b}$$

where $\Omega_\tau < 0$, $\Omega_h < 0$, $\Gamma_\tau > 0$, and $\Gamma_h > 0$.[20]

There are three cases: (1) β_h=β, (2) $\beta_h > \beta$ and (3) $\beta_h < \beta$. While the case of $\beta_h = \beta$ corresponds to an institutional regime where workers are equally concerned about working hours and wages, the case of $\beta_h > \beta$ characterizes an institutional regime where workers are more concerned about working hours relative to wages: workers use their bargaining power in setting hours. By contrast, the case of $\beta_h < \beta$ corresponds to an institutional regime where workers are less concerned about working hours relative to wages.

First, in the case when $\beta_h = \beta$, $(1-\tau)f' = MRS \cdot g'$ and we can simplify the expressions for Ω_τ, Ω_h, Γ_τ and Γ_h. In this case, under a linear leisure utility, $g' = \bar{g}$ and $g'' = 0$ Then, ((16a) and (16b) become, respectively,

$$\left.\frac{dh}{d\tau}\right|_{LD} = -\frac{f'}{MRS_h \cdot \bar{g}} < 0, \tag{17a}$$

$$\left.\frac{dh}{d\tau}\right|_{LS} = -\frac{f'}{MRS_h \cdot \bar{g} - (1-\tau)f''} < 0, \tag{17b}$$

First, a higher labor tax shifts the LD curve downward. The reason is that a higher labor tax increases the bargained wage and decreases a firm's marginal benefit of vacant jobs. In optimum, given employment, hours per worker need to lower in order to increase the marginal benefit of vacant jobs thereby shifting the LD curve downward. Moreover, a higher labor tax also shifts the LS curve downward, since it decreases a household's after-tax marginal gain of hours. In optimum, given employment, the household needs to decrease hours per worker in order to decrease the net marginal cost of hours per worker. Notice that a linear leisure utility in hours helps pin down the relative shift. With ε=0 and thus $g(h) = \bar{g}h$, the LD curve is shifted downward more than the LS curve, as $MRS_h \cdot \bar{g} - (1-\tau)f'' > MRS_h \cdot \bar{g} > 0$. See E_1 in Fig. 2. The relative shifts are similar when $g(h)$ is concave. It follows that a higher labor income tax reduces both hours and employment.

Intuitively, given employment, a higher labor tax increases the hourly bargained wage and lowers the firm's demand for hours per worker. Similarly, given employment, a higher labor tax reduces the net hourly bargained wage and lowers hours worked per worker. Now, the household cannot flexibly change but needs to negotiate hours per worker with the matched firm. Then, the household is not able to reduce hours worked per worker sufficiently even if the leisure utility is linear in hours. As a result, a higher labor tax reduces both hours worked per worker and employment, like those in Fang and Rogerson (2009).

Next, we explore the case of $\beta_h > \beta$ and examine the effects of labor taxes on employment and hours. To see the effects in this case, we carry out the exercise of increasing β_h while holding the worker's share in the wage bargaining fixed at β so

[20] See the "Appendix" for the derivation.

that $\beta_h > \beta$. While such a change does not influence the LD curve, the effect on the LS curve is affected as follows.[21]

$$\frac{d\Gamma_\tau}{d\beta_h} = \frac{\beta}{1-\beta}\frac{1}{\beta_h^2}\left(\frac{\beta(\rho+\lambda+p)}{\rho+\lambda+\beta p}AP(h) - f'\right) > 0,$$
$$\frac{d\Gamma_h}{d\beta_h} = \frac{\beta}{1-\beta}\frac{(1-\tau)}{\beta_h^2}(f'' - w_h) < 0.$$

Obviously, when workers are more concerned about working hours relative to wages, the firm's net marginal benefit of labor demand is not influenced. Yet, the effect of labor taxes on the net marginal cost of labor supply increases [i.e., the numerator in (16b)] and the effect of work hours on the net marginal cost of labor supply decreases [i.e., the denominator in (16b)]. As a result, the LS curve shifts downward by more to LS_2 in Fig. 2. Given a fixed level of employment, this means a relatively smaller adverse effect of labor hours on the household's net marginal cost of labor supply, which implies an amplified response of hours and a diminished response of employment to changes in labor taxes.

Finally, the exercise in the case of $\beta_h < \beta$ is carried out by decreasing β_h while holding the worker's hour bargaining power fixed at β. Now, as workers are less concerned about hours relative to wages, hours per worker are decreased by less and employment is decreased by more.

To summarize the effects of labor taxes when workers have different concerns about hours relative to wages,

Proposition 1 *Let hours worked per worker and the wage be determined by a cooperative bargaining game and there is a rise in labor taxes.*

(i) *When the wage bargaining power is equal to the worker's hour bargaining power, both hours worked per worker and employment are decreased;*
(ii) *as the hour bargaining power increases, hours per worker is decreased by more and employment is decreased by less;*
(iii) *as the hour bargaining power decreases, hours per worker is decreased by less and employment is decreased by more.*

We must point out that the above results are not affected by changes in lump-sum transfers. If the government does not transfer the tax revenue to household but throws away the tax revenue, the income effect is reduced. As consumption and leisure are normal goods, both reduce and thus work hours increase. Yet, the effects of higher labor taxes on labor hours are qualitatively the same, because higher labor taxes bring in a substitution effect between leisure and work hours and the household would choose more leisure and less work hours. In particular, with other things being equal, in response to higher labor taxes, working hours would be reduced by more in an economy with a larger worker's hour bargaining power.

[21] The sign holds when β is not too small or the curvature of the production $f(h)$ is not too flat.

3.2 Hours determined by households

The above subsection analyzes the relative effect of labor taxes on employment and hours when hours per worker are determined by bargaining. Now, we analyze the relative effect of labor taxes on employment and hours in the situation when hours per worker are determined by the household. In this case, the household chooses hours by trading off between consumption and leisure. Prescott (2004) and many other neoclassical growth models such as Rogerson (2008) and Azariadis et al. (2013) use the same mechanism to determine hours worked per worker. If we maximize (3) subject to (1) and (2), the first order condition with respect to h_t gives

$$MRS(c_t, 1 - e_t g(h_t))g' \equiv \frac{g'}{u'(c_t)} = (1-\tau)w_t. \tag{18a}$$

In the left-hand side of (18a) is the marginal rate of substitution between leisure and consumption which is the marginal cost of hours worked per worker. The right-hand side is the after-tax wage rate which is the marginal gain of hours worked per worker. Notice that in (14b), when β_h is larger, there is a larger household's marginal cost of hours worked per worker and a smaller firm's marginal gain of hours. When the household can freely choose hours worked, β_h goes to the largest so that β_h=1. Then, the household's marginal cost of hours is the largest and the firm's marginal gain of hours is the smallest. In this situation, the right-hand side of (14b) is zero so that (14b) degenerates to (18a). Thus, (18a) is a special case of (14b) which emerges when β_h=1.

By using the bargained wage (11) and the consumption expression, (18a) is rewritten as a form of a zero net marginal cost of hours as in (15b).[22]

$$\Gamma\left(\underset{(+)}{e}, \underset{(+)}{h}; \underset{(+)}{\tau}\right) \equiv MRS(c(e,h), 1 - \bar{g}eh)\bar{g} - (1-\tau)AP(h) = 0. \tag{18b}$$

which is referred to as the **flexible-hour labor supply** (**FLS**) curve.[23]

Like the LS curve in (15b), here the FLS curve is also downward-sloping in the $h - e$ space. The LD curve in (12) and the FLS curve in (18b) together determine a unique pair of e and h in a steady state. See E_0 in Fig. 3. As in Sect. 3.1, a higher labor tax shifts both the LD and the FLS curves downward. In particular, when ε=0, given employment, both curves decrease hours at the same level and as a result, a higher labor tax reduces only hours without affecting employment.

$$\left.\frac{dh}{d\tau}\right|_{LD} = -\frac{\Omega_\tau}{\Omega_h} = -\frac{AP(h)}{MRS_h \cdot \bar{g} - (1-\tau)AP_h(h)} < 0,$$

[22] If $e = 1$, there is no friction in the labor market and the wage rate is determined solely by the marginal product of labor as it is in Prescott (2004).

