The welfare effects of tax progressivity and unemployment insurance in a frictional labor market

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Alessandra Pizzo *

Universidad de Chile

Abstract

A progressive tax schedule, as it is observed in many developed countries, is usually justified in terms of redistributive purposes; however, when labor markets are frictional, progressive taxation has been shown to have a beneficial effect on the unemployment rate. On the other hand, a more progressive tax schedule discourages individual labor supply and (precautionary) savings, thus potentially reducing capital accumulation and total production. In this paper, I take into account the different effects of a progressive tax and transfer schedule on unemployment, individual labor supply and savings. I consider the progressive tax and transfer schedule in combination with unemployment benefits, which are an additional way to provide public insurance against income drop during unemployment spells. Simple steady state comparisons, based on the utilitarian welfare criterion, point to the desirability of a tax and transfer schedule with a positive degree of progressivity, without calling for additional unemployment insurance: in other words, the welfare criterion calls for a progressive tax schedule combined with a negative income tax at the bottom of the asset distribution. In terms of modelling strategy, I start from the workhorse model of Krusell et al. (2010), which combines the Huggett-Aiyagari framework of heterogeneous agents with matching frictions in the labor market, and I introduce individual labor supply. I also allow for heterogeneity in productivity, as in Lifschitz et al. (2016), as well as in preferences for leisure: the model clarifies that behind the overall welfare effects there is a tension among the low and high productive individuals with respect to the effects of the different policies.

*Email: ale.pizzo@gmail.com

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Contents

1 Introduction

Most developed economies have redistributive fiscal system: in order to raise tax revenues, the state asks to the rich to contribute relatively more, while the poor generally receive transfers.

In a framework in which insurance markets are not complete, a progressive tax and transfer system helps in providing insurance against (labor) income shocks. However, it distorts labor and accumulation choices: if more productive agents have higher incomes, progressive taxation distorts labor supply and potentially decreases total productivity; the publicly provided insurance can induce lower savings and therefore lower accumulation of physical capital[1].

The pros and cons of progressive taxation have been analysed at length in papers featuring incomplete financial markets, as for example recently in Conesa and Krueger (2006), Heathcote et al. (2014), Bakış et al. (2015) or Heathcote and Tsujiyama (2015). However, typically these papers consider a Walrasian labor market, while the labor market literature has pointed out that progressive taxation interacts with other frictions affecting the labor market.

The effect of progressive taxation in the context of frictional labor markets has been analysed since the 1990s, within a representative agent framework[2]: the conclusion of this strand of literature is that, in the context of frictional labor markets, a more progressive tax schedule can decrease the rate of unemployment, through its effect on wage bargaining[3].

In a framework in which the main source of labor income risk is job loss, it is important to endogeneize in the model the unemployment process: there are feedback effects between the policies providing insurance (the level of progressivity of the tax and transfer system as well the unemployment insurance) and the labor market performance, which cannot be taken into account in the literature which considers the unemployment process as exogenous.

In this paper therefore I analyse the efficiency losses and gains induced by a progressive tax and transfer system, in a framework in which the labor market is frictional and financial markets are incomplete: risk-averse agents are subject only to unemployment risk[4], they save to insure themselves and end up with different levels of assets, due to the sequence of

[1] Investment in human capital is also affected: higher progressivity can decrease the incentive in invest in education, by decreasing its return. However, in this paper I will focus on the first two aspects of labor supply and physical capital accumulation.

[2] Consider for example, as a non-exhaustive list, the papers by Lockwood and Manning (1993), Holmlund and Kolm (1995), Sørensen (1999), Røed and Strøm (2002). More recently, this effect has been analysed by authors including Parmentier (2006) and Hüngerbuhler et al. (2006).

[3] Parmentier (2006) adds considerations about the ambiguous results of progressive taxes on wage, and therefore on unemployment, once the hours of work are variable (and set through Nash bargaining).

[4] There is no aggregate uncertainty, only idiosyncratic unemployment risk.

employment/unemployment spells.

I thus aim to encompass both the effects of tax progressivity highlighted by the labor market literature, which focuses on the effects on the unemployment rate, and those pointed out in the heterogeneous agents framework, in particular the effect on total savings.

My results show that an utilitarian welfare criterion calls for a progressive tax system: higher progressivity in fact implies lower capital, but higher total labor supply (a lower individual labor supply is counteracted by a lower unemployment rate). Moreover, tax progressivity is always preferred to unemployment benefits, which are an alternative system to provide public insurance against income drops.

