Union, efficiency of labour and endogenous growth

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by

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Abstract:

This paper develops an endogenous growth model with human capital formation and 'Efficiency Wage Hypothesis' to investigate the growth effect of unionisation and to analyse properties of optimum income tax rate in the presence of an unionised labour market and with taxation only on labour income. 'Efficient Bargaining' model as well as 'Right to Manage' model is used to solve the negotiation problem between the labour union and the employer's association. In both type modelling framework, the growth effect of unionisation is independent of its employment effect; and it depends on its net effect on worker's efficiency. The growth rate maximizing tax rate on labour income is different from the corresponding welfare maximizing tax rate; and the nature of the growth effect of unionisation is different from its welfare effect.

JEL classification: J51; O41; J31; J24; H52; H21

Keywords: Labour union; Efficiency wage hypothesis; Human capital Formation; income tax; Endogenous growth

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1 Introduction:

During recent years, many European countries have been suffering from high unemployment rate as well as from low economic growth rate. During 2009 to 2013, the unemployment rates of most of the European countries as well as of the European Union remained quite high compared to the rest of the world. For the World, it remained constant around 6.0% throughout this period but for the European Union, it moved from 8.9% to 11%[1]. Also during 2004 to 2013, annual percentage growth rate of GDP at market prices in European Union was lower than that of the world; and it is shown in figure[2] 1.

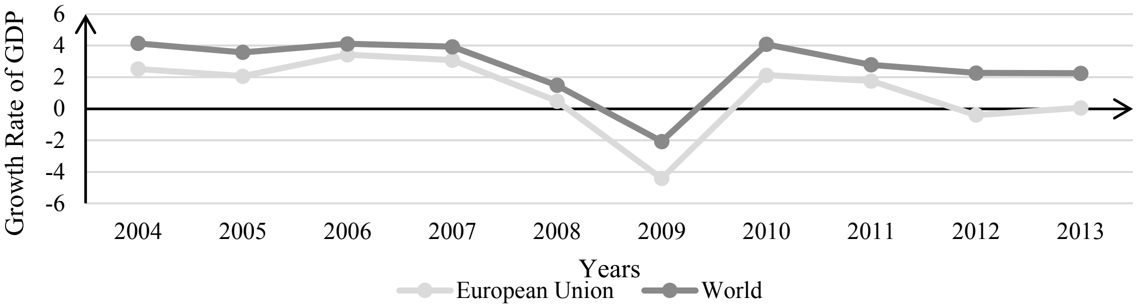

Figure 1: Annual growth rate of GDP during 2004 - 2013

Since pro-competitive market ideology opines in favour of reduction in labour market frictions to generate employment and economic growth, the role of labour unions on economic growth has become an important topic of discussion for policy makers. It has become extremely important to analyse channels through which labour market frictions can affect employment and growth rate of the economy. This motivates researchers to have a theoretical analysis on the effect of unionisation in the labour market on the growth rate of the economy.

There already exists a set of theoretical works[3] serving this purpose. A subset[4] of that literature focuses on the changes in efficiency of workers due to unionisation to analyse its growth effect. However, this subset does not consider the empirically confirmed[5] 'Efficiency Wage Hypothesis'[6,7]. This is a serious problem of the existing literature because, on the one

[1] Empirical support are obtained from data provided by World Bank web-site.
[2] The graph is drawn on the basis of data provided by World Bank web-site.
[3] This set consists of Palokangas (1996, 2004), Sorensen (1997), Bräuninger (2000b), Irmen and Wigger (2002/2003), Ramos-Parreño and Sánchez-Losada (2002), Lingens (2003a, 2003b), Chang et al. (2007), Adjemian et al. (2010), Lai and Wang (2010) etc.
[4] For example, Lingens (2003b), Sorensen (1997) and Ramos-Parreño and Sánchez-Losada (2002).
[5] See for example Peach and Stanley (2009).
[6] 'Efficiency wage hypothesis' is well-explored in the literature. For example, Solow (1979), Yellen (1984), Stiglitz (1976), Shapiro and Stiglitz (1984), Akerlof (1982, 1984), Akerlof and Yellen (1986) etc. can be seen.
[7] Only an earlier version of Palokangas (2004) paper, i.e., Palokangas (2003) incorporates 'Efficiency Wage Hypothesis' in his model. However, this version does not stress on the role of 'Efficiency Wage Hypothesis'

hand, this hypothesis states that a higher wage rate leads to a higher efficiency level of the worker[8], but, on the other hand, a powerful labour union goes for a higher wage rate. So the exclusion of 'Efficiency Wage Hypothesis' to determine the growth effect of unionisation is a serious limitation in the model - building literature. Though a few works consider the role of efficiency wage on union firm bargaining[9] using a static framework, they do not analyse its role on economic growth in a dynamic model.

This subset also ignores the government's role to raise workers' efficiency through investment in human capital accumulation. In most of the countries, the government spends a huge amount for education to raise the efficiency of workers. The government not only spends for primary education, secondary education and higher education but also spends for training of unskilled workers[10]. The figure 2 presented below[11] shows percentages of total government expenditure allocated for education in a few developed countries for the year 2011.

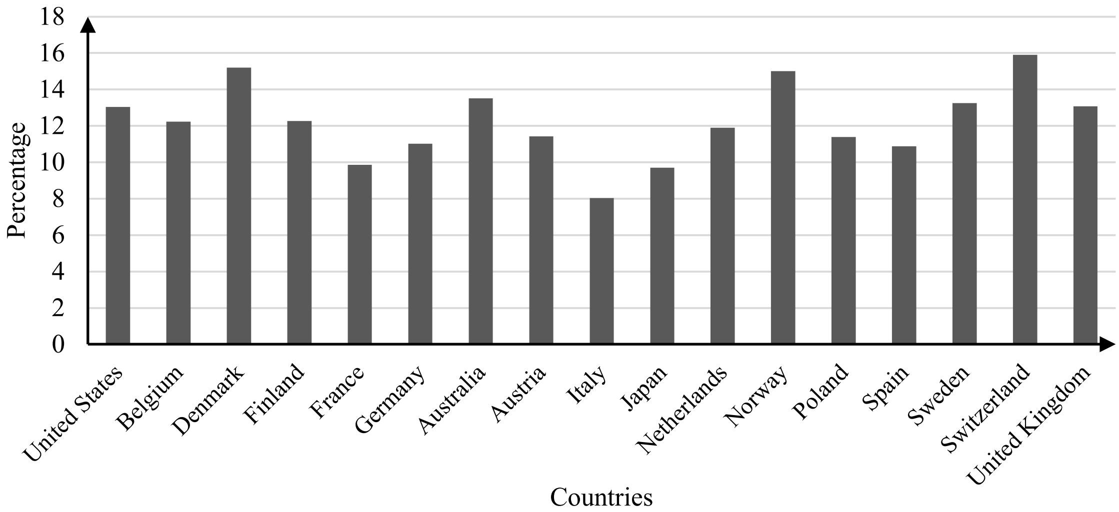

Figure 2: Expenditure on education as a percentage of total government expenditure

From the figure 2, government's priority towards skill formation can be easily understood. The budgeted share of education varies from country to country in between 8% and 16%. Since the government is a very powerful economic institution and can play an important role

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while analysing effects of unionisation. Indeed in a footnote, this fact is accepted and written as "*However, the results in this paper hold even if the effort per worker is wholly inflexible……*". However, the published version of this paper, i.e., Palokangas (2004) does not consider the 'Efficiency Wage Hypothesis'.

[8] See sections 9.2 and 9.3 of Romer (2006).

[9] Some examples are Garino and Martin (2000), Marti (1997), Mauleon and Vannetelbosch (2003) and Pereau and Sanz (2006).

[10] Government also spends for health development of the people to raise their efficiency. However, in this model we overlook the health aspect of workers. As a result, skill level becomes equivalent to the stock of human capital in this model.

[11] The graph is drawn on the basis of data provided by World Bank web-site.

to raise the level of efficiency of workers, we should study the effect of unionisation on economic growth with a special focus on the government's role on human capital accumulation.

There also exists a set[12] of theoretical endogenous growth models focusing on human capital formation and they also do search for optimum taxation. However, these models do not consider unionised labour markets. In the real world, labour unions are very active in Europe and in many countries in other continents. The figure 3 gives a concise impression of this fact showing the labour union density [13] in a few European countries for the year 2012.

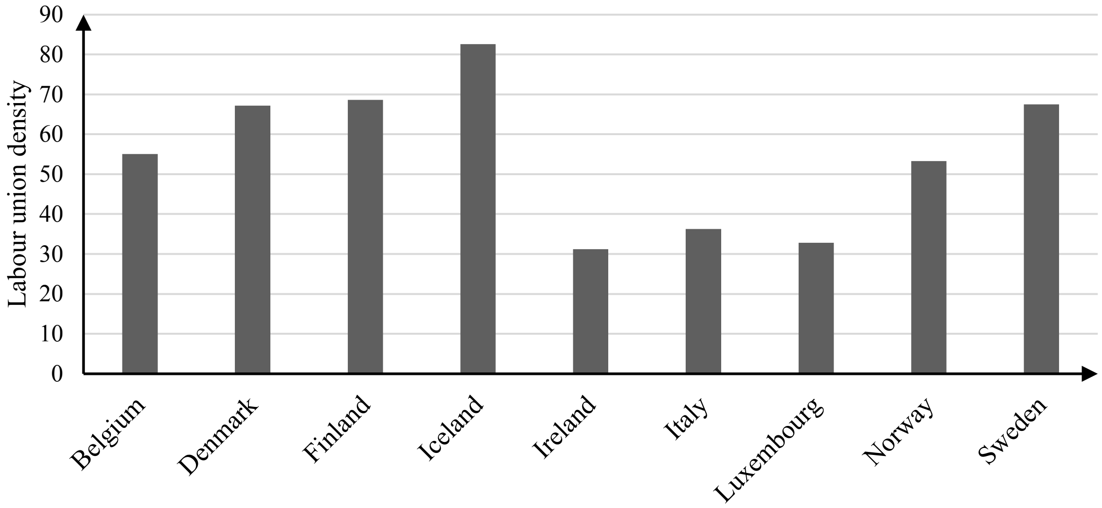

Figure 3: Labour union density

Characteristics of unionised labour markets are different from those of competitive labour markets; and the very presence of labour unions directly affect the mechanism to determine wage and employment. As a result, the optimum income tax rate imposed to finance human capital accumulation to raise workers' efficiency in an unionised labour market should be different from that obtained in the competitive labour market. So it is very important to analyse the properties of optimum income tax rate[14] to finance investment in human capital accumulation when the labour market is unionised.