[23] Note that if ε=0 and thus, a linear utility of leisure in hours, then $MRS \cdot g' = MRS \cdot \bar{g}$. Hence, the difference lies only in $MP(h)$ in (15b) and $AP(h)$ in (18b).

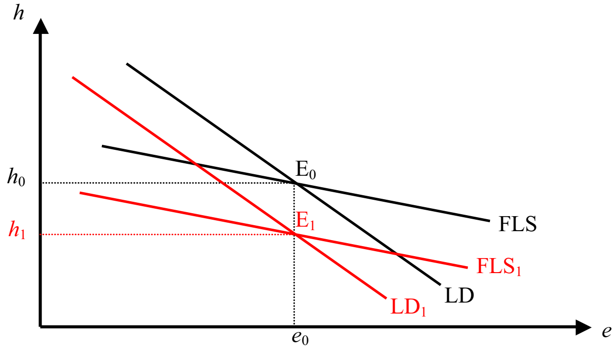

Fig. 3 Steady state and effects of higher wage taxes when the supply of hours is determined by households

$$\left.\frac{dh}{d\tau}\right|_{FLS} = -\frac{\Gamma_\tau}{\Gamma_h} = -\frac{AP(h)}{MRS_h \cdot \bar{g} - (1-\tau)AP_h(h)} < 0,$$

where $MRS_h = -\frac{u'' c_h}{(u')^2} > 0$ and $AP_h(h) = \frac{1}{h}(f'(h) - AP(h)) < 0$.

The result can be understood as follows. Now, the household can flexibly choose hours worked per worker. In the case when ε=0, the Frisch hour elasticity ($1/\varepsilon$) is the infinite. Then, as labor taxes increase, given employment, the household would reduce the supply of hours worked per worker exactly to the level the firm demands. As a result, employment is not changed and all the effects are on hours. Conversely, when ε >0, the Frisch hour elasticity is less than infinite. Then, given employment, the household would not reduce the supply of hours per worker to exactly the level the firm demands. Thus, employment is also reduced in a steady state. Nevertheless, when ε is smaller, the Frisch hour elasticity is larger. The household reduces more of hours worked per worker and less of employment. Thus, the negative effect on hours is larger and the negative effect on employment is smaller.

To summarize results, we obtain[24]

Proposition 2 *Let hours worked per worker be exclusively determined by the household. Then,*

(i) *under a linear utility of leisure in hours, a higher labor tax reduces only hours without an impact on employment;*

[24] Our results in this subsection indicate that in a search model, when hours worked per worker is completely determined by the household, a rise in labor taxes does not have an adverse effect on employment. All the detrimental effects of labor taxes are on hours per worker. Intuitively, as the after-tax wage per hour is decreased, the employed worker chooses more leisure hours and less work hours and thus, less consumption. As in a frictionless neoclassical growth model, the adverse effect on work hours emerges here because we assume that the substitution effect dominates the income effect. In the case when the substitution effect is small, it is possible that the income effect dominates the substitution effect and there is thus a backward bending portion of the labor supply curve. Then a rise in labor tax would increase rather than decrease hours worked per worker.

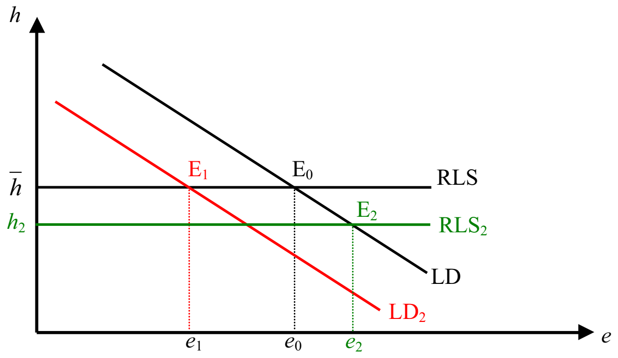

Fig. 4 Steady state and effects of higher wage taxes when the supply of hours is regulated by authorities

(ii) *if the utility of leisure is convex in hours, the flatter the utility, the more hours worked per worker and the less employment are decreased.*

3.3 Hours regulated by authorities

Finally, we analyze the relative effect of labor taxes on employment and hours in the situation when hours worked per worker are regulated by the union and the government. In this case, hours worked per worker are fixed. Marimon and Zilibotti (2000) and others used regulation to determine hours worked per worker.[25] Following Marimon and Zilibotti (2000), we assume that there is a regulation of maximum work time which is reduced from the level of bargained hours in Sect. 3.1 and the regulation is effectively enforced. Suppose that hours are initially at the level of the market equilibrium. In this case, $h_t = \bar{h}$ is referred to as the **regulated-hour labor supply** (**RLS**) curve in Fig. 4. In steady state, while the horizontal RLS curve $h = \bar{h}$ determines hours worked per worker, the downward-sloping LD curve (12) determines employment e. We have shown that there exists a unique steady state. With$h = \bar{h}$ in Fig. 4, then E_0 is the steady state and $e = e_0$.

To analyze the effect of a higher labor income tax, it is obvious that the RLS curve is not affected while the FE curve is shifted downward in the $h - e$ space. As a result, hours are unchanged but the employment is reduced. See E_1 in Fig. 4. Intuitively, a higher labor tax drives up the bargained wage and thus depresses the value of an unfilled job. As hours worked per worker are fixed, firms will respond to a higher labor income tax by creating less vacant jobs so employment is reduced in steady state. Thus, when hours are regulated, the labor tax only reduces employment without affecting hours.[26]

[25] See Calmfors (1985), Hoel and Vale (1986) and Marimon and Zilibotti (2000), among others.

[26] It is worth noting that when regulated hours are reduced, say from $\bar{h}$ to h_2 in Fig. 4, with other things being equal, the steady state changes from E_0 to E_2. Thus, a working time reducing policy can increase employment that achieves the goal "work less, work all."

This model matches the standard Mortensen–Pissarides search model wherein there is no hour margin and labor taxes only affect employment. In Ljungqvist and Sargent (2007a, 2008b), the labor supply is represented by jobs with some fixed hours and thus the labor supply is adjusted only by employment. Thus, when the labor income tax is increased, firms respond only by adjusting job creation and households only by changing job search. As a result, the effect of a higher labor tax is entirely on employment.

To recapitulate our results in this section, the relative effects of a higher labor income tax on employment and hours worked per worker depends on hour-shaping mechanisms. The effect on employment changes from a small negative effect when hours worked per worker are determined exclusively by the household, to a larger negative effect when hours worked per worker are determined by bargaining, and finally to a full negative effect when hours worked per worker are effectively regulated. Although our analysis above abstracts from the capital adjustment, we have shown that these results are robust if capital is adjustable. See the Appendix 1.

3.4 Tax effects when other parameters change

The previous three subsections envisage the relative responses of employment and hours to labor taxes when the mechanisms determining hours are changed. Other factors may also affect the relative effects on employment and hours to labor taxes. This subsection investigate parameters such as productivity, leisure preferences, costs of job creation and maintenance, job extinction rates, the matching efficiency, interest rates and time preferences. In order to study how changes in these parameters influence the relative responses of employment and hours to labor taxes, we focus on the case when the hour bargaining power is equal to the wage bargaining power, $\beta_h = \beta$.