These results refer to the aggregate (utilitarian) welfare. However, agents differ in many more dimensions than just the employment status (and the accumulated wealth): in order to capture this heterogeneity in a reduced form, I follow Lifschitz et al. (2016) in considering agents as characterised by (permanently) different skill or productivity levels, which refer to different (segmented) labor markets[5]. In addition I also allow agents to differ in terms of patience and preferences for leisure.

This heterogeneity in agents' types allows to show that the overall welfare evaluation is driven by different interests, as it is expected: the welfare of high skill agents in fact is negatively affected by progressivity, while it improves the conditions of the unskilled agents. Moreover, only the skilled would see their welfare to increase with unemployment insurance: since the unemployment rate they face is very low, the advantages of higher unemployment benefits are not compensated by the disadvantages of a higher unemployment rate (and a heavier tax burden).

To sum up, different trade-off are at stake: on the one hand, tax progressivity reduces individual labor supply and savings, thus reducing the total size of the economy; however, the decrease in labor supply is valuable in terms of gained leisure time[6], and the decrease in savings implies a higher level of consumption.

On the other, tax progressivity, by exerting a downward pressure on wage (through Nash bargaining), has a decreasing effect on unemployment, thus contributing to increase total labor input.

In contrast, unemployment benefits, even if they allow constrained agents to better smooth consumption, increase unemployment rate, thus making the total cost of unemployment insurance too high.

The progressive tax system which is studied is, more precisely, a tax and transfer system[7],

[5]The labor market conditions for people having a college degree or more are very different from those faced by people without high school diploma.

[6]The fact that labor supply can be inefficiently high, in an incomplete market framework, with respect to the complete market case, has been shown by Pijoan-Mas (2006).

[7]I adopt a widely used functional form for expressing the disposable income, used by for example Sørensen

which allows for negative taxes (i.e. transfers) to be paid to agents under a certain income threshold. Although the chosen function has to be interpreted as only an approximation to reality, it allows to study social welfare systems characterised by a "negative income tax", financed through tax revenues raised with increasing marginal tax rates.

In terms of modelling choices, I start from the workhorse model of Krusell et al. (2010), which combines the Bewley-Huggett-Aiyagari (BHA) model of incomplete markets with the search and matching model à la Mortensen and Pissarides. Lifschitz et al. (2016) build on the version of the model of Krusell et al. (2010) without aggregate uncertainty to study the role of unemployment benefits, in a context in which there is more "heterogeneity": agents differ permanently in their skill or productivity levels, which are interpreted as reflecting different educational attainments.

I extend the version of the model in Lifschitz et al. (2016) by allowing for variable hours of labor and progressive taxation; moreover, I allow for preference heterogeneity in leisure and impatience to better match some features of the data [8], in particular the basic facts that skilled agents earn more and accumulate more assets than the other types.

The result that a positive (and higher of the actual level characterising the US economy) level of fiscal redistribution is optimal is in line with the results of a strand of the literature: papers as Piketty and Saez (2013) as well as Chang et al. (2016) or Heathcote and Tsujiyama (2015) find that, according to a utilitarian welfare criterion, the optimal tax rates should be higher than the observed ones in the US. While Piketty and Saez (2013) adopt a different view [9], their conclusion is coherent with that one of Chang et al. (2016), who adopt a Ramsey approach in a context of incomplete financial markets, or Heathcote and Tsujiyama (2015) who provide a comparison of both approaches.

The result that the optimal level of unemployment insurance is very low is in line with the conclusions of the previous literature which adopts a similar setting: the steady state comparisons in Krusell et al. (2010) indicate that, according to an utilitarian criterion, the optimal level of unemployment benefit is very low[10]. Their results differ from what suggested by the basic Aiyagari (1994) model: if unemployment risk is exogenous, therefore not affected by the unemployment insurance level, it would be optimal to provide perfect insurance (i.e. a level equal to the wage). The reason is that, as explained by Krusell et al. (2010), self-insurance through savings is quite effective, while the distortions induced by the

(1999), Bénabou (2002), Heathcote et al. (2014) and Bakış et al. (2015); the convenience of such a functional form lies also in the fact that a unique measure of progressivity, the so called Coefficient or Residual Income progression, can be defined.