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[12] This set consists of Blankenau and Simpson (2004), Ni and Wang (1994), Corsetti and Roubini (1996), Glomm and Ravikumar (1997), Chakraborty and Gupta (2009), Bandyopadhyay and Basu (2001), Tournemaine and Tsoukis (Forthcoming) etc.

[13] Data for figure 3 are obtained from (http://stats.oecd.org/viewhtml.aspx?datasetcode=UN_DEN&lang=en#).

[14] There exists a set of works analysing optimal income tax rate to finance productive public expenditure when labour market is unionised. They are Raurich and Sorolla (2003), Kitaura (2010) etc. However, optimal income tax rate to finance productive public expenditure in an unionised economy should be different from optimal income tax rate to finance investment in human capital accumulation in an unionised economy because the positive externality of productive public capital enjoyed by the private producers is independent of the number of employed workers. Contrary to this, the amount of benefit enjoyed by producers due to rise in the efficiency

This paper develops a simple endogenous growth model with a special focus on the 'Efficiency Wage Hypothesis' and on the government's role in human capital accumulation. In this model, we analyse the effect of unionisation on the economic growth rate as well as on the optimum tax rate to finance public education when the educational expenditure is financed by taxation only on labour income. Unionisation is defined as an exogenous increase in the relative bargaining power of the labour union. We use two different bargaining models to solve the negotiation problem between the employers' association and the labour union - 'Efficient Bargaining' model of McDonald and Solow (1981) and 'Right to Manage' model of Nickell and Andrews (1983).

Our main findings are as follows. First, in each of these two bargaining models, for a given tax rate on labour income, unionisation lowers the number of employed workers but raises their effort level. However, when the government imposes the growth rate maximising tax rate on labour income, then the number of employed workers becomes independent of labour union's bargaining power but varies inversely with the elasticity of efficiency with respect to human capital. Secondly, this growth rate maximising tax rate varies positively with the elasticity of worker's efficiency with respect to human capital as well as with the budget share of investment in human capital accumulation; and, on the other hand, varies inversely with the degree of unionisation in the labour market. Thirdly, the growth rate maximising tax rate is different from the corresponding welfare maximising tax rate; and the welfare effect of unionisation is also different from the growth effect of unionisation in each of these two bargaining models. Lastly, growth effect of unionisation consists of a positive effort effect and an ambiguous human capital accumulation effect. In the case of 'Efficient Bargaining' ('Right to Manage') model, a higher value of the elasticity of worker's efficiency with respect to the wage premium than the value of that elasticity with respect to human capital is a sufficient but not a necessary (both necessary and sufficient) condition to ensure a positive growth effect of unionisation. Our results regarding the growth effect of unionisation is different from those available in the existing literature.

Rest of the paper is organized as follows. In section 2, we describe the basic model with 'Efficient Bargaining'. In the section 3, we analyse the existence, uniqueness and stability of the balanced growth equilibrium. We also analyse properties of growth rate maximising tax rate and the growth effect of unionisation in this section. In section 4, same issues are dealt with a 'Right to Manage' model. The paper is concluded in the Section 5.

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level of workers depends on the number of employed workers which is very much affected by unionisation in the labour market.

2 The model

2.1 Production of final good

The representative competitive firm[15] produces the final good, *Y*, with the following production function[16].

$$Y = AK^{\alpha}(eL)^{\beta}\bar{K}^{\gamma} \quad ; \qquad \alpha, \beta, \gamma, \alpha + \beta \in (0,1) \qquad . \tag{1}$$

Here $A > 0$ is a time independent technology parameter and *K* denotes the amount of capital used by the representative firm. e*L* represents firm's effective employment in efficiency unit where *L* stands for the number of workers employed and *e* stands for the efficiency per worker.[17] $\bar{K}$ symbolizes average quantity of capital stock existing in the economy; and $0 < \alpha < 1$ ensures that the external effect of capital is positive. The Cobb – Douglas production function satisfies private diminishing returns. However, social returns to scale may not be diminishing. Decreasing returns to private inputs in the production function results into a positive profit in equilibrium; and this profit is the rent in the bargaining to be negotiated between the employers' association and the labour union. Following Chang et al. (2007), we assume that fixed amount of land is necessary to setup a firm; and as a result, the number of firms remains unchanged even in the presence of positive profit.[18]

We assume that net efficiency per worker, e, depends on his accumulated stock of efficiency, e_1, as well as on his effort level, e_2. Efficiency stock of a worker, e_1, varies positively with his level of human capital. This is consistent with the assumptions made in Lucas (1988), Uzawa (1965), Caballé and Santos (1993), Bucci (2008), Docquier et al. (2008) etc. His effort level, e_2, varies positively with his net wage relative to his net reservation income. This keeps consistency with the assumption made by the 'Efficiency Wage Hypothesis'.[19] For simplicity, we assume that a worker's net reservation income is the after tax unemployment benefit given to an unemployed worker. So the worker's net efficiency, *e*, is given by [20]

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[15] Following Chang et al. (2007), here also free entry assumption of perfect competition is restricted by the existence of a fixed factor land. Necessity of this assumption will be discussed in a little while.
[16] Chang et al. (2007) does not consider efficiency of workers, *e*. Otherwise, this production function is identical to that in Chang et al. (2007).
[17] It is assumed that all workers have identical efficiency level.
[18] Number of firms is normalized to unity.
[19] See footnotes 6 and 8.
[20] Danthine and Kurmann (2006) has also used similar functional form.

$$e = e_1 e_2 \quad . \tag{2}$$

Here

$$e_1 = h^{\eta} \quad \text{with } 0 < \eta < 1 \ ; \tag{2.a}$$

and

$$e_2 = \left(\frac{[1-\tau]w}{[1-\tau]b}\right)^{\delta} = \left(\frac{w}{b}\right)^{\delta} \quad \text{with } 0 < \delta < 1 \ . \tag{2.b}$$

Here *h* and *w* denote the level of human capital and the wage rate respectively; and *b* stands for the rate of unemployment benefit. η and δ represent elasticities of net efficiency with respect to the stock of human capital and with respect to the relative wage rate respectively; and they are assumed to be positive fractions. Chang et al. (2007) does not distinguish between labour time and labour efficiency. So, in Chang et al. (2007), $e \equiv e_1 \equiv e_2 \equiv 1$, i.e., $\eta = \delta = 0$.

The firm maximises profit, π, given by

$$\pi = Y - wL - rK \tag{3}$$

where *r* represents rental rate on capital.

Capital market is perfectly competitive; and so the equilibrium value of rental rate on capital is determined by the supply-demand equality in this market. The inverted demand function for capital is obtained from firm's profit maximization exercise; and it is given by

$$r = \alpha A K^{\alpha-1}(eL)^{\beta}\bar{K}^{\gamma} = \frac{\alpha Y}{K} \quad . \tag{4}$$

2.2 Government

The government finances investment in human capital accumulation (educational expenditure) as well as benefit given to unemployed workers. To finance these expenditures, a proportional tax on wage income as well as on unemployment benefit is imposed at the rate τ; and the budget remains balanced at each point of time. The total tax revenue is allocated to these two types of expenditures in an exogenously given proportion.[21] For the sake of

[21] Since we do not consider any productive role of unemployment benefit in this model, so endogenous determination of this proportion by maximising the economic growth rate is beyond the scope of this model.

simplicity, it is also assumed that the rate of human capital accumulation is proportional to the educational expenditure of the government. So we have

$$\lambda[\tau wL + \tau b(1 - L)] = \dot{h} \qquad ; \tag{5}$$

and

$$(1 - \lambda)[\tau wL + \tau b(1 - L)] = b(1 - L) \qquad . \tag{6}$$

Here $(1 - L)$ is the unemployment level and λ is the fraction of revenue allocated to finance investment in human capital.

We consider taxation only on labour income but not on capital income. This is due to three reasons. First, both the channels of expenditure provide benefits to workers and not to capitalists. Secondly, taxation on capital income makes the analysis complicated. Thirdly, capital income taxation reduces the net marginal productivity of capital and thereby reduces the rate of growth. A set of works on public economics consisting of Bräuninger (2000a, 2005), Crossley and Low (2011), Landais et al. (2010), Davidson and Woodbury (1997) etc. also considers taxation only on wage income to finance unemployment benefit scheme.