Firstly, to study the effect of a rise in the productivity, we denote A as the productivity. Then, it is clear that $\frac{df'}{dA} \equiv f'_A > 0$ and $\frac{df''}{dA} \equiv f''_A < 0$. A rise in the productivity does not influence the effect of labor taxes on the LD curve. The effect on the LS curve is

$$\frac{d\Gamma_\tau}{dA} = f'_A > 0, \quad \frac{d\Gamma_h}{dA} = -(1-\tau) f''_A < 0,$$

Intuitively, a rise in the productivity increases the effect of labor taxes on the net marginal cost of labor supply and decreases the effect of labor hours on the net marginal cost of labor supply. As the result, there is a relatively smaller adverse effect of labor hours on the net marginal cost of labor supply. Thus, the response of hours to labor taxes increases and the response of employment decreases. Next, when the preference for leisure increases (an increase in$\bar{g}$), we also find that the effect of a higher labor tax on the LD curve is not affected. The effect on the LS curve is as follows.

$$\frac{d\Gamma_\tau}{d\bar{g}} = 0, \quad \frac{d\Gamma_h}{d\bar{g}} = MRS_h \cdot (1+\varepsilon)h^\varepsilon + MRS \cdot \varepsilon(1+\varepsilon)h^{\varepsilon-1} > 0,$$

which indicates that the numerator in (16b) is not affected and the denominator in (16b) is increased. Thus, the LS curve is shifted downward by less. As a result, a higher preference for leisure has effects qualitatively opposite to those of a higher productivity. Intuitively, a higher preference for leisure increases the effect of labor hours on the household's net marginal cost of labor supply. As a result, the response of hours to labor taxes decreases and the response of employment to labor taxes increases. This finding partly complements Eugster et al. (2011), Giavazzi et al. (2013) and Azariadis et al. (2013) who suggested an explanation of declining labor supply between Europeans and Americans based on different preferences for leisure.

Moreover, when the unit cost of job creation is increased (a higher ϕ), both the LD curve and the BH curves are shifted downward more as follows.[27]

$$\frac{d(-\frac{\Omega_\tau}{\Omega_h})}{d\phi} = \frac{c_\phi}{(1-\tau)c_h} < 0, \quad \frac{d\Gamma_\tau}{d\phi} = 0, \quad \frac{d\Gamma_h}{d\phi} = \frac{u'' c_\phi}{(u')^2}\left(2\frac{u'' c_h}{u'} \cdot g' - g''\right) < 0.$$

As a result, the adverse responses of employment and hours are both ambiguous. Intuitively, as a rise in job creation cost reduces the firm's net marginal gain of labor demand, the response of employment increases and the response of hours decreases. Yet, a rise in job creation cost also gives a relatively smaller adverse effect of labor hours on the household's net marginal cost of labor supply, which tends to increase the response of hour and decrease the response of employment. Therefore, the net effect on the responses of employment and hours are ambiguous, depending on whether the effect via the firm's labor demand or the effect via the household's labor supply dominates.

Furthermore, we analyze the effects of a rise in the matching efficiency (a higher m), the time preference rate (a higher r), and the interest rate (a higher ρ) on the relative responses of employment and hours to labor taxes. Note that in a steady state, the interest rate is equal to the time preference rate. We find that changes in all these parameters affected neither the LD curve nor the LS curve. Thus, they do not influence the magnitude of the response of employment and hour to a rise in labor taxes.

Finally, when there is a rise in the job extinction rate (a higher λ), both the LD curve and the LS curve are affected as follows.[28]

$$\frac{d(-\frac{\Omega_\tau}{\Omega_h})}{d\lambda} = \frac{\frac{1}{1-\tau}\left(\frac{MRS}{\rho+\lambda+\beta p} + \frac{u''}{(u')^2}c_\lambda\right)}{MRS_h \cdot \left(\frac{1}{\rho+\lambda+\beta p} + \frac{2u'' c_\lambda}{u'}\right)} > 0,$$

$$\frac{d\Gamma_\tau}{d\lambda} = 0, \quad \frac{d\Gamma_h}{d\lambda} = \frac{u'' c_\lambda}{u'}\left(2MRS_h g' - \frac{1}{u'}g''\right)\gtrless 0.$$

Thus, the LD curve is shifted downward less, which tends to give a larger adverse effect on hours and a smaller adverse effect on employment. However, the LS curve may be shifted downward more or less. As a result, the effects on the magnitude of the response of hours and the response of employment are ambiguous.

27 Under the assumption $u''' = 0$.

28 Under the assumption $u''' = 0$.

3.5 Model calibration

Our results indicate that the relative effects of a higher labor tax on employment and hours are different under different hour's determination mechanisms. This subsection studies a calibrated version of our model at a quarterly frequency and quantifies these effects. European countries increased their labor tax rates over past three decades. In calibration, we use as a baseline parameterization the average effective tax rate on the labor income in Europe in the early 1970s. The average effective tax rate was increased by about 30 % in the early 2000s. We quantify the effect of a 30 % increase in the average effective labor tax rate on employment and hours and envisage how the quantitative effect changes as the labor's hour-bargaining power increases.

The fraction of employment in the working-age population is about 75 % (cf. Kydland and Prescott 1991) and thus we set $e = 0.75$. As pointed out by Prescott (2006), the fraction of productive time allocated to the market ($L = eh$) is 25 % and this implies $h = 0.3333$. According to Shimer (2005), the quarterly separation rate is $\lambda = 0.1$. We employ the Beveridge curve relationships to compute the quarterly job finding rate at $p = \lambda e/(1 - e) = 0.3$. Moreover, we follow Shimer (2005) by normalizing the steady-state ratio of vacancies to searching workers to unity ($v/(1 - e) = 1$) which implies the vacancy creation in a steady state at $v = 0.25$. Then, we utilize the Beveridge curve relationships to calibrate the recruitment rate $q = \lambda e/v = 0.3$. Because the depreciation rate of capital is assumed to be zero in the model, we set a higher quarterly time preference rate at $\rho = 0.015$ to target the annual real interest rate of 6 % which is used by Bils et al. (2011). We assume the production function is $y_{it} = f(h_t) = Ak_i^{\alpha} h_t^{1-\alpha}$, where following Marimon and Zilibotti (2000), k_i is a firm-specific productive factor and all firms have an identical endowment of the fixed factor, i.e., $k_i = k$. The parameter A is normalized to be unity. The capital share is about one-third and we use the value $\alpha = 0.333$. (cf. Ljungqvist and Sargent 2007b, 2008b). Since the interest rate equals the time preference rate in the steady state, we use the production function to compute the level of capital at $k = 34.7856$.

By setting the aggregate consumption-output ratio at $c/(ey) = 0.6$, we use the consumption expression to calibrate $\phi = 6.2677$. We can then calibrate the wage rate at $w = 2.4638$ from (12). McDaniel (2007) calculated a series of tax rates in OECD countries. On the basis of average tax rates calculated by McDaniel (2007), Rogerson (2008) used the labor taxes in Belgium, France, Germany, Italy, and the Netherlands to represent the tax in Europe.[29] We follow this strand and calculate the population-weighted average effective tax rate on the labor income for these five European countries. We find that the average effective tax rate in 1970–1973 is 0.3982 which gives the labor tax rate at $\tau = 0.3982$ in the baseline.

Finally, for the utility function adopted in our paper, the parameter ε is the reciprocal of the labor supply elasticity (henceforth, *LSE*). The *LSE* ranged from 0.75 (Chetty et al. 2011) to 3.8 (Imai and Keane 2004). Within the range 0.75–3.8, we take 1 as the

[29] 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).

baseline value which implies $\varepsilon = 1$.[30] Given this value and under an equal bargaining power of the wage and the hour in the baseline $\beta_h = \beta$, (19b) is used to solve for $\bar{g} = 4.014$. We then use (11) to obtain $\beta = 0.6998$, which is close to the value of 0.72 used by Shimer (2005). Assuming that Hosios' rule holds (Hosios 1990), $\gamma = \beta$ and hence a search worker's contribution to matching is pinned down by the labor's share in the wage bargaining. Then, from the Beveridge curve relationship to calibrate $m = 0.3$. The parameter values, observables and calibrated values are listed in Table 1. Under the benchmark parameter values, we obtain a unique steady state.

We now quantify the effect of labor income taxes (τ) on employment e and hour per worker h and thus hours per person eh. Using the data in McDaniel (2007), the population-weighted average effective tax rate on the labor income in Belgium, France, Germany, Italy, and the Netherlands is 0.5168 in 2000–2003, which is about an increase by 30 % from the baseline tax rate in 1970–1973.

First, to see the effect of an increase in labor taxes, we hold all parameter values unchanged except for the effective labor tax rate τ which is increased by 30 % from the baseline. See Table 2. In Row 3 wherein $\beta_h = \beta$, we find that as results of higher labor taxes, the employment e is decreased by 1.58 % while hours per worker h is decreased by 7.99 %. The results indicate that in a standard calibration model, labor income taxes have quantitatively large negative effects on employment and hours per worker. The results are consistent with existing studies on employment as well as those on hours.