[8]Consider the recent papers by Krueger et al. (2016) or the arguments in Christopher D. Carroll and White (2015).

[9]they study an optimal tax schedule in a Mirleesian approach.

[10]Earlier contributions about the optimal level of unemployment benefits in similar models are those by Pollak (2007) and Reichling (2006).

unemployment insurance (an increase in the unemployment rate) are important[11].

Since the resolution of the model is numerical, I provide some additional results about the sensitivity to alternative hypothesis: in particular, I show that: *(i)* the higher the elasticity of hours, the lower the optimal level of progressivity; *(ii)* the optimal level of progressivity is higher (lower) if the bargaining power of workers is higher (lower) than the elasticity of the matching function.

The paper is organised as follows: Section 2 presents the model; Section 3 discusses the calibration and quantitative results. Section 4 contains some robustness checks of the model, to assess the stability of the results depending on different calibrations. Section 5 concludes.

2 A model of frictional labor market with labor supply and progressive taxation

I adopt a general equilibrium model with segmented labor markets. Agent i is characterised by his skill or productivity level, preferences for leisure and impatience (discount factor). For each skill level, the labor market is affected by search and matching frictions: the level of frictions can vary among them, in particular the (exogenous) separation rate and the vacancy posting costs can be different; in each market, the worker and the firm set wage and hours through Nash bargaining.

Financial markets are incomplete: agents can save to (partially) self-insure against the idiosyncratic risk of becoming unemployed, but they cannot borrow.

Because of different employment histories, agents of each type i end up accumulating different levels of assets. The dimensions of heterogeneity are therefore three: the type i, the employment status and the level of wealth.

Thus the model is very close to the one developed by Lifschitz et al. (2016), who build on Krusell et al. (2010), but it differentiates for the presence of individual labor supply and the focus on progressive taxation.

Agents' instantaneous utility depends on consumption and leisure.

The tax schedule I adopt follows, among others, Sørensen (1999), Heathcote et al. (2014) and Bakış et al. (2015). It is actually a tax and transfer scheme, that allows for different levels of progressivity; the particular case of a proportional tax schedule is also embedded. The tax revenues are used to finance the transfers and unemployment benefits.

[11]Mukoyama (2013) considers the effects of unemployment benefits in the framework developed by Krusell et al. (2010), including the transitional path to different steady states.

2.1 Labor markets

As in Lifschitz et al. (2016), there is a finite number of types of agents, according to their labor market characteristics (productivity, separation rate, vacancy cost) and preferences (value of leisure, impatience). The type of agent can be summarised referring to his productivity or skill level, that is linked to the level of education accomplished.

I distinguish three skills levels: people with less than the high school degree, with high school degree and with a college degree degree or more.

The proportion of agents of type i (ψ_i) is fixed and obviously $\Sigma_i \psi_i = 1$. Firms open vacancies of type i for agents of type i, i.e. labor markets are segmented[12].

The flows on the labor market are modelled following the workhorse model of Diamond, Mortensen and Pissarides. Firms of type i post vacancies to fill their job. They are randomly matched with unemployed workers of type i who look for a job; the matching function has the standard Cobb-Douglas form $M_i = M(v_i, u_i) = \chi v_i^{1-\eta} u_i^{\eta}$, and labor market tightness is defined as the ratio between the vacancy and the unemployment rates: $\theta_i = \frac{v_i}{u_i}$. After a match is created, the firm and worker bargain over the wage bill (they set the wage and the hours worked). The reservation wages differ across agents' types and according to their level of accumulated assets.

The steady state unemployment rate for each type is given by the equalization between the flows in and out of the stock of employment; i.e., $f_i(\theta_i)u_i = s_i(1-u_i)$, which implies that steady state unemployment is given by:

$$u_i = \frac{f_i(\theta_i)}{s_i + f_i(\theta_i)} \tag{2.1}$$

where $f_i(\theta_i) = M_i/u_i$ and $q_i(\theta_i) = M_i/v_i = f_i(\theta_i)/\theta_i$ indicate respectively the job-finding and job-filling probabilities.