2.3 Labour union and Efficient Bargaining

In this model, the labour union derives utility from the net wage premium defined as the difference between the after tax bargained wage rate and the after tax unemployment benefit rate[22] as well as from the number of members of the union. All employed workers are assumed to be members of the union.[23] The utility function of the labour union is defined as follows.

$$u_T = [(1 - \tau)w - (1 - \tau)b]^m L^n = (1 - \tau)^m (w - b)^m L^n \quad \text{with} \quad m, n > 0 \quad . \tag{7}$$

Here u_T symbolizes the level of utility of the labour union. Two parameters, m and n represent elasticities of labour union's utility with respect to wage premium and with respect to number of members respectively. If m > (<) (=) n, then the labour union is said to be wage

[22] In Irmen and Wigger (2002/2003), Lingens (2003a) and Lai and Wang (2010), the difference between the bargained wage rate and the competitive wage rate is an argument in the labour union's utility function. Contrary to this, in Adjemian et al. (2010) and Chang et al. (2007), the difference between the after tax bargained wage rate and the net unemployment benefit is an argument in the labour union's utility function. So, this paper belongs to the second group.

[23] This is due to our assumption of a closed shop labour union.

oriented (employment oriented) (neutral). Chang et al. (2007) contains a brief discussion of these parameters.

We now consider the 'Efficient Bargaining' model where both the wage rate and the number of employed workers are determined mutually by the labour union and the employer's association. To obtain these results of bargaining, we maximize the 'generalised Nash product' function given by

$$\psi = (u_T - \overline{u_T})^{\theta}(\pi - \bar{\pi})^{(1-\theta)} \quad \text{satisfying} \quad 0 < \theta < 1 \quad . \tag{8}$$

Here $\overline{u_T}$ and $\bar{\pi}$ represent the reservation utility level of the labour union and the reservation profit level of the firm respectively. $\overline{u_T}$ and $\bar{\pi}$ are assumed to be zero as, bargaining disagreement stops production and hence employment. θ represents the relative bargaining power of the labour union. Unionisation is defined as an exogenous increase in the value of θ.

Now, using equations (3), (7) and (8), we obtain

$$\psi = \{(1-\tau)^m (w-b)^m L^n\}^{\theta}\{Y - wL - rK\}^{(1-\theta)} \quad . \tag{9}$$

Here ψ is to be maximised with respect to *w* and L. The first order conditions of maximization are given by

$$\frac{\theta m}{w-b} + \frac{(1-\theta)}{[Y - wL - rK]}\left\{\frac{\beta\delta Y}{w} - L\right\} = 0 \quad ; \tag{10}$$

and

$$\frac{\theta n}{L} + \frac{(1-\theta)}{[Y - wL - rK]}\left\{\frac{\beta Y}{L} - w\right\} = 0 \quad . \tag{11}$$

Using equations (4) and (11) we obtain

$$\frac{wL}{Y} = \frac{[\theta n(1-\alpha) + \beta(1-\theta)]}{(1-\theta+\theta n)} \quad . \tag{11.a}$$

Equation (11.a) shows that the labour share of income is time independent and it varies positively with the relative bargaining power of the union.[24] If the labour union has no

[24] $\frac{\partial\left(\frac{wL}{Y}\right)}{\partial\theta} = \frac{n(1-\alpha-\beta)}{(1-\theta+\theta n)^2} > 0$.

bargaining power, i.e., if θ = 0, then this labour share of income is equal to its competitive share, i.e. β. However, if the labour union is a monopolist, i.e., if θ = 1, then it takes away all the income left after paying return on capital; and hence the labour share is equal to (1-α).

Using equations (1), (2), (2.a), (2.b), (4), (6), (10) and (11), we obtain[25]

$$L^* = \frac{[1-(1-\lambda)\tau]}{[1-(1-\lambda)\tau]+\Theta_1(1-\lambda)\tau} \quad ; \tag{12}$$

and

$$w^* = b\Theta_1 \quad . \tag{13}$$

where,

$$\Theta_1 = \frac{[\theta n(1-\alpha-\beta)+\beta(1-\delta)(1-\theta+\theta n)]}{[\theta(n-m)(1-\alpha-\beta)+\beta(1-\delta)(1-\theta+\theta n)]} \quad . \tag{14}$$

Θ_1 represents the equilibrium value of the negotiated wage rate relative to the unemployment benefit rate. We assume the denominator of Θ_1 to be positive in order to ensure $0 < L^* < 1$. When the labour union is neutral or employment oriented, i.e., when $m \leq n$, the denominator of Θ_1 is always positive. However, when the union is wage oriented, i.e., when $m > n$, $\Theta_1 > 0$ implies that the labour union can not be highly biased for wage premium. This assumption also implies that $\Theta_1 > 1$,[26] which further implies that $w^* > b$. Now from equations (2.b) and (13), we obtain the effort level per worker as given by

$$e_2{}^* = (\Theta_1)^\delta \quad . \tag{15}$$

Equation (12) shows that L^* varies inversely with Θ_1. As Θ_1 is increased, the union claims for a higher wage; and so the number of employed workers is reduced. Equation (12) also shows that $L^* \rightarrow 1$ as $(1-\lambda) \rightarrow 0$. This implies that unemployment does not exist when there is no unemployment benefit. The number of employed workers, L^*, varies inversely with $(1-\lambda)$ as well as with τ. It can be easily shown that

$$\frac{\partial L^*}{\partial \tau} = -\frac{(1-\lambda)\Theta_1}{\{[1-(1-\lambda)\tau]+\Theta_1(1-\lambda)\tau\}^2} < 0 \quad ; \tag{16}$$

[25] See appendix A for derivation of optimal w and L.

[26] If the denominator of Θ_1 is positive, then Θ_1 is greater than unity as the numerator of Θ_1 is obviously greater than the denominator of Θ_1.

and

$$\frac{\partial L^*}{\partial \lambda} = \frac{\tau \Theta_1}{\{[1-(1-\lambda)\tau] + \Theta_1(1-\lambda)\tau\}^2} > 0 \quad . \tag{17}$$

As the tax rate is increased and the proportion for funding unemployment benefit remains unchanged, unemployment benefit per worker, b, is also increased. This unemployment benefit is the reservation income of the worker. So the labour union wants a higher wage rate and the employer lowers the number of employed workers in this case. By the similar logic, the number of employed workers is reduced when the proportion for funding unemployment benefit is increased but the tax rate remains unchanged.

Now from equation (14), we obtain

$$\frac{\partial \Theta_1}{\partial \theta} = \frac{m\beta(1-\alpha-\beta)(1-\delta)}{[\theta(n-m)(1-\alpha-\beta) + \beta(1-\delta)(1-\theta+\theta n)]^2} > 0 \quad ; \tag{18}$$

and from equation (15), we have

$$\frac{\partial {e_2}^*}{\partial \theta} = \delta(\Theta_1)^{\delta-1}\frac{\partial \Theta_1}{\partial \theta} > 0 \quad . \tag{19}$$

As the labour union becomes more powerful, it claims a higher wage relative to the alternative income of the worker. As a result of this, equation (19) implies that the effort level per worker varies positively with the degree of unionisation.

Now, from equations (12) and (18), we obtain

$$\frac{\partial L^*}{\partial \theta} = -\frac{[1-(1-\lambda)\tau](1-\lambda)\tau}{\{[1-(1-\lambda)\tau] + \Theta_1(1-\lambda)\tau\}^2}\frac{\partial \Theta_1}{\partial \theta} < 0 \quad . \tag{20}$$

Equation (20) shows that, given the tax rate, the negotiated number of employed workers varies inversely with the degree of unionisation. This is so because unionisation raises the negotiated wage rate as well as the ratio of that wage to the unemployment benefit; and, as a result, effort level per worker is increased[27]. This rise in the wage rate reduces the demand for labour and the rise in worker's effort level substitutes the number of employed workers. As a result, number of employed workers declines due to unionisation. We summarize this result in the following proposition.

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[27] See equation (19).

Proposition 1: For a given tax rate, unionisation lowers the number of employed workers but raises the wage rate as well as the effort level of the worker irrespective of the orientation of the labour union.

Lingens (2003a, 2003b) and Adjemian et al. (2010) consider a neutral labour union and show that unionisation reduces the number of employed workers due to rise in the wage rate. On the contrary, Chang et al. (2007) shows that unionisation does not necessarily lower the number of employed workers; and the employment effect of unionisation is positive for an employment oriented labour union. However, we consider 'Efficiency wage hypothesis' and show that unionisation leads to a decline in the number of employed workers irrespective of the orientation of the labour union. Our result is due to the substitution effect resulting from an increase in the efficiency of the worker.

2.4 The representative household

The representative household derives instantaneous utility only from consumption of the final good[28]. She maximises her discounted present value of instantaneous utility over the infinite time horizon subject to her intertemporal budget constraint. So her dynamic optimisation problem is defined as follows.

$$Max \int_0^\infty \frac{c^{1-\sigma}-1}{1-\sigma} e^{-\rho t}\, dt \tag{21}$$

subject to, $\dot{K} = (1-\tau)wL + rK + \pi + (1-\tau)b(1-L) - c$; (22)

$K(0) = K_0$ (K_0 is historically given) ;

and $c \in [0, (1-\tau)wL + rK + \pi + (1-\tau)b(1-L)]$.

Here *c* is the consumption level of the representative household; and σ and ρ are two parameters representing elasticity of marginal utility of consumption and the rate of discount respectively. We assume entire savings to be invested and rule out depreciation of capital. We also assume that unemployment rate is equal among households. Here *c* is the control variable and *K* is the state variable.

[28] For technical simplicity, we assume that the representative household does not obtain utility from her human capital stock. In reality, people enjoy good health as well as respect from others due to his/her skill level.