Next, to see how a different labor's hour-bargaining power β_h affects the relative effect of a higher labor tax rate on employment and hours per worker, we quantify the effect of a deviation of the value of β_h from a labor's wage bargaining power β. See Table 2. It is clear that given β, when the labor's hour bargaining power β_h is decreased from the baseline, the negative effect on employment is quantitatively increasing while the negative effect on hours per worker are quantitatively decreasing (Rows 1–2). By contrast, when the labor's hour bargaining power β_h is increased from the baseline, the negative effect on employment is quantitatively diminishing while the negative effect on hours is quantitatively increasing (Rows 4–9). In particular, in the limit case when β_h increases to 100 % and thus hours worked per worker are completely determined by households, the negative effect on hours per worker is as high as 22.5 % and the negative effect on employment is only 0.29 % which is close to zero.

We may wonder how sensitive our quantitative responses of employment and hours to changes in labor taxes are with respect to the labor supply elasticity. To see the robustness, we carry out quantitative exercises by lowering the value of *LSE* from the baseline. We find that our results are robust when the value of *LSE* is lower to 0.6 (cf. Table 3). When the value of *LSE* is decreased to 0.5 or smaller, although our results remain hold true for cases of $\beta_h > \beta$, some of the results for the cases of $\beta_h < \beta$ no longer hold (cf. Table 4). In this case of $\beta_h < \beta$, a rise in labor tax causes an increase in hours worked per worker. The results arise because now the smaller substitution effect is dominated by the income effect and thus the labor supply is in the backward-bending

[30] We will do robustness analysis when a smaller value of *LSE* is used.

Table 1 Benchmark parameter values and calibration

	Variable	Quarterly	Sources
Benchmark parameters and observables			
Fraction of employment	e	0.7500	Kydland and Prescott (1991)
Hours of work	eh	0.2500	Prescott (2006)
Vacancy-searching worker ratio	$v/(1-e)$	1.0000	Shimer (2005)
Job separation rate	λ	0.1000	Shimer (2005)
Time preference rate	ρ	0.0150	Bils et al. (2011)
Capital's share	α	0.3330	Ljungqvist and Sargent (2007b, 2008b)
Aggregate consumption-output ratio	$c/(ey)$	0.6000	Data
Labor tax rate	τ	0.3982	McDaniel (2007), Rogerson (2008)
Labor supply elasticity (*LSE*)	$1/\varepsilon$	1.0000	Andolfatto (1996)
Calibration			
Hours worked per worker	h	0.3333	
Vacancy creation	v	0.2500	
Job finding rate	p	0.3000	
Employee recruitment rate	q	0.3000	
Capital	k	34.7856	
Unit cost of vacancy creation	ϕ	6.2677	
Equilibrium wage	w	2.4638	
Disutility of hours for the employed	$\bar{g}$	4.0140	
Labor's bargaining power for wage	β	0.6998	
Labor's bargaining power for hour	β_h	0.6998	
Labor's share in matching production	γ	0.6998	
Coefficient of matching technology	m	0.3000	

portion. The results complement Alesina et al. (2006) who suggested that Prescott's results held true only under a high *LSE*.

Finally, we also carry out exercises to understand how changes in the values of the productivity, leisure preferences, costs of job creation and job extinction rates quantitatively affect the magnitude of the response of hours and employment to increases in labor taxes. As an exercise, we increase the value of these parameters by 10 %. To be more specific, while maintaining the baseline parameter values unchanged, we

Table 2 Effects of increasing τ by 30 % when the hour bargaining power is different from the wage bargaining power (*LSE* = 1)

	e		h		eh	
Benchmark	0.75000	100 %	0.33333	100 %	0.25000	100 %
$\beta_h = 0.6$	0.73091	−2.55 %	0.32274	−3.18 %	0.23590	−5.64 %
$\beta_h = 0.65$	0.73489	−2.01 %	0.31459	−5.62 %	0.23119	−7.52 %
$\beta_h = \beta$	0.73815	−1.58 %	0.30670	−7.99 %	0.22639	−9.44 %
$\beta_h = 0.75$	0.74084	−1.22 %	0.29890	−10.33 %	0.22144	−11.42 %
$\beta_h = 0.8$	0.74304	−0.93 %	0.29117	−12.65 %	0.21635	−13.46 %
$\beta_h = 0.85$	0.74482	−0.69 %	0.28339	−14.98 %	0.21107	−15.57 %
$\beta_h = 0.9$	0.74622	−0.50 %	0.27543	−17.37 %	0.20553	−17.79 %
$\beta_h = 0.95$	0.74724	−0.37 %	0.26713	−19.86 %	0.19961	−20.16 %
$\beta_h = 1$	0.74786	−0.29 %	0.25827	−22.52 %	0.19315	−22.74 %

Parameter values are in Table 1 with baseline $\beta_h = \beta = 0.6998$

Table 3 Robustness of effects of increasing τ by 30 % when the *LSE* is decreased to *LSE* = 0.6

	e		h		eh	
Benchmark	0.75000	100 %	0.33333	100 %	0.25000	100 %
$\beta_h = 0.65$	0.74110	−1.19 %	0.32816	−1.55 %	0.24320	−2.72 %
$\beta_h = 0.7$	0.74267	−0.98 %	0.32110	−3.67 %	0.23847	−4.61 %
$\beta_h = \beta$	0.74438	−0.75 %	0.31132	−6.60 %	0.23174	−7.30 %
$\beta_h = 0.8$	0.74496	−0.67 %	0.30716	−7.85 %	0.22882	−8.47 %
$\beta_h = 0.85$	0.74576	−0.57 %	0.30012	−9.96 %	0.22382	−10.47 %
$\beta_h = 0.9$	0.74635	−0.49 %	0.29290	−12.13 %	0.21861	−12.56 %
$\beta_h = 0.95$	0.74674	−0.44 %	0.28538	−14.39 %	0.21310	−14.76 %
$\beta_h = 1$	0.74690	−0.41 %	0.27735	−16.79 %	0.20715	−17.14 %

Parameter values are in Table 1 except for $\varepsilon = 1.6667$, $\bar{g} = 6.2627$ and $\beta = \gamma = 0.7702$

increase the labor tax rate by 30 % and one of these other parameter values by 10 %. The changes in the effects from the baseline (i.e., Row 3 in Table 2) are reported in Table 5. As compared to Row 3 in Table 2, a higher productivity reduces the response of employment to changes in labor taxes with a slight increase in the response of hours to increases in labor taxes. Next, a higher leisure preference runs an opposite result that increases the response of employment and decreases the response of hours to increases in labor taxes. Moreover, a larger cost of job creation increases the response of employment and decreases the response of hours to increases in labor taxes. In addition, a larger job extinction rate increases the response of employment with a slight increase in the response of hours to increases in labor taxes.

Our results in Table 5 indicate that, as compared to Row 3 in Table 2, in an economy with a higher preference for leisure, the overall effect on labor supply is negative, indicating the preference for leisure is one of the explanations for differential changes in labor supply in Europe and the U.S. based on different preferences for leisure.