2.2 The financial structure

The financial structure of the model follows Krusell et al. (2010). Consumers can hold two types of assets: physical capital k or equity, denoted as x (in the following, I drop the subscript i for notational convenience); the total amount of equity is normalised to one, while the equity price is given by the actual value of the future gain, which is given by the dividend and the price of the equity itself (if it were to be sold in the future): $p = \frac{p+d}{1+r}$. Because of the arbitrage condition, the return on equity or on physical capital must be the same; a variable "asset" can therefore be considered, given by the combination of the two types of assets, so that the portfolio combination choice can be discarded.

[12] I then abstract from the issues connected to the composition externality.

$$a = k + px \tag{2.2}$$

so that

$$a' = k(1+r) + px\frac{p+d}{p} = (1+r)(k+px) \tag{2.3}$$

2.3 The tax and transfer schedule

I consider a simple way to introduce non-linear labor income taxation, that has been adopted by Sørensen (1999), Bénabou (2002), Heathcote et al. (2014) and recently by Bakış et al. (2015), among others; it is a two-parameters functional form for the tax schedule, that allows for negative taxes (i.e. transfers) to low income agents. It presents some convenient properties, already identified by Jakobsson (1976), notably the fact that the Coefficient of Residual Income Progression is constant across the distribution (it does not depend on the income level).

The CRIP, defined originally by Musgrave and Thin (1948), is one of the most-used measure of progressivity[13]: it represents the elasticity of post-tax income to pre-tax income. A tax schedule is considered progressive if the CRIP is strictly less than one, regressive if it is bigger than one; in the case of a flat tax, the CRIP is equal to one. One advantage of this measure of tax progressivity is that it is also defined when the average tax rate is null. The chosen functional form for the tax schedule defines disposable income as:

$$y^d = (1-\tau)y^{1-\lambda} \tag{2.4}$$

so that total (net) taxes are given by:

$$T(y) = y - (1-\tau)y^{1-\lambda} \tag{2.5}$$

The coefficient λ governs the level of progressivity, while τ is a shift parameter that serves to balance the government budget. The CRIP relates to the marginal and average tax rates as follows:

$$\text{CRIP(y)} = \frac{\partial y^d}{\partial y}\frac{y}{y^d} = \frac{1-T'(y)}{1-T(y)/y} \tag{2.6}$$

Considering the chosen tax schedule, the expression for the CRIP is given by:

$$\text{CRIP(y)} = (1-\lambda) \tag{2.7}$$

so that if λ is zero the tax schedule is flat, while if $0 < \lambda < 1$ the tax schedule is progres-

[13]See Røed and Strøm (2002) for a comprehensive survey.

sive[14]. The chosen tax schedule is actually a tax and transfer scheme: it allows for "negative" taxes if the revenue is lower than a certain threshold[15]. Moreover, there exists a minimum for the net tax schedule, which implies that transfers are non-monotonic in income:

$$T'(y) = 0 \leftrightarrow y = [(1-\tau)(1-\lambda)]^{1/\lambda} = y_{00} \tag{2.8}$$

The definition of revenue of agent i, y_i is different for the employed and the unemployed agent: both receive the interests on their stock of wealth ($r * a_i$), the employed receive the hourly wage, which varies according to his skill level, multiplied by the hours he works.The unemployed agent receives an unemployment benefit (UB), which is given by a proportion μ of the wage bill he would have received if employed [16], which is encompassed within the definition of taxable income.

To sum up, the disposable income of agent i is defined as:

$$\begin{aligned} y^d_{e,i} &= (1-\tau)(w_i h_i + r a_i)^{1-\lambda} && (2.9)\\ y^d_{u,i} &= (1-\tau)(\mu w_i h_i + r a_i)^{1-\lambda} && (2.10) \end{aligned}$$

2.4 The households

I turn to the maximization problem of the employed and unemployed agent of type i in the economy:

$$\begin{aligned} W_i(a) &= max_{c_{e,i},a'_i} u(c_{e,i}(a), 1-h_i(a)) + \beta_i[(1-s_i)W(g_{e,i}(a)) + s_i U_i(g_{u,i}(a))] && (2.11)\\ U_i(a) &= max_{c_{u,i},a'_i} u(c_{u,i}(a), \Gamma^u_i) + \beta_i[f_i(\theta_i)W_i(g_{e,i}(a)) + (1-f_i(\theta_i))U_i(g_{u,i}(a))] && (2.12) \end{aligned}$$

$$\begin{aligned} \text{s.t. } c_{e,i} &= a_i + (1-\tau)(w_i(a)h_i(a) + r a_i)^{(1-\lambda)} - a'_{e,i}\\ c_{u,i} &= a_i + (1-\tau)(\mu w_i(a)h_i(a) + r a_i)^{(1-\lambda)} - a'_{u,i} \end{aligned}$$

where the decision rules for savings (and therefore for consumption) of the employed and

[14]It has to be understood that the "optimal" level of progressivity (which could be in theory be null or negative) is conditional on the chosen functional form of the tax and transfer schedule; this one, however, is not the optimal one, as already noted in Sørensen (1999) p. 439.