Solving this dynamic optimisation problem, we derive the rate of growth of consumption as given by[29]

$$g = \frac{\dot{c}}{c} = \frac{\alpha A K^{\alpha-1}(eL)^{\beta}\bar{K}^{\gamma} - \rho}{\sigma} \quad . \tag{23}$$

3 Steady state equilibrium

3.1 Existence and stability

The symmetric steady state growth equilibrium satisfies following properties:

(i) $\frac{\dot{c}}{c} = \frac{\dot{K}}{K} = \frac{\dot{h}}{h} = \frac{\dot{Y}}{Y} = \frac{\dot{w}^{*}}{w^{*}} = \frac{\dot{\pi}}{\pi} = \frac{\dot{b}}{b} = g$;

(ii) $K = \bar{K}$; and

(iii) r, L^*, τ, λ, $e_2{}^*$ and g are time independent. To ensure that h, K and Y grow at the same rate, i.e., to satisfy property (i), we further assume that $\gamma = 1 - \alpha - \beta\eta$. This implies that the production function satisfies the property of social constant returns to scale.

Using equations (1), (2), (2.a), (5), (6), (11.a), (15), (22), (23), and putting $\gamma = 1 - \alpha - \beta\eta$, $L = L^*$ and $K = \bar{K}$, we obtain

$$g = \frac{\dot{c}}{c} = \frac{\alpha A L^{*\beta}\left(\frac{h}{K}\right)^{\beta\eta}[\Theta_1]^{\beta\delta} - \rho}{\sigma} \quad ; \tag{24}$$

$$g = \frac{\dot{h}}{h} = \frac{\lambda\tau[\theta n(1-\alpha) + \beta(1-\theta)]A\left(\frac{K}{h}\right)^{1-\beta\eta} L^{*\beta}[\Theta_1]^{\beta\delta}}{[1-(1-\lambda)\tau](1-\theta+\theta n)} \quad ; \tag{25}$$

and

$$g = \frac{\dot{K}}{K} = AL^{*\,\beta}\left(\frac{h}{K}\right)^{\beta\eta}[\Theta_1]^{\beta\delta}\left[1 - \frac{\lambda\tau[\theta n(1-\alpha) + \beta(1-\theta)]}{(1-\theta+\theta n)[1-(1-\lambda)\tau]}\right] - \frac{c}{K} \quad . \tag{26}$$

We define two new variables M and N such that $M = (c/K)$ and $N = (h/K)$. So using equations (24), (25) and (26), we obtain

$$\frac{\dot{M}}{M} = \frac{\alpha A L^{*\beta}(N)^{\beta\eta}[\Theta_1]^{\beta\delta} - \rho}{\sigma} - AL^{*\,\beta}(N)^{\beta\eta}[\Theta_1]^{\beta\delta}\left[1 - \frac{\lambda\tau[\theta n(1-\alpha) + \beta(1-\theta)]}{(1-\theta+\theta n)[1-(1-\lambda)\tau]}\right] + M \quad ; \tag{27}$$

and

$$\frac{\dot{N}}{N} = \frac{\lambda\tau[\theta n(1-\alpha) + \beta(1-\theta)]A(N)^{\beta\eta-1}L^{*\beta}[\Theta_1]^{\beta\delta}}{[1-(1-\lambda)\tau](1-\theta+\theta n)}$$

[29] See appendix B for derivation of equation (23).

$$-AL^{*\,\beta}(N)^{\beta\eta}[\Theta_1]^{\beta\delta}\left[1-\frac{\lambda\tau[\theta n(1-\alpha)+\beta(1-\theta)]}{(1-\theta+\theta n)[1-(1-\lambda)\tau]}\right]+M \quad . \tag{28}$$

In the steady state growth equilibrium, $\frac{\dot{M}}{M}=\frac{\dot{N}}{N}=0$; and this implies that

$$\frac{\alpha AL^{*\beta}(N)^{\beta\eta}[\Theta_1]^{\beta\delta}-\rho}{\sigma}=\frac{\lambda\tau[\theta n(1-\alpha)+\beta(1-\theta)]A(N)^{\beta\eta-1}L^{*\beta}[\Theta_1]^{\beta\delta}}{[1-(1-\lambda)\tau](1-\theta+\theta n)} \quad . \tag{29}$$

Equation (29) is solely a function of *N*. We now turn to show the existence and uniqueness of the steady state equilibrium; i.e., a unique solution of equation (29). For this purpose, we use a diagram. In figure 4, L.H.S. and R.H.S. of equation (29) are measured on the vertical axis and *N* on the horizontal axis.

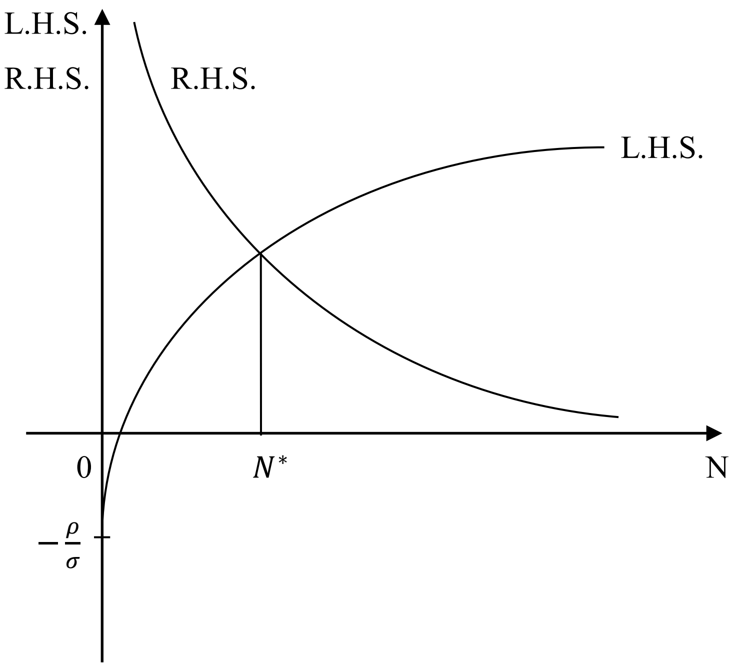

Figure 4: Existence of a unique steady state equilibrium

The L.H.S. curve is positively sloped and is concave to the horizontal axis with a point of intersection on that axis. However the R.H.S. curve is negatively sloped, convex to the origin and asymptotic to both axes. The unique point of intersection of these two curves at N^* shows the existence of a unique steady state growth equilibrium.

To analyse stability of the system, we use equations (27) and (28). The mathematical sign of the Jacobian determinant, given by

$$|J|=\begin{vmatrix}\frac{\partial\left(\frac{\dot{M}}{M}\right)}{\partial M} & \frac{\partial\left(\frac{\dot{M}}{M}\right)}{\partial N}\\ \frac{\partial\left(\frac{\dot{N}}{N}\right)}{\partial M} & \frac{\partial\left(\frac{\dot{N}}{N}\right)}{\partial N}\end{vmatrix} \quad ,$$

is to be evaluated. It can be easily shown that[30]

$$|J| = -\left[(1-\beta\eta)\frac{\lambda\tau[\theta n(1-\alpha)+\beta(1-\theta)]A(N)^{\beta\eta-2}L^{*\beta}[\Theta_1]^{\beta\delta}}{[1-(1-\lambda)\tau](1-\theta+\theta n)} + \frac{\beta\eta\alpha A L^{*\beta}(N)^{\beta\eta-1}[\Theta_1]^{\beta\delta}}{\sigma}\right] < 0 \quad ; \tag{30}$$

And the negative sign of $|J|$ implies that the two latent roots of *J* matrix are of opposite sign. This implies that the unique steady state growth equilibrium is saddle point stable.

3.2 Growth rate maximising tax rate

We assume that the government wants to maximise the rate of growth in the steady state equilibrium[31]; and now turn to analyse properties of growth rate maximising tax rate. Substituting (*h/K*) from equation (25) into equation (24), we obtain

$$(\rho+\sigma g)[g]^{\frac{\beta\eta}{1-\beta\eta}} = A^{\frac{1}{1-\beta\eta}}\alpha L^{*\frac{\beta}{1-\beta\eta}}[\Theta_1]^{\frac{\beta\delta}{1-\beta\eta}}\left\{\lambda\tau\frac{[\theta n(1-\alpha)+\beta(1-\theta)]}{[1-(1-\lambda)\tau](1-\theta+\theta n)}\right\}^{\frac{\beta\eta}{1-\beta\eta}}. \tag{31}$$

The L.H.S. of equation (31) is a monotonically increasing function of *g*. So the tax rate, which maximises the R.H.S. of equation (31), also maximises the growth rate. So from equations (12) and (31), we obtain the growth rate maximising tax rate as given by

$$\tau^* = \frac{\eta}{[(1-\eta)\Theta_1+\eta](1-\lambda)} \quad . \tag{32}$$

Equation (32) shows that τ^{*}[32] varies positively with η and λ. If human capital is not productive, i.e., if $\eta = 0$, then no tax should be imposed in order to maximise the growth rate. Equation (31) clearly shows that the rate of growth varies inversely with the tax rate when $\eta = 0$. This is so because L^* varies inversely with τ. Again, from equation (32), we obtain

$$\frac{\partial\tau^*}{\partial\theta} = -\frac{\eta(1-\eta)}{[(1-\eta)\Theta_1+\eta]^2(1-\lambda)}\frac{\partial\Theta_1}{\partial\theta} < 0 \quad . \tag{33}$$

Equation (33) shows that growth rate maximising tax rate varies inversely with the degree of unionisation in the labour market. The intuition behind this result is as follows. The change in tax rate has two opposite effects on the growth rate. The first effect works by reducing

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[30] See appendix C for derivation of equation (30).

[31] Usually it is assumed that the objective of the government is to maximise social welfare. However, for technical simplicity, here we consider growth rate maximization. Agénor and Neanidis (2014) also focuses on growth rate maximisation rather than on welfare maximisation on the ground that, in practice, imperfect knowledge about household preferences makes it easier to measure their income level rather than their welfare level.