Table 4 Robustness of effects of increasing τ by 30 % when the *LSE* is decreased further to *LSE* = 0.5

	e		h		eh	
Benchmark	0.75000	100 %	0.33333	100 %	0.25000	100 %
$\beta_h = 0.6$	0.74129	−1.16 %	0.33813	1.44 %	0.25065	0.26 %
$\beta_h = 0.65$	0.74279	−0.96 %	0.33130	−0.61 %	0.24609	−1.56 %
$\beta_h = 0.7$	0.74400	−0.80 %	0.32464	−2.61 %	0.24153	−3.39 %
$\beta_h = \beta$	0.74557	−0.59 %	0.31322	−6.03 %	0.23353	−6.59 %
$\beta_h = 0.8$	0.74575	−0.57 %	0.31149	−6.55 %	0.23229	−7.08 %
$\beta_h = 0.85$	0.74635	−0.49 %	0.30486	−8.54 %	0.22753	−8.99 %
$\beta_h = 0.9$	0.74677	−0.43 %	0.29807	−10.58 %	0.22259	−10.96 %
$\beta_h = 0.95$	0.74703	−0.40 %	0.29100	−12.70 %	0.21739	−13.04 %
$\beta_h = 1$	0.74711	−0.39 %	0.28351	−14.95 %	0.21181	−15.28 %

Parameter values are in parameter table except for $\varepsilon = 2$, $\bar{g} = 8.0280$ and $\beta = \gamma = 0.7868$

Table 5 Effects of increasing τ is 30 % when other parameters are increased

	e		h		eh	
Benchmark	0.75000	100 %	0.33333	100 %	0.25000	100 %
A	0.73991	−1.34 %	0.30667	−8.00 %	0.22691	−9.24 %
$\bar{g}$	0.73742	−1.68 %	0.30797	−7.61 %	0.22710	−9.16 %
ϕ	0.73566	−1.91 %	0.30685	−7.95 %	0.22573	−9.71 %
λ	0.73589	−1.88 %	0.30664	−8.01 %	0.22565	−9.74 %

Parameter values are in Table 1 except that the value of A, $\bar{g}$, λ or ϕ is increased by 10 % from their baseline

Moreover, a higher productivity (high creation) mitigates the adverse effect of labor taxes on labor supply (*eh*), and a higher job separation rate (high extinction) increase the adverse effect of labor taxes on labor supply. The results are useful to explain the observed adverse effects of an increase in taxes on labor supply in the EU (low creation/low extinction) relative to the US (high creation/high extinction).

4 Concluding remarks

The past 30 years have witnessed large declines in the labor supply in Europe relative to the US. High labor taxes are considered an important reason resulting in declines in labor supply. Increases in labor taxes sometimes have larger negative effects on employment but at times have larger negative effects on hours worked per worker. This paper studies the relative detrimental effects of higher labor taxes on employment and hours worked per worker and shows that the relative effects depend on the hour-shaping mechanisms.

We find that in the mechanism when hours worked per worker are bargained by a matched job-worker pair, a higher labor income tax would reduce employment and hours worked per worker. As the worker's share in the hour bargaining increases, hours worked per worker are decreased by more and employment is decreased by less. In the mechanism when hours worked per worker are decided exclusively by the household, this goes to the case that arises when the worker has a one-hundred percent hour bargaining power. In this situation, the negative effect on hours worked per worker is the largest and the effect on employment is the smallest. In extremis, when the utility of leisure is linear in hours, the negative effect is completely on hours worked per worker with a zero effect on employment. At the other extreme, in the mechanism when hours worked per worker are effectively regulated, a higher labor tax only reduces employment with a zero effect on hours worked per worker. The quantitative effects are consistent with the theoretical predictions. Thus, these different hour-shaping mechanisms help understand why, in facing higher labor taxes, there are sometimes stronger negative effects on hours worked per worker but at times stronger negative effects on employment.

Finally, we should remark some limitations of our model. In the model, the labor tax only affects the margin between working time and leisure time and between employment and unemployment. There is no option of non-participation and thus no arbitration between job search and inactivity. Our choice is based on two reasons. First, in reality the distinction between unemployment and non-participation is somewhat less clear. Indeed, Jones and Riddell (1999) used data from Canada and found that the active search criterion used by many statistical agencies to determine the allocation of workers between the unemployed state and the out of the labor force state is potentially misleading. The data excluded a group of so-called marginally attached workers wanting a job but having not actively searched in the last four weeks. These workers do have somewhat lower transition rates into employment than do active searchers, but they have transition rates into employment that are more than four times as high as the other nonparticipants. The same findings have emerged when this analysis was repeated for many other countries. Thus, Krusell et al. (2011) concluded that these passive searchers are more similar to unemployed workers than they are to nonparticipants. Second, we want to maintain the same tradeoffs between working hours and leisure hours and between employment and unemployment in our model as those of Andolfatto (1996) and Fang and Rogerson (2009). By maintaining these same tradeoffs, we can understand how separate bargaining powers for hours and wage affect the magnitude of responses of hours and responses of employment to changes in labor taxes. Nevertheless, there is indeed a non-labor force and an unemployed worker may choose to leave the labor force. This thus points to an extension of our model for further research.

Appendix A: This appendix derives matching rates, vacant jobs, and the values of the change in total household utility, a filled job and a vacant job in the steady state

We use the matching relationships to solve the two matching rates and the vacant jobs as functions of e.

$$p(e) = \frac{\lambda e}{1-e}, \quad \text{where } p'(e) > 0, \tag{19a}$$

$$q(e) = m^{\frac{1}{1-\gamma}} \left(\frac{\lambda e}{1-e}\right)^{\frac{-\gamma}{1-\gamma}} = m^{\frac{1}{1-\gamma}} [p(e)]^{\frac{-\gamma}{1-\gamma}}, \quad \text{where } q'(e) < 0, \tag{19b}$$

$$v(e) = \left[\frac{\lambda e}{m(1-e)^{\gamma}}\right]^{\frac{1}{1-\gamma}} = m^{\frac{-1}{1-\gamma}} [p(e)]^{\frac{\gamma}{1-\gamma}} \lambda e, \quad \text{where } v'(e) > 0. \tag{19c}$$

Then, from (4), the change in total household utility in a steady state is

$$U_e(e) = \frac{1+\rho}{\rho+\lambda+p}\left[u'(c)(1-\tau)wh - g(h)\right]. \tag{20a}$$

From (5a), the value of a filled job in a steady state is

$$\pi_e = \frac{1+\rho}{\rho+\lambda}(f(h) - wh). \tag{20b}$$

Obviously, $f(h) > wh$ if employment is positive.

Moreover, in a steady state, the free-entry condition implies that a firm will create vacant jobs until $\pi_v = \phi$. Using (5b) and (20b), the free-entry condition implies

$$\pi_v = \frac{q}{\rho+q}\frac{1+\rho}{\rho+\lambda}(f(h) - wh) = \phi. \tag{20c}$$

Appendix B: This appendix derives the effects of labor taxes

The stead-state conditions are (12) and (15a). Differentiating these two conditions gives

$$\Gamma_e = MRS_e \cdot g' - \frac{\beta_h - \beta}{\beta_h(1-\beta)}(1-\tau)w_e \overset{\beta_h=\beta}{=} MRS_e \cdot g' > 0,$$

$$\begin{aligned}\Gamma_h &= MRS_h \cdot g' + MRS \cdot g'' - \tfrac{\beta}{\beta_h}\tfrac{1-\beta_h}{1-\beta}(1-\tau)f'' - \tfrac{\beta_h-\beta}{\beta_h(1-\beta)}(1-\tau)w_h \\ &\overset{\beta_h=\beta}{=} \underbrace{MRS_h \cdot g' +}_{\Gamma_h^1>0} \underbrace{MRS \cdot g'' - (1-\tau)f''}_{\Gamma_h^2>0} > 0,\end{aligned}$$

$$\Gamma_\tau = \frac{\beta}{\beta_h}\frac{1-\beta_h}{1-\beta}f' + \frac{\beta_h-\beta}{\beta_h(1-\beta)}\frac{\beta(\rho+\lambda+p)}{\rho+\lambda+\beta p}AP \overset{\beta_h=\beta}{=} f' > 0,$$

$$\begin{aligned}\Omega_e = &\underbrace{-\frac{q}{\rho+q}\frac{1+\rho}{\rho+\lambda+\beta p}\frac{(1-\beta)}{1-\tau}MRS_e g}_{\Omega_e^1<0} \\ &+ \underbrace{\frac{1+\rho}{\rho+q}\left[\frac{\rho q'}{\rho+q}\frac{f-wh}{\rho+\lambda} - \frac{q(1-\beta)\beta p'}{(\rho+\lambda+\beta p)^2}(AP - \frac{MRS}{1-\tau}\frac{g}{h})h\right]}_{\Omega_e^2<0} < 0,\end{aligned}$$

$$\Omega_h = \frac{q}{\rho+q}\frac{1+\rho}{\rho+\lambda+\beta p}\frac{(1-\beta)}{1-\tau}\left[\underbrace{(1-\tau)f' - MRS\cdot g'}_{=0 \text{ if } \beta_h=\beta} - MRS_h\cdot g\right] < 0,$$

$$\Omega_\tau = -\frac{q}{\rho+q}\frac{1+\rho}{\rho+\lambda+\beta p}\frac{(1-\beta)}{1-\tau}\frac{MRS\cdot g}{1-\tau} < 0.$$