[32] We assume that the second order condition is satisfied.

employment level and the second effect works by increasing human capital accumulation. These two effects balances each other at $\tau = \tau^*$. Now, a rise in θ lowers employment level; and to raise it back to its previous level, τ^* should decline due to the inverse relationship between L^* and τ. So the growth rate maximising tax rate is reduced due to unionisation in this case. These properties of growth rate maximising tax rate is summarised in the following proposition.

Proposition 2: The growth rate maximising tax rate on labour income, on the one hand, varies positively with the elasticity of efficiency with respect to human capital as well as with the budget share of investment in human capital accumulation; and, on the other hand, varies inversely with the degree of unionisation in the labour market.

Incorporating the value of τ^* from equation (32) in equation (12), we obtain

$$L^* = 1 - \eta \quad . \tag{34}$$

Equation (34) shows that the rate of employment of workers is independent of the degree of unionisation when government imposes the growth rate maximising tax rate; and it varies inversely with the elasticity of efficiency with respect to human capital stock. This is so because unionisation has two different effects on employment. One is the direct effect; and the other is the indirect effect operating through the change in the tax rate. Equations (20) and (33) show that both L^* and τ^* vary in the same direction with unionisation; and equation (16) shows that L^* varies inversely with τ^*. As a result, these two effects of unionisation on L^* cancel out each other; and thus employment level becomes independent of the degree of unionisation. L^* varies inversely with η because a higher value of η indicates a higher level of efficiency and the efficiency gain always substitutes the number of employed workers. This is stated in the following proposition.

Proposition 3: When the government imposes the growth rate maximising tax rate on labour income, rate of employment becomes independent of the degree of unionisation in the labour market but varies inversely with the elasticity of efficiency with respect to human capital.

The welfare level of the representative household, ω, is defined as her discounted present value of instantaneous utility over the infinite time horizon. It is obtained from equations (1), (3), (6), (11.a), (21), (22) and (23) and is given by[33]

[33] See appendix D for derivation of equation (35).

$$\omega = \frac{{K_0}^{1-\sigma}\left[\left\{\frac{\rho+\sigma g}{\alpha}\right\}\left\{1-\frac{\lambda\tau}{[1-(1-\lambda)\tau]}\frac{[\theta n(1-\alpha)+\beta(1-\theta)]}{(1-\theta+\theta n)}\right\}-g\right]^{1-\sigma}}{(1-\sigma)[\rho-g(1-\sigma)]} + constant \quad . \qquad (35)$$

We assume 1 > σ and ρ > $g(1\text{-}\sigma)$. Since initial consumption c_0 is positive, so $\left\{\frac{\rho+\sigma g}{\alpha}\right\}\left\{1-\frac{\lambda\tau}{[1-(1-\lambda)\tau]}\frac{[\theta n(1-\alpha)+\beta(1-\theta)]}{(1-\theta+\theta n)}\right\}$ has to be greater than g. Here, we do not attempt to derive the welfare maximising income tax rate on labour income for technical complexity. Rather, here we check whether the growth rate maximising income tax rate on labour income, given by equation (32), is identical to the welfare maximising labour income tax rate or not. For this purpose, we differentiate ω with respect to τ at $\tau = \tau^*$ and obtain

$$\left.\frac{\partial\omega}{\partial\tau}\right|_{\tau=\tau^*} = -\frac{{K_0}^{1-\sigma}\left\{\frac{\rho+\sigma g^*}{\alpha}\right\}\left\{\frac{[\theta n(1-\alpha)+\beta(1-\theta)]\lambda}{(1-\theta+\theta n)[1-(1-\lambda)\tau^*]^2}\right\}[\rho-g^*(1-\sigma)]^{-1}}{\left[\left\{\frac{\rho+\sigma g^*}{\alpha}\right\}\left\{1-\frac{\lambda\tau^*}{[1-(1-\lambda)\tau^*]}\frac{[\theta n(1-\alpha)+\beta(1-\theta)]}{(1-\theta+\theta n)}\right\}-g^*\right]^{\sigma}} < 0 \quad . \qquad (36)$$

Here $g^* = g|_{\tau=\tau^*}$. Equation (36) implies that the welfare maximising tax rate on labour income is lower than the growth rate maximising tax rate. This is so because, given the allocation of tax revenue between investment in human capital accumulation and unemployment subsidy, initial consumption level of the representative household falls with increase in the labour income tax rate. Since the economic growth rate in the steady state equilibrium does not depend on the level of initial consumption[34], so the growth rate maximising tax rate, τ^*, does not take into account this negative effect of taxation on initial consumption. On the other hand, welfare level depends on the level of initial consumption; and so the welfare maximising labour income tax rate takes into account this negative effect. This result is stated in the following proposition.

Proposition 4: Welfare maximising tax rate on labour income is lower than the corresponding growth rate maximising tax rate in the presence of public investment in human capital accumulation.

3.3 Effect of unionisation

[34] See equation (31).

We now turn to analyse the effect of an increase in θ on the endogenous growth rate when the government charges the growth rate maximising labour income tax rate[35]. Using equations (31) and (32), we obtain

$$(\rho+\sigma g^*)[g^*]^{\frac{\beta\eta}{1-\beta\eta}}$$
$$=A^{\frac{1}{1-\beta\eta}}\alpha(1-\eta)^{\frac{\beta}{1-\beta\eta}}[\Theta_1]^{\frac{\beta\delta}{1-\beta\eta}}\left\{\frac{\eta\lambda[\theta n(1-\alpha)+\beta(1-\theta)]}{(1-\eta)\Theta_1(1-\lambda)(1-\theta+\theta n)}\right\}^{\frac{\beta\eta}{1-\beta\eta}} . \quad (37)$$

From equation (37), we have

$$\left[\frac{\sigma g^*}{(\rho+\sigma g^*)}+\frac{\beta\eta}{1-\beta\eta}\right]\frac{\frac{\partial g^*}{\partial\theta}}{g^*}=\left(\frac{\beta\eta}{1-\beta\eta}\right)\left\{\frac{n(1-\alpha-\beta)}{(1-\theta+\theta n)[\theta n(1-\alpha)+\beta(1-\theta)]}\right\}$$
$$-\frac{\beta^2 m\eta(1-\alpha-\beta)(1-\delta)}{(1-\beta\eta)[\theta(n-m)(1-\alpha-\beta)+\beta(1-\delta)(1-\theta+\theta n)]^2}$$
$$+\frac{\beta^2 m\delta(1-\alpha-\beta)(1-\delta)}{(1-\beta\eta)[\theta(n-m)(1-\alpha-\beta)+\beta(1-\delta)(1-\theta+\theta n)]^2} . \quad (38)$$

Equation (38) shows that the growth effect of unionisation is ambiguous. It consists of two effects – (i) the effort effect and (ii) the human capital accumulation effect. The first effect is operated through the change in the effort level of the worker. It is positive and is captured by the third term in the R.H.S. of equation (38). The second effect is operated through the change in the rate of human capital accumulation. It is ambiguous in sign and is captured by the first term as well as by the second term in the R.H.S. of equation (38). On the one hand, unionisation raises labour share of income and thereby the tax base[36]. This positive effect is captured by the first term. However, on the other hand, unionisation lowers the growth rate maximising tax rate; and this negative effect is captured by the second term. So the net effect on tax revenue generation is ambiguous. Since a fixed fraction of tax revenue is spent to finance human capital accumulation, the effect on human capital accumulation is also ambiguous. If human capital is not productive, i.e., if $\eta=0$, then only the positive effort effect remains and unionisation always raises the rate of economic growth. Similarly, if the effort level is independent of the wage rate, i.e., if $\delta=0$, then the third term is vanished and the effect of unionisation depends only on the human capital accumulation effect. However, if we ignore the entire dynamic 'Efficiency Wage Hypothesis', i.e., if we assume that $\delta=$

[35] Since we cannot derive the welfare maximising labour income tax rate, so we are unable to derive the growth effect of unionisation when the government charges the welfare maximising labour income tax rate.
[36] See footnote 23.

$\eta = 0$, then unionisation does not affect the growth rate of the economy. This result is valid regardless of the nature of orientation of the labour union. This happens because unionisation does not affect the level of employment when government chooses the growth rate maximising tax rate.

Combining the second and the third term in the R.H.S. of equation (38), we find that the positive work effort effect dominates the negative component of human capital accumulation effect if the elasticity of worker's efficiency with respect to the wage premium rate, δ, is higher than the elasticity of worker's efficiency with respect to the stock of human capital, η. So unionisation in this case is definitely growth generating as the other component of human capital accumulation effect is always positive. However, the converse is not necessarily true. So, $\delta > \eta$ is a sufficient condition but not a necessary condition to ensure positive growth effect of unionisation. These results are summarised in the following proposition.

Proposition 5: Growth effect of unionisation consists of a positive work effort effect and an ambiguous human capital accumulation effect. If the elasticity of worker's efficiency with respect to the stock of human capital is not higher than the elasticity of worker's efficiency with respect to the wage premium, then unionisation always raises the economic growth rate.

Now, we analyse the effect of unionisation in the labour market on the welfare level of the representative household, ω, when the government imposes the economic growth rate maximising tax rate on labour income. For this purpose, we use equations (32) and (35); and obtain

$$\left.\frac{\partial \omega}{\partial \theta}\right|_{\tau=\tau^*} = \frac{\partial g^*}{\partial \theta} \frac{\left[\left\{\frac{\rho+\sigma g^*}{\alpha}\right\}\left\{1 - \frac{\lambda\eta[\theta n(1-\alpha)+\beta(1-\theta)]}{\Theta_1(1-\eta)(1-\lambda)(1-\theta+\theta n)}\right\} - g^*\right]^{1-\sigma}}{{K_0}^{\sigma-1}[\rho - g^*(1-\sigma)]} \left\{\frac{1}{[\rho - g^*(1-\sigma)]} + \frac{\left[\frac{\sigma}{\alpha}\left\{1 - \frac{\lambda\eta[\theta n(1-\alpha)+\beta(1-\theta)]}{\Theta_1(1-\eta)(1-\lambda)(1-\theta+\theta n)}\right\} - 1\right]}{\left[\left\{\frac{\rho+\sigma g^*}{\alpha}\right\}\left\{1 - \frac{\lambda\eta[\theta n(1-\alpha)+\beta(1-\theta)]}{\Theta_1(1-\eta)(1-\lambda)(1-\theta+\theta n)}\right\} - g^*\right]}\right\}$$
$$- \frac{\left\{\frac{(n-m)(1-\alpha-\beta)\theta n[\theta n(1-\alpha-\beta)+2\beta(1-\delta)(1-\theta+\theta n)]+\beta^2(1-\delta)(1-\theta+\theta n)^2[n(1-\delta)-m]}{(1-\theta+\theta n)^2[\theta n(1-\alpha-\beta)+\beta(1-\delta)(1-\theta+\theta n)]^2}\right\}}{\left\{\frac{\rho+\sigma g^*}{\alpha}\right\}^{-1}\left[\frac{\lambda\eta(1-\alpha-\beta)}{(1-\eta)(1-\lambda)}\right]^{-1}{K_0}^{\sigma-1}\left[\left\{\frac{\rho+\sigma g^*}{\alpha}\right\}\left\{1-\frac{\lambda\eta[\theta n(1-\alpha)+\beta(1-\theta)]}{\Theta_1(1-\eta)(1-\lambda)(1-\theta+\theta n)}\right\}-g^*\right]^{\sigma}[\rho-g^*(1-\sigma)]} . \quad (39)$$

Equation (39) shows that welfare effect of unionisation consists of two effects. One of them is the growth effect of unionisation and it is captured by the first term in the R.H.S. of equation (39). The second effect comes from the change in initial consumption level of the household due to change in the educational expenditure; and it is captured by the second term in the R.H.S. of equation (39). This effect is ambiguous because the term $\big[(n-m)(1-\alpha-\beta)\theta n[\theta n(1-\alpha-\beta)+2\beta(1-\delta)(1-\theta+\theta n)]+\beta^2(1-\delta)(1-\theta+\theta n)^2[n(1-\delta)-m]\big]$ is ambiguous in sign. This is so because, on the one hand, unionisation lowers the tax rate and thereby lowers investment in human capital accumulation. This can be easily understood from the term $\lambda\tau/[1-(1-\lambda)\tau]$ in the R.H.S. of equation (35). On the other hand, unionisation raises the income share of labour and thereby the tax base. This can be easily understood from the term $[\theta n(1-\alpha)+\beta(1-\theta)]/(1-\theta+\theta n)$ in the R.H.S. of equation (35). So if $m \geq n$, then the effect on tax rate dominates the other effect and the initial consumption effect becomes positive. So the welfare effect of unionisation is stronger than its growth effect in this case. The major result is stated in the following proposition.

Proposition 6: The welfare effect of unionisation is different from its growth effect when the government invests in human capital accumulation; and is stronger than the growth effect if $m \geq n$.

In Chang et al. (2007), growth effect as well as welfare effect of unionisation solely consists of the employment effect of unionisation, which depends only on the orientation of the labour union. However, there is no employment effect in our model; and hence the growth effect as well as the welfare effect of unionisation does not depend on the orientation of labour union.

We now contrast our result to the related results of existing literature. In Palokangas (1996), unionisation reduces employment of both unskilled labour and skilled labour in production of the final good due to their complementary relationship; and this leads to a rise in the employment of skilled labour in the R&D sector and therefore raises the growth rate. In Sorensen (1997), on the one hand, unionization raises the skill of the workers, but, on the other hand, lowers the profit and, in turn, the marginal return from skill accumulation. The growth rate is reduced (increased) in the 'Efficient Bargaining' model ('Right to manage model'). Bräuninger (2000b) shows that, in general, unionisation dampens capital accumulation and thereby growth. Lingens (2003a) shows in a creative destruction growth model that, unionisation lessens the expected profit of the innovators and employment of skilled labour in the manufacturing sector. This surplus labour is absorbed in the R&D sector and rate of innovation is raised. So the aggregate effect on growth is indeterminate and depends on the elasticity of substitution between the two types of labour in the manufacturing sector. In an OLG model, Irmen and Wigger (2002/2003) shows that unionisation causes a transfer of income from the dissaving old to the saving young. This raises capital accumulation and thereby raises growth. In Lingens (2003b), skill formation is endogenous; and due to unionisation in the unskilled labour market, the skilled unskilled relative wage ratio falls and thus the supply of skilled labour goes down. If the long-run equilibrium level of skilled workers is low (high), then unionisation lowers (raises) the economic growth rate. Lai and Wang (2010) shows that unionisation raises (lowers) the growth rate if and only if the balanced growth equilibrium is locally determinate (indeterminate). In Adjemian et al. (2010), unionization reduces profit and thus reduces the expected value of innovation; and thereby discourages R&D and economic growth. However, our result is different from the above results and none of these above mentioned works considers the role of dynamic efficiency of workers.

4 Negotiation with 'Right to Manage' model

In this case, the employers' union and the employees' union bargain only over the wage rate; and the firm determines the number of employed workers from its labour demand function obtained from its profit maximisation exercise. So, from equations (1), (2), (2.a), (2.b) and (3), we obtain the inverted labour demand function of the representative firm as given by

$$w = \left[\beta A K^{\alpha} \overline{K}^{\gamma} L^{\beta-1} h^{\beta\eta} b^{-\beta\delta}\right]^{\frac{1}{1-\beta\delta}} \quad . \qquad (40)$$

So the firms' association and the labour union jointly maximise the 'generalised Nash product' function given by equation (9) with respect to *w* only subject to equation (40). Using the first order condition of maximisation and equations (1), (2), (2.a), (2.b), (4), (6) and (40), optimum values of L and w are obtained as[37]

$$L^{**} = \frac{[1-\tau(1-\lambda)]\{\theta n(1-\alpha-\beta)(1-\beta\delta)+\beta(1-\delta)(1-\theta)(1-\beta)-\theta m(1-\beta)(1-\alpha-\beta)\}}{\{\theta n(1-\alpha-\beta)(1-\beta\delta)+\beta(1-\delta)(1-\theta)(1-\beta)\}-[1-\tau(1-\lambda)]\theta m(1-\beta)(1-\alpha-\beta)} < 1 \quad ; \qquad (41)$$

and

$$w^{**} = \beta A K^{\alpha} \overline{K}^{\gamma} h^{\beta\eta} {L^{**}}^{\beta-1-\beta\delta} \tau^{-\beta\delta} (1-L^{**})^{\beta\delta} (1-\lambda)^{-\beta\delta} [1-\tau(1-\lambda)]^{\beta\delta} \quad . \qquad (42)$$

We assume the following parametric restriction to be valid in order to ensure that $L^{**} > 0$.

$$\{\theta n(1-\alpha-\beta)(1-\beta\delta) + \beta(1-\delta)(1-\theta)(1-\beta)\} > \theta m(1-\beta)(1-\alpha-\beta) \quad .$$

[37] Derivations of equations (41), (42) and (44) are provided in appendix E. We assume that second order condition of maximisation is satisfied.

This restriction implies that the labour union can not be highly wage oriented. In this model also, L^{*} varies inversely with θ when τ and λ are given. This is shown by

$$\frac{\partial L^{**}}{\partial \theta} = -\frac{[1-(1-\lambda)\tau](1-\lambda)\tau\beta m(1-\beta)^2(1-\alpha-\beta)(1-\delta)}{[\{\theta n(1-\alpha-\beta)(1-\beta\delta)+\beta(1-\delta)(1-\theta)(1-\beta)\}-[1-\tau(1-\lambda)]\theta m(1-\beta)(1-\alpha-\beta)]^2} < 0 \quad . \qquad (43)$$

Now, from equations (2.b), (6) and (41), representative worker's effort level is obtained and is given by

$$e_2^{**} = \left[\frac{[1-(1-\lambda)\tau](1-L^{**})}{(1-\lambda)\tau L^{**}}\right]^{\delta}$$

$$= \left[\frac{\{\theta n(1-\alpha-\beta)(1-\beta\delta)+\beta(1-\delta)(1-\theta)(1-\beta)\}}{\{\theta n(1-\alpha-\beta)(1-\beta\delta)+\beta(1-\delta)(1-\theta)(1-\beta)-\theta m(1-\beta)(1-\alpha-\beta)\}}\right]^{\delta} \quad . \qquad (44)$$

From equation (44), we have

$$\frac{\partial e_2^{**}}{\partial \theta} = \frac{\delta\{\theta n(1-\alpha-\beta)(1-\beta\delta)+\beta(1-\delta)(1-\theta)(1-\beta)\}^{\delta-1}\beta m(1-\beta)^2(1-\alpha-\beta)(1-\delta)}{[\theta n(1-\alpha-\beta)(1-\beta\delta)+\beta(1-\delta)(1-\theta)(1-\beta)-\theta m(1-\beta)(1-\alpha-\beta)]^{\delta+1}} > 0 \quad . \qquad (45)$$

Equation (45) implies that effort level of the worker varies positively with the degree of unionisation. Since, in this model, the government's budget balancing equations as well as the representative household's behaviour are identical to those given in the 'Efficient Bargaining' model, so the existence and stability properties of the steady state equilibrium derived in that model will remain unchanged here.