Note that $\Omega_e^2 < 0$, because the surplus of a filled job net of the labor cost $(AP - \frac{MRS}{1-\tau}\frac{g}{h})$ must be positive in order for a vacant job to fill a worker. Under a linear leisure utility, $(AP - \frac{MRS}{1-\tau}\frac{g}{h}) == AP - MP$. Since $-\frac{\Gamma_e}{\Gamma_h} < 0$ and $-\frac{\Omega_e}{\Omega_h} < 0$, the BH and the FE curves are both downward sloping in the $h-e$ space. Moreover, by noting that $\Gamma_e\Omega_h = \Gamma_h^1\Omega_e^1$, we have $\Gamma_e\Omega_h - \Gamma_h\Omega_e = -\Gamma_h^1\Omega_e^2 - \Gamma_h^2\Omega_e > 0$, which implies $-\frac{\Gamma_e}{\Gamma_h} > -\frac{\Omega_e}{\Omega_h}$. Since the BH curve is always flatter than the FE curve at any point of intersection, there is at most one intersection.

For a given e, when τ increases, the BH and the FE curves shift downward as follows.

$$\left.\frac{dh}{d\tau}\right|_{LD} = -\frac{\Omega_\tau}{\Omega_h} = -\frac{MRS\cdot g/(1-\tau)}{MRS_h\cdot g + MRS\cdot g' - (1-\tau)f'} \overset{g(h)=\bar{g}h}{=} -\frac{f'}{MRS_h\cdot\bar{g}} < 0,$$

$$\left.\frac{dh}{d\tau}\right|_{LS} = -\frac{\Gamma_\tau}{\Gamma_h} = -\frac{\frac{\beta}{\beta_h}\frac{1-\beta_h}{1-\beta}f' + \frac{\beta_h-\beta}{\beta_h(1-\beta)}\frac{\beta(\rho+\lambda+p)}{\rho+\lambda+\beta p}AP}{MRS_h\cdot g' + MRS\cdot g'' - \frac{\beta}{\beta_h}\frac{1-\beta_h}{1-\beta}(1-\tau)f'' - \frac{\beta_h-\beta}{\beta_h(1-\beta)}(1-\tau)w_h}$$
$$\overset{\beta_h=\beta}{=} -\frac{f'}{MRS_h\cdot g' + MRS\cdot g'' - (1-\tau)f''} \overset{g(h)=\bar{g}h}{=} -\frac{f'}{MRS_h\cdot\bar{g} - (1-\tau)f''} < 0.$$

Although it is difficult to compare the relative downward shift of these two curves, a linear leisure utility helps pin down the relative magnitude. Under $g(h) = \bar{g}h$, since $(1-\tau)f''(h) < 0$, the BH curve is unambiguously shifted downward less than the FE curve. The following comparative state confirms this conjecture. As $\Gamma_\tau\Omega_h = \Gamma_h^1\Omega_\tau$ and $\Gamma_e\Omega_\tau = \Gamma_\tau\Omega_e^1$, we have $\Gamma_\tau\Omega_h - \Gamma_h\Omega_\tau = -\Gamma_h^2\Omega_\tau > 0$ and $\Gamma_e\Omega_\tau - \Gamma_\tau\Omega_e = -\Gamma_\tau\Omega_e^2 > 0$. Thus, $\frac{de}{d\tau} = -\frac{\Gamma_\tau\Omega_h - \Gamma_h\Omega_\tau}{\Gamma_e\Omega_h - \Gamma_h\Omega_e} <$ and $\frac{dh}{d\tau} = -\frac{\Gamma_e\Omega_\tau - \Gamma_\tau\Omega_e}{\Gamma_e\Omega_h - \Gamma_h\Omega_e} < 0$.

Appendix C: The model with capital adjustments

In this appendix, we show that the results in Sect. 3 are robust if capital is adjustable in the same way as was in Marimon and Zilibotti (2000).[31] We assume that the production function is now $y_t = k_t^\alpha(h_t)^{1-\alpha} = f(h_t, k_t)$ and capital k_t is accumulated by firms. As in Marimon and Zilibotti (2000), we think of final-goods producing firms that take the output from worker firms and combine it with capital. Hence, capital is separate from the wage bargaining process. The result will be the same if the firm rents capital from the household since the capital market is perfect. By assuming that capital k

[31] While the case with capital adjustment in Marimon and Zilibotti (2000) was carried out in a small open economy when the interest rate is taken as given, we will maintain the closed-economy setup and thus the interest rate is endogenously determined.

does not depreciate in order to simplify our analysis, then the interest rate equals the marginal product of capital: $r_t = f_k(h_{t+1}, k_{t+1})$.

The representative household's problem and the optimization conditions all remain the same as the model above. The government's behavior remains the same as (9). While the lifetime value of an unfilled job is also the same as (5b), the lifetime value of a filled job in (5a) is modified as

$$\pi_{et} = [f(h_t, k_t) - w_t h_t + k_t] + \frac{1}{1+r_t}(1-\lambda)\pi_{e(t+1)}. \tag{21}$$

Note that different from (5a), here the flow value in t includes the value of capital. In a steady state, the interest rate satisfies $r = \rho$ and hence $f_k(h, k) = \rho$. This implies that the capital-hour ratio in a steady state is constant and thus k is in proportion to h,

$$k = \kappa h \equiv k(h), \quad \text{where } \kappa = \left(\frac{\alpha}{\rho}\right)^{\frac{1}{1-\alpha}}.$$

The goods market clearing condition is now

$$c = e(f(h, k(h)) - \phi\lambda) \equiv \widehat{c}(e, h), \tag{22}$$

where $\widehat{c}_e = f(h, k(h)) - \phi\lambda > 0$ and $\widehat{c}_h = e(f_h + f_k k_h) > 0$.

From (21), the value of a filled job in a steady state is

$$\pi_e = \frac{1+\rho}{\rho+\lambda}(f(h, k(h)) - wh + k(h)),$$

and then the free-entry condition in a steady state is

$$\pi_v = \frac{q}{\rho+q}\frac{1+\rho}{\rho+\lambda}(f(h, k(h)) - wh + k(h)) = \phi. \tag{23}$$

From the first order condition of the wage bargaining problem, the bargained wage rate is

$$\begin{aligned} w = \widehat{w}(e, h; \tau) \equiv{}& \frac{\beta(\rho+\lambda+p)}{\rho+\lambda+\beta p}[AP(h)] + \frac{(1-\beta)(\rho+\lambda)}{\rho+\lambda+\beta p} \\ &\times \left[\frac{MRS(\widehat{c}, 1-eg(h))}{1-\tau}\frac{g(h)}{h}\right], \end{aligned} \tag{24}$$

where $AP(h) \equiv \frac{1}{h}(f(h, k(h)) + k(h) - \frac{\rho+\lambda}{1+\rho}\phi)$. Notice that the steady-state matching relationships given in the text still hold. Thus, p and q both are functions of e as stated in (19a) and (19b).

Substituting the bargained wage rate in (24) into (23) yields the free-entry condition

$$\Omega\left(\underset{(-)}{e},\underset{(-)}{h};\underset{(-)}{\tau}\right) \equiv \frac{q(e)}{\rho+q(e)}\frac{1+\rho}{\rho+\lambda}\left(f(h,k(h)) - \widehat{w}(e,h)h + k(h)\right) - \phi = 0, \tag{25}$$

which relates employment negatively to hours. As in Sect. 3, (25) is referred to as the LD curve.