Now, using equations (2), (2.a), (2.b), (5), (6), (23), (42) and (44), we obtain the balanced growth equation given by

$$(\rho+\sigma g)[g]^{\frac{\beta\eta}{1-\beta\eta}} = A^{\frac{1}{1-\beta\eta}}\alpha L^{**\frac{\beta(1-\delta)}{1-\beta\eta}}\left[\frac{(1-L^{**})}{(1-\lambda)}\right]^{\frac{\beta\delta}{1-\beta\eta}}[\beta\lambda]^{\frac{\beta\eta}{1-\beta\eta}}\left\{\frac{[1-(1-\lambda)\tau]}{\tau}\right\}^{\frac{\beta\delta-\beta\eta}{1-\beta\eta}} \quad . \qquad (46)$$

Using equations (41) and (46), we obtain the growth rate maximising tax rate given by

$$\tau^{**} = \frac{\eta\{\theta n(1-\alpha-\beta)(1-\beta\delta)+\beta(1-\delta)(1-\theta)(1-\beta)-\theta m(1-\beta)(1-\alpha-\beta)\}}{\{\theta n(1-\alpha-\beta)(1-\beta\delta)+\beta(1-\delta)(1-\theta)(1-\beta)-\eta\theta m(1-\beta)(1-\alpha-\beta)\}(1-\lambda)} \quad . \qquad (47)$$

From equation (47), we obtain

$$\frac{\partial \tau^{**}}{\partial \theta} = -\frac{\eta(1-\eta)\beta m(1-\beta)^2(1-\alpha-\beta)(1-\delta)}{\{\theta n(1-\alpha-\beta)(1-\beta\delta)+\beta(1-\delta)(1-\theta)(1-\beta)-\eta\theta m(1-\beta)(1-\alpha-\beta)\}^2(1-\lambda)} < 0 \quad . \qquad (48)$$

So the growth rate maximising tax rate varies inversely with the degree of unionisation. Incorporating the value of τ^{**} from equation (47) in equation (41), we obtain the same value of L^{**} as that is given in equation (34). Now, to check the equivalence between the growth rate maximising labour income tax rate and the welfare maximising labour income tax rate, we use equations (1), (3), (6), (21), (22), (23) and (40); and thus obtain

$$\omega = \frac{{K_0}^{1-\sigma}\left[\left\{\frac{\rho+\sigma g}{\alpha}\right\}\left\{1-\frac{\lambda\tau\beta}{[1-(1-\lambda)\tau]}\right\}-g\right]^{1-\sigma}}{(1-\sigma)[\rho-g(1-\sigma)]}+constant \quad . \tag{49}$$

We assume 1 > σ and ρ > $g(1\text{-}\sigma)$. Since initial consumption, c_0, is positive, so $\left\{\frac{\rho+\sigma g}{\alpha}\right\}\left\{1-\frac{\lambda\tau\beta}{[1-(1-\lambda)\tau]}\right\}$ has to be greater than g. From equation (49), we obtain

$$\left.\frac{\partial\omega}{\partial\tau}\right|_{\tau=\tau^{**}} = -\frac{{K_0}^{1-\sigma}\left\{\frac{\rho+\sigma g^{**}}{\alpha}\right\}\left\{\frac{\beta\lambda}{[1-(1-\lambda)\tau^{**}]^2}\right\}}{\left[\left\{\frac{\rho+\sigma g^{**}}{\alpha}\right\}\left\{1-\frac{\lambda\tau^{**}\beta}{[1-(1-\lambda)\tau^{**}]}\right\}-g^{**}\right]^{\sigma}[\rho-g^{**}(1-\sigma)]} < 0 \quad ; \tag{50}$$

Equation (50) shows that here also the welfare maximising tax rate falls short of the growth rate maximising tax rate due to the negative effect of taxation on initial consumption.

Now, using equations (34), (46) and (47), we obtain

$$\left[\frac{\sigma g^{**}}{(\rho+\sigma g^{**})}+\frac{\beta\eta}{1-\beta\eta}\right]\frac{\frac{\partial g^{**}}{\partial\theta}}{g^{**}} = -\left(\frac{\beta[\delta-\eta]}{1-\beta\eta}\right)\left\{\frac{(1-\lambda)}{[1-(1-\lambda)\tau^{**}]}+\frac{1}{\tau^{**}}\right\}\frac{\partial\tau^{**}}{\partial\theta} \gtreqless 0 \quad iff \quad \delta \gtreqless \eta \quad . \tag{51}$$

Equation (51) shows that the sign of the growth effect of unionisation depends solely on the sign of $(\delta-\eta)$. So, if the elasticity of worker's efficiency with respect to the wage premium, δ, is higher than (equal to) (lower than) the elasticity of worker's efficiency with respect to the stock of human capital, η, then unionisation in the labour market raises (does not affect) (lowers) the rate of economic growth. In the 'Efficient Bargaining' model, the growth effect of unionisation partially depends on the mathematical sign of $(\delta-\eta)$. However, in the 'Right to Manage' model, growth effect of unionisation fully depends on the mathematical sign of $(\delta-\eta)$. So in this model, $\delta > \eta$ is a necessary as well as a sufficient condition to ensure positive growth effect of unionisation. Important results derived in this section are summarized in the following proposition.

Proposition 7: *In the 'Right to Manage' model of bargaining, unionisation in the labour market raises (does not change) (lowers) the rate of economic growth if the elasticity of worker's efficiency with respect to the wage premium is higher than (equal to) (lower than) the elasticity of worker's efficiency with respect to the stock of human capital.*

To analyse the welfare effect of unionisation, we use equation (49) and obtain

$$\left.\frac{\partial \omega}{\partial \theta}\right|_{\tau=\tau^{**}} = \frac{{K_0}^{1-\sigma}[\rho - g^{**}(1-\sigma)]^{-1}\frac{\partial g^{**}}{\partial \theta}}{\left[\left\{\frac{\rho+\sigma g^{**}}{\alpha}\right\}\left\{1-\frac{\lambda\beta\tau^{**}}{[1-(1-\lambda)\tau^{**}]}\right\}-g^{**}\right]^{\sigma-1}}\left\{\frac{\left[\frac{\sigma}{\alpha}\left\{1-\frac{\lambda\tau^{**}\beta}{[1-(1-\lambda)\tau^{**}]}\right\}-1\right]}{\left[\left\{\frac{\rho+\sigma g^{**}}{\alpha}\right\}\left\{1-\frac{\lambda\tau^{**}\beta}{[1-(1-\lambda)\tau^{**}]}\right\}-g^{**}\right]}\right.$$

$$\left.+\frac{1}{[\rho-g^{**}(1-\sigma)]}\right\}-\frac{[\rho-g^{**}(1-\sigma)]^{-1}\left\{\frac{\rho+\sigma g^{**}}{\alpha}\right\}\frac{\lambda\beta}{[1-(1-\lambda)\tau^{**}]^2}\frac{\partial \tau^{**}}{\partial \theta}}{{K_0}^{\sigma-1}\left[\left\{\frac{\rho+\sigma g^{**}}{\alpha}\right\}\left\{1-\frac{\lambda\tau^{**}\beta}{[1-(1-\lambda)\tau^{**}]}\right\}-g^{**}\right]^{\sigma}} \quad . \quad (52)$$

Equation (52) implies that here also the welfare effect of unionisation consists of growth effect as well as initial consumption effect. However, the initial consumption effect is always positive here because, unlike the previous model, income share of labour in this model is independent of the level of unionisation. So the welfare effect of unionisation is always stronger than its growth effect.

5 Conclusions

This paper has developed an endogenous growth model with a special focus on human capital formation and on the "Efficiency Wage Hypothesis' in order to study the effect of unionisation in the labour market on the long run economic growth rate. We also have derived properties of growth rate maximizing tax rate on labour income which is used to finance investment in human capital formation as well as unemployment benefit given to unemployed workers. We have used both the 'Efficient Bargaining' model of McDonald and Solow (1981) and the 'Right to Manage' model of Nickell and Andrews (1983) to derive the outcome of negotiation between the labour union and the employers' association. The existing literature neither focuses on the role of 'Efficiency Wage Hypothesis' nor on the government's role on human capital formation while analysing unionisation's effect on economic growth.

We have derived many interesting results. First, in each of these two type of bargaining models, for a given tax rate on labour income, unionisation lowers the number of employed workers but raises the wage rate as well as the effort level of the worker irrespective of the orientation of the labour union. The growth rate maximising tax rate on labour income varies positively with the elasticity of efficiency with respect to human capital as well as with the budget share of investment in human capital accumulation but varies inversely with the degree of unionisation in the labour market. When the government imposes the growth rate maximising tax rate on labour income, rate of employment becomes independent of the degree of unionisation in the labour market but varies inversely with the elasticity of efficiency with respect to human capital. Secondly, the growth rate maximising tax rate on labour income is different from the corresponding welfare maximising tax rate. The Welfare effect of unionisation is also different from the growth effect of unionisation in both these two models. Thirdly, in case of the 'Efficient Bargaining' model, if the elasticity of worker's effort level with respect to the wage premium is higher than the elasticity of worker's efficiency with respect to the stock of human capital, then there exists a positive growth effect of unionisation in the labour market though this condition is not necessary. However, in case of the 'Right to Manage' model, this condition becomes necessary as well as sufficient to obtain a positive growth effect of unionisation. These results stand on a sharp contrast to those of the existing literature.