C.1 Hours bargained by job-worker pairs

First, consider the mechanism when a worker's hours is determined by a matched pair in a bargaining game. When the laborer's hour bargaining power is β_h, the hour is determined by

$$-\beta_h \frac{u'(c)(1-\tau)w - g'(h)}{\frac{1+\rho}{\rho+\lambda+p}\left[u'(c)(1-\tau)wh - g(h)\right]} = (1-\beta_b)\frac{f_h(h,k(h)) - w}{\frac{1+\rho}{\rho+\lambda}(f(h,k(h)) - wh + k(h)) - \phi}.$$

Substituting (24) and (22) into the above expression yields

$$\begin{aligned}\Gamma(e,h;\tau) &\equiv MRS(\widehat{c}, 1-eg(h))g'(h) - \frac{\beta}{\beta_h}\frac{1-\beta_h}{1-\beta}(1-\tau)MP(h)\\ &-\frac{\beta_h-\beta}{\beta_h(1-\beta)}(1-\tau)\,\widehat{w}(e,h) = 0,\end{aligned} \tag{26}$$

which is the same as (15a) in Sect. 3.1 except $MP(h) \equiv f_h(h,k(h))$.

When $\beta_h = \beta$, (26) yields the LS curve like (15b) in Sect. 3.1 as follows.

$$\Gamma(e,h;\tau) \equiv MRS(\widehat{c}(e,h), 1-eg(h))g'(h) - (1-\tau)MP(h) = 0. \tag{27}$$

Hence, the steady-state condition includes the LD curve (25) and the LS curve (27) and determines e and h. Differentiating (25) and (27) gives

$$\Gamma_e = MRS_e \cdot g' - \frac{\beta_h - \beta}{\beta_h(1-\beta)}(1-\tau)\widehat{w}_e \overset{\beta_h=\beta}{=} MRS_e \cdot g' > 0,$$

$$\begin{aligned}\Gamma_h &= MRS_h \cdot g' + MRS \cdot g'' - \tfrac{\beta}{\beta_h}\tfrac{1-\beta_h}{1-\beta}(1-\tau)\underbrace{(f_{hh} + f_{hk}k_h)}_{=0} - \tfrac{\beta_h-\beta}{\beta_h(1-\beta)}(1-\tau)\widehat{w}_h\\ &\overset{\beta_h=\beta}{=} \underbrace{MRS_h \cdot g'}_{\Gamma_h^1>0} + \underbrace{MRS \cdot g''}_{\Gamma_h^2>0} > 0,\end{aligned}$$

$$\Gamma_\tau = \frac{\beta}{\beta_h}\frac{1-\beta_h}{1-\beta}f_h + \frac{\beta_h-\beta}{\beta_h(1-\beta)}\frac{\beta(\rho+\lambda+p)}{\rho+\lambda+\beta p}AP \overset{\beta_h=\beta}{=} f_h > 0,$$

$$\Omega_e = \underbrace{-\frac{q}{\rho+q}\frac{1+\rho}{\rho+\lambda+\beta p}\frac{(1-\beta)}{1-\tau}MRS_e \cdot g}_{\Omega_e^1<0}$$
$$+\underbrace{\frac{1+\rho}{\rho+q}\left[\frac{\rho q'}{\rho+q}\frac{f-wh+k}{\rho+\lambda}-\frac{q(1-\beta)\beta p'}{(\rho+\lambda+\beta p)^2}(AP-\frac{MRS}{1-\tau}\frac{g}{h})h\right]}_{\Omega_e^2<0} < 0,$$

$$\Omega_h = \underbrace{\frac{q}{\rho+q}\frac{(1+\rho)^2(1-\beta)}{\rho+\lambda+\beta p}k_h}_{\Omega_h^1>0}$$
$$+\underbrace{\frac{q}{\rho+q}\frac{1+\rho}{\rho+\lambda+\beta p}\frac{(1-\beta)}{1-\tau}\left[\underbrace{(1-\tau)f_h - MRS \cdot g'}_{=0} - MRS_h \cdot g\right]}_{\Omega_h^2<0},$$

$$\Omega_\tau = -\frac{q}{\rho+q}\frac{1+\rho}{\rho+\lambda+\beta p}\frac{(1-\beta)}{1-\tau}\frac{MRS \cdot g}{1-\tau} < 0.$$

By noting that $\Gamma_e\Omega_h^2 = \Gamma_h^1\Omega_e^1$, we have $\Gamma_e\Omega_h - \Gamma_h\Omega_e = \Gamma_e\Omega_h^1 - \Gamma_h^1\Omega_e^2 - \Gamma_h^2\Omega_e > 0$, which implies $-\frac{\Gamma_e}{\Gamma_h} > -\frac{\Omega_e}{\Omega_h}$. Since the LS curve is always flatter than the LD curve at any point of intersection, there is a unique steady state.

Given e, when τ is increased, the LS and the LD curves shift downward, respectively, as follows.

$$\left.\frac{dh}{d\tau}\right|_{LD} = -\frac{\Omega_\tau}{\Omega_h} = -\frac{MRS \cdot g/(1-\tau)}{MRS_h \cdot g + MRS \cdot g' - (1-\tau)f_h - (1-\tau)(1+\rho)k_h}$$
$$\overset{\tilde{g}(h)=gh}{=} -\frac{f_h}{MRS_h \cdot \bar{g} - (1-\tau)(1+\rho)k_h/h} < 0,$$

$$\left.\frac{dh}{d\tau}\right|_{LS} = -\frac{\Gamma_\tau}{\Gamma_h} = -\frac{\frac{\beta}{\beta_h}\frac{1-\beta_h}{1-\beta}f_h + \frac{\beta_h-\beta}{\beta_h(1-\beta)}\frac{\beta(\rho+\lambda+p)}{\rho+\lambda+\beta p}AP}{MRS_h \cdot g' + MRS \cdot g'' - \frac{\beta}{\beta_h}\frac{1-\beta_h}{1-\beta}(1-\tau)\widehat{w}_h}$$
$$\overset{\beta_h=\beta}{=} -\frac{f_h}{MRS_h \cdot g' + MRS \cdot g''} \overset{\tilde{g}(h)=gh}{=} -\frac{f_h}{MRS_h \cdot \bar{g}} < 0.$$

Thus, even under a linear leisure utility, the LS curve is shifted downward less than the LD curve and thus hours and employment both are reduced.

Finally, as $\Gamma_\tau\Omega_h^2 = \Gamma_h^1\Omega_\tau$ and $\Gamma_e\Omega_\tau = \Gamma_\tau\Omega_e^2$, then $\Gamma_\tau\Omega_h - \Gamma_h\Omega_\tau = \Gamma_\tau\Omega_h^1 - \Gamma_h^2\Omega_\tau > 0$ and $\Gamma_e\Omega_\tau - \Gamma_\tau\Omega_e = -\Gamma_\tau\Omega_e^2 > 0$. Thus, a higher labor tax reduces both hours per worker and employment.

$$\frac{de}{d\tau} = -\frac{\Gamma_\tau\Omega_h - \Gamma_h\Omega_\tau}{\Gamma_e\Omega_h - \Gamma_h\Omega_e} < 0 \quad \text{and} \quad \frac{dh}{d\tau} = -\frac{\Gamma_e\Omega_\tau - \Gamma_\tau\Omega_e}{\Gamma_e\Omega_h - \Gamma_h\Omega_e} < 0.$$

When $\beta_h > \beta$, we find that the LD curve is not affected. Moreover, $\frac{d\Gamma_h}{d\beta_h} = -\frac{\beta}{1-\beta}\frac{1-\tau}{\beta_h^2}\widehat{w}_h < 0$ and $\frac{d\Gamma_\tau}{d\beta_h} = -\frac{\beta}{1-\beta}\frac{1}{\beta_h^2}(\frac{\beta(\rho+\lambda+p)}{\rho+\lambda+\beta p}AP - f_h) > 0$ if β is not too small or productivity diminishes more in h. Thus, the BH curve is shifted downward more. Hence, even though capital is adjustable, when the worker's supply of hours is determined by a bargaining game, the relative effect of a higher labor tax on the intensive and extensive margins of labor supply in Proposition 1 continues to hold.