However, our simple theoretical model does not consider many important aspects of reality. Issues like population growth, technological progress, positive externality of public goods etc. are ignored for the sake of simplicity. We also do not consider capital income taxation for analytical simplicity. We only focuses on publicly financed education and not on privately financed education. So, household's income allocation towards education, is not considered here. To avoid complexity in the theoretical analysis, we assume 'closed shop labour union', rather than the more common 'open shop labour union'. The labour union's simple utility function does not take care of its other priorities like workplace safety and environmental issues. We plan to do further research in future removing these limitations.

Appendix

Appendix A: Derivation of optimal w and L

From equations (4) and (10), we obtain

$$\theta m[(1-\alpha)Y - wL] = (1-\theta)(w-b)\left\{L - \frac{\beta\delta Y}{w}\right\} \quad . \qquad (A.1)$$

Now from equation (6), we obtain

$$b(1-L) = \frac{(1-\lambda)\,\tau wL}{[1-(1-\lambda)\,\tau]} \quad . \qquad (A.2)$$

Using equations (A.1) and (A.2), we obtain

$$\theta m[(1-\alpha)Y - wL] = (1-\theta)\left(w - \frac{(1-\lambda)\,\tau wL}{[1-(1-\lambda)\,\tau](1-L)}\right)\left\{L - \frac{\beta\delta Y}{w}\right\} \quad . \qquad (A.3)$$

Using equations (11.a) and (A.3), we obtain

$$\frac{(1-L)[1-(1-\lambda)\tau]}{(1-\lambda)\tau L} = \Theta_1 \qquad . \qquad (A.4)$$

From equation (A.4), we obtain equation (12) in the body of the article.

Incorporating the value of L^* from equation (12) in equation (A.2), we obtain equation (13) in the body of the article. We assume that second order conditions of maximisation is satisfied.

Appendix B: Derivation of equation (23)

Using equations (21) and (22), we construct the Current Value Hamiltonian as given by

$$H_c = \frac{c^{1-\sigma}-1}{1-\sigma} + \mu[(1-\tau)wL + rK + \pi + (1-\tau)b(1-L) - c] \qquad . \qquad (B.1)$$

Here μ is the co-state variable. Maximising equation (B.1) with respect to c, we obtain the following first order condition.

$$c^{-\sigma} - \mu = 0 \quad ; \qquad (B.2)$$

Again from equation (B.1), we have

$$\frac{\dot{\mu}}{\mu} = \rho - r \quad ; \qquad (B.3)$$

and from equation (B.2), we have

$$\frac{\dot{\mu}}{\mu} = -\sigma\frac{\dot{c}}{c} \qquad . \qquad (B.4)$$

Using equations (B.3) and (B.4), we have equation (23) in the body of the article.

Appendix C: Derivation of the Jacobian determinant

The Jacobian determinant is given below.

$$|J| = \begin{vmatrix} \frac{\partial\left(\frac{\dot{M}}{M}\right)}{\partial M} & \frac{\partial\left(\frac{\dot{M}}{M}\right)}{\partial N} \\ \frac{\partial\left(\frac{\dot{N}}{N}\right)}{\partial M} & \frac{\partial\left(\frac{\dot{N}}{N}\right)}{\partial N} \end{vmatrix} \qquad .$$

From equations (27) and (28), we have

$$\frac{\partial\left(\frac{\dot{M}}{M}\right)}{\partial M} = \frac{\partial\left(\frac{\dot{N}}{N}\right)}{\partial M} = 1 \quad ;$$

$$\frac{\partial\left(\frac{\dot{M}}{M}\right)}{\partial N} = \frac{\beta\eta\alpha A L^{*\beta}[\Theta_1]^{\beta\delta}}{\sigma N^{1-\beta\eta}} - \frac{\beta\eta A L^{*\,\beta}[\Theta_1]^{\beta\delta}}{N^{1-\beta\eta}}\left[1 - \frac{\lambda\tau[\theta n(1-\alpha)+\beta(1-\theta)]}{(1-\theta+\theta n)[1-(1-\lambda)\tau]}\right] \qquad ;$$

and

$$\frac{\partial\left(\frac{\dot{N}}{N}\right)}{\partial N} = -\frac{(1-\beta\eta)\lambda\tau[\theta n(1-\alpha)+\beta(1-\theta)]AL^{*\beta}[\Theta_1]^{\beta\delta}}{N^{2-\beta\eta}[1-(1-\lambda)\tau](1-\theta+\theta n)}$$
$$-\frac{\beta\eta AL^{*\,\beta}[\Theta_1]^{\beta\delta}}{N^{1-\beta\eta}}\left[1-\frac{\lambda\tau[\theta n(1-\alpha)+\beta(1-\theta)]}{(1-\theta+\theta n)[1-(1-\lambda)\tau]}\right] \quad .$$

Using these equations, we obtain equation (30) in the body of the article.

Appendix D: Derivation of equation (35)

From equation (21), we obtain

$$\omega = \frac{{c_0}^{1-\sigma}}{[\rho-g(1-\sigma)](1-\sigma)} + constant \quad . \qquad (D.1)$$

Here, $c(0) = c_0$.

Now, from equations (22) and (3), we obtain

$$\dot{K} = (1-\tau)wL + Y - wL + (1-\tau)b(1-L) - c \quad . \qquad (D.2)$$

Using equations (D.2) and (6), we obtain

$$\dot{K} = (1-\tau)wL + Y - wL + \frac{(1-\tau)(1-\lambda)\,\tau wL}{[1-(1-\lambda)\,\tau]} - c \quad . \qquad (D.3)$$

Using equations (D.3) and (11.a), we obtain

$$\dot{K} = Y\left\{1-\frac{\tau\lambda[\theta n(1-\alpha)+\beta(1-\theta)]}{[1-(1-\lambda)\,\tau](1-\theta+\theta n)}\right\} - c \quad . \qquad (D.4)$$

From Equation (D.4), we obtain

$$c_0 = K_0\left\{\frac{Y_0}{K_0}\left[1-\frac{\tau\lambda[\theta n(1-\alpha)+\beta(1-\theta)]}{[1-(1-\lambda)\,\tau](1-\theta+\theta n)}\right] - g\right\} \quad . \qquad (D.5)$$

Using equations (D.5), (1) and (23), we obtain

$$c_0 = K_0\left\{\left\{\frac{(\rho+\sigma g)}{\alpha}\right\}\left[1-\frac{\tau\lambda[\theta n(1-\alpha)+\beta(1-\theta)]}{[1-(1-\lambda)\,\tau](1-\theta+\theta n)}\right] - g\right\} \quad . \qquad (D.6)$$

Using equations (D.1) and (D.6), we obtain equation (35) in the body of the article.

Appendix E: Derivation of equations (41), (42) and (44)

Incorporating the inverted labour demand function of the representative firm from equation (40) in equation (9) and obtain

$$\psi = \{(1-\tau)^m\left(\left[\beta AK^{\alpha}\overline{K}^{\gamma}L^{\beta-1}h^{\beta\eta}b^{-\beta\delta}\right]^{\frac{1}{1-\beta\delta}} - b\right)^m L^n\}^{\theta}$$
$$.\ \{(1-\beta)\left[\beta AK^{\alpha}\overline{K}^{\gamma}h^{\beta\eta}b^{-\beta\delta}\right]^{\frac{1}{1-\beta\delta}}L^{\frac{\beta(1-\delta)}{1-\beta\delta}} - rK\}^{(1-\theta)} \quad . \qquad (E.1)$$

Since equation (40) shows a monotonic relationship between w and L, so we maximise equation (E.1) with respect to L. Using this first order condition and equation (4), we obtain

$$\frac{\frac{\theta m(\beta-1)}{1-\beta\delta}\left[\beta AK^{\alpha}\overline{K}^{\gamma}h^{\beta\eta}b^{-\beta\delta}\right]^{\frac{1}{1-\beta\delta}}L^{\frac{\beta(1+\delta)-2}{1-\beta\delta}}}{\left[\beta AK^{\alpha}\overline{K}^{\gamma}L^{\beta-1}h^{\beta\eta}b^{-\beta\delta}\right]^{\frac{1}{1-\beta\delta}}-b}+\frac{\theta n}{L}$$

$$+\frac{(1-\theta)(1-\beta)\left[\beta^{\beta\delta}AK^{\alpha}\overline{K}^{\gamma}h^{\beta\eta}b^{-\beta\delta}\right]^{\frac{1}{1-\beta\delta}}\frac{\beta(1-\delta)}{1-\beta\delta}L^{\frac{\beta-1}{1-\beta\delta}}}{(1-\alpha-\beta)\left[\beta^{\beta\delta}AK^{\alpha}\overline{K}^{\gamma}h^{\beta\eta}b^{-\beta\delta}\right]^{\frac{1}{1-\beta\delta}}L^{\frac{\beta(1-\delta)}{1-\beta\delta}}}=0 \quad . \qquad (E.2)$$

From equation (6), we have

$$b=\frac{(1-\lambda)\tau wL}{[1-(1-\lambda)\tau](1-L)} \quad . \qquad (E.3)$$

Now, using equations (40) and (E.3), we obtain

$$b=\frac{(1-\lambda)\tau\left[\beta AK^{\alpha}\overline{K}^{\gamma}L^{\beta(1-\delta)}h^{\beta\eta}b^{-\beta\delta}\right]^{\frac{1}{1-\beta\delta}}}{[1-(1-\lambda)\tau](1-L)} \quad . \qquad (E.4)$$

Using equations (E.2) and (E.4), we obtain the equation (41) in the body of the article. Now, using equations (E.3) and (41), we obtain the equation (44) in the body of the article. We obtain the equation (42) of the main article using equations (E.3) and (40).

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