C.2 Hours determined by households

Next, consider the mechanism wherein, given employment, the supply of hours is exclusively decided the household. The leisure-consumption tradeoff condition is (18a). By using the bargained wage in (24), consumption in (22) and the utility of leisure linear in hours $\tilde{g}(h_t) = gh_t$, (18a) is rewritten to yield the following FH curve

$$\Gamma\left(\underset{(+)}{e}, \underset{(+)}{h}; \underset{(+)}{\tau}\right) \equiv MRS(\widehat{c}(e,h), 1 - eg(h))\bar{g} - (1-\tau)AP(h) = 0. \tag{28}$$

The steady-state conditions of model are (25) and (28) wherein p and q are functions of e, defined by (19a) and (19b), and c is a function of e and h, given by (22). Differentiating (25) and (28) gives $\Gamma_e = MRS_e \cdot \bar{g} > 0$, $\Gamma_h = MRS_h \cdot \bar{g} - (1-\tau)AP_h > 0$, $\Gamma_\tau = AP > 0$,

$$\Omega_e = \underbrace{-\frac{q}{\rho+q}\frac{1+\rho}{\rho+\lambda+\beta p}\frac{(1-\beta)}{1-\tau}MRS_e \cdot \bar{g}h}_{\Omega_e^1<0}$$

$$+ \underbrace{\frac{1+\rho}{\rho+q}\left[\frac{\rho q'}{\rho+q}\frac{f-wh+k}{\rho+\lambda} - \frac{q(1-\beta)\beta p'}{(\rho+\lambda+\beta p)^2}\overbrace{(AP - \frac{MRS\cdot\bar{g}}{1-\tau})}^{=0}h\right]}_{\Omega_e^2<0} < 0,$$

$$\Omega_h = \frac{q}{\rho+q}\frac{1+\rho}{\rho+\lambda+\beta p}\frac{(1-\beta)}{1-\tau} \times [(1-\tau)(f_h + f_k k_h + k_h) - MRS\cdot\bar{g} - MRS_h\cdot\bar{g}h] < 0,$$

$$\Omega_\tau = -\frac{q}{\rho+q}\frac{1+\rho}{\rho+\lambda+\beta p}\frac{(1-\beta)}{1-\tau}\frac{MRS\cdot\bar{g}}{1-\tau}h < 0,$$

where $AP_h = \frac{1}{h}(f_h + f_k k_h + k_h - AP)$. Since $\Gamma_e\Omega_h = \Gamma_h\Omega_e^1$, we have $\Gamma_e\Omega_h - \Gamma_h\Omega_e = -\Gamma_h\Omega_e^2 > 0$, which implies $-\frac{\Gamma_b}{\Gamma_e} > -\frac{\Omega_h}{\Omega_e}$. Since the FH curve is always flatter than the FE curve at any point of intersection, there is at most one intersection.

Further, by noting that $\Gamma_e\Omega_\tau = \Gamma_\tau\Omega_e^1$, we obtain $\Gamma_\tau\Omega_h - \Gamma_h\Omega_\tau = 0$ and $\Gamma_e\Omega_\tau - \Gamma_\tau\Omega_e = -\Gamma_\tau\Omega_e^2 > 0$. Thus, $\frac{de}{d\tau} = -\frac{\Gamma_\tau\Omega_h - \Gamma_h\Omega_\tau}{\Gamma_e\Omega_h - \Gamma_h\Omega_e} = 0$ and $\frac{dh}{d\tau} = -\frac{\Gamma_e\Omega_\tau - \Gamma_\tau\Omega_e}{\Gamma\Gamma_e\Omega_h - \Gamma_h\Omega_e} < 0$. Hence, even though capital is adjusted, when the supply of hours is determined exclusively by the household, under a linear leisure utility, a higher labor income tax only reduces hours per worker without affecting employment, a result the same as Proposition 2.

C.3 Hours regulated by authorities

Finally, when the worker's supply of hours is regulated effectively, the hour curve is replaced by $h = \bar{h}$. Then, the steady state is characterized by $h = \bar{h}$ and (25). The conditions are (25) and

$$\Gamma(e, h; \bar{h}, \tau) \equiv h - \bar{h} = 0. \tag{29}$$

Differentiating (25) and (29) gives

$$\Gamma_e = 0, \Gamma_h = 1, \Gamma_{\bar{h}} = -1, \Gamma_\tau = 0, \Omega_{\bar{h}} = 0,$$
$$\Omega_\tau = -\frac{q}{\rho+q}\frac{1+\rho}{\rho+\lambda+\beta p}\frac{(1-\beta)}{1-\tau}\frac{MRS\cdot g}{1-\tau} < 0,$$

$$\Omega_e = \underbrace{-\frac{q}{\rho+q}\frac{1+\rho}{\rho+\lambda+\beta p}\frac{(1-\beta)}{1-\tau}MRS_e\cdot g}_{\Omega_e^1<0}$$
$$+\underbrace{\frac{1+\rho}{\rho+q}\left[\frac{\rho q'}{\rho+q}\frac{f-wh+k}{\rho+\lambda} - \frac{q(1-\beta)\beta p'}{(\rho+\lambda+\beta p)^2}(AP - \frac{MRS}{1-\tau}\frac{g}{h})h\right]}_{\Omega_e^2<0} < 0,$$

$$\Omega_h = \underbrace{\frac{q}{\rho+q}\frac{(1+\rho)^2(1-\beta)}{\rho+\lambda+\beta p}k_h}_{\Omega_h^1>0}$$
$$\underbrace{+\frac{q}{\rho+q}\frac{1+\rho}{\rho+\lambda+\beta p}\frac{(1-\beta)}{1-\tau}\left[\underbrace{(1-\tau)f_h - MRS\cdot g'}_{=0} - MRS_h\cdot g\right]}_{\Omega_h^2<0}.$$

The comparative-static results are as follow: $\frac{de}{d\tau} = -\frac{\Gamma_\tau\Omega_h - \Gamma_h\Omega_\tau}{\Gamma_e\Omega_h - \Gamma_h\Omega_e} = -\frac{-\Omega_\tau}{-\Omega_e} < 0$, $\frac{dh}{d\tau} = -\frac{\Gamma_e\Omega_\tau - \Gamma_\tau\Omega_e}{\Gamma_e\Omega_h - \Gamma_h\Omega_e} = 0$. Thus, a higher labor tax rate only reduces employment. Hence, the results in Sect. 3.3 continue to hold.

Table 6 Working hours and employment in selected OECD countries relative to the US, 1970–1973 and 2000–2003

	Hours worked per person			Employment rate			Hours worked per worker		
	1970–1973	2000–2003	Diff.	1970–1973	2000–2003	Diff.	1970–1973	2000–2003	Diff.
Mostly from intensive margin									
Ireland	110.14	85.69	**−24.45**	89.97	86.78	−3.19	122.41	98.75	**−23.65**
The Netherlands	96.80	80.80	**−16.00**	98.27	98.20	−0.07	98.49	82.29	**−16.20**
Norway	99.99	84.66	**−15.33**	100.14	102.37	2.23	99.85	82.69	**−17.16**
Mostly from extensive margin									
Australia	103.03	92.58	**−10.45**	101.16	91.26	**−9.90**	101.85	101.45	−0.40
New Zealand	120.23	100.02	**−20.21**	114.32	94.71	**−19.62**	105.16	105.63	0.46
Turkey	119.57	75.83	**−43.74**	103.91	67.28	**−36.63**	115.07	112.74	−2.33
From both margins									
Belgium	92.86	72.50	**−20.36**	90.42	79.56	**−10.86**	102.70	91.13	**−11.57**
France	109.64	74.87	**−34.77**	98.01	86.04	**−11.97**	111.86	87.02	**−24.84**
Germany	132.79	77.41	**−55.39**	126.69	91.69	**−35.00**	104.81	84.43	**−20.38**
United Kingdom	110.00	91.42	**−18.58**	104.01	93.12	**−10.89**	105.75	98.19	**−7.57**
United States	100	100	**0**	100	100	**0**	100	100	**0**

All US values were normalized to 100 in 1970-73 and 2000-03 and all other data in 1970-73 and 2000-03 normalized to the U.S. values in the respective period. We divide total hours worked by the number of the employed to obtain hours per worker. The employment rate is the number of the employed divided by the number of the population aged 15-64. The product of these two values provides a measure of working hours per person of working age which can also be calculated by dividing total hours worked by the number of the population aged 15-64.The calculation method we employ is the same as those used in Prescott (2004) and Rogerson (2006). We thank Rogerson for sharing the calculation method. Bold values are those differences that are significant. *Sources*: OECD (2010a) and OECD (2010b)

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