[15]I define the value of revenue which is associated with a zero net tax as $y_0 = (1-\tau)^{1/\lambda}$; if the agent's revenue is lower than this threshold, i.e. if $y < y_0$, the agent pays a negative tax.

[16]The unemployment compensation is thus not explicit indexed on the previous wage of the agent, but since every type of agent is characterised by his own level of accumulated wealth, it is possible to define a "counter-factual wage", i.e. the wage he would have received, given his level of wealth, if employed.

unemployed are respectively[17]:

$$a'_{e,i} = g_{e,i}(a)$$
$$a'_{u,i} = g_{u,i}(a)$$

The employed agent chooses his level of consumption and savings considering his instantaneous utility and the continuation value: with (exogenous) probability s_i, the separation rate, he will be separated from the job, while with the complementary probability he will remain employed. The problem of the unemployed is to maximise his value function, considering that with (endogenous) probability $f_i(\theta_i)$ he will find a job and with the complementary probability he will remain unemployed.

The specific form of the instantaneous utility function that I adopt is sperable in consumption and leisure:

$$u(c_i, h_i, a_i) = \log(c_i) + \Gamma_i^z \tag{2.13}$$

where $z = \{e, u\}$, $\Gamma_i^e = \sigma_{l,i} \frac{(1-h_i)^{1-\nu}}{1-\nu}$ and Γ_i^u is a constant.

2.5 The firm

Firms produce using capital and labor: they post vacancies to hire workers, and they rent capital from the households. After a match is created, the firm and the worker set the wage and the hours. The firm chooses to open vacancies of type i by taking into consideration the value of a filled job, which is given by:

$$J_i(a) = \max_{k_i} \left(\frac{k_i}{z_i h_i} \right)^{\alpha} h_i(a) - (r+\delta)k_i - w_i(a)h_i(a) + \frac{1}{1+r} \left[s_i V_i + (1-s_i) J_i(a'_{e,i}) \right] \tag{2.14}$$

The filled job produces an amount of output given by $\left(\frac{k_i}{z_i h_i} \right)^{\alpha} h_i(a)$, where z_i is the level of productivity of agent i. The firm has to pay the rental cost of capital and the wage bill; in addition, the firm takes into account that the job has a probability s_i of being destroyed. In this case, the firm is left with the value of opening a vacancy, indicate by V_i[18].

The term $(\frac{k_i}{z_i h_i}) \equiv \tilde{k}_i$ represents the capital per effective labor ratio. In equilibrium, it must be the same across all matched firms, because the capital market is perfectly competitive;

[17] It is important to notice that the variables consumption, hours of work and wage are all function of the wealth level, i.e. in terms of notation for a generic variable x, $x_i = x_i(a)$

[18] Notice that v_i indicates the number of vacancies while V_i the value for the firm of opening one vacancy of type i.

this means that each firm must set the capital labor ratio as $\tilde{k_i} = \frac{K}{H}$, where K is aggregate capital and H represents total effective labor supply:

$$K = \Sigma_i \psi_i \int a(P_{e,i}(a) + P_{u,i})da \tag{2.15}$$

$$H = \Sigma_i \psi_i \int z_i h_i(a) P_{e,i}(a)da \tag{2.16}$$

The interest rate is given by:

$$r = \alpha \left(\frac{k_i}{z_i h_i}\right)^{(\alpha-1)} - \delta \tag{2.17}$$

The value of a vacancy is given by:

$$V_i = -\omega_i + \frac{1}{1+r}\left[q_i(\theta_i)\int J_i(a'_{u,i})\frac{P_{u,i}(a)}{u_i}da + (1-q_i(\theta_i))V_i\right] \tag{2.18}$$

The value of opening a vacancy depends on the vacancy posting cost ω_i and on the probability $q_i(\theta_i)$ of filling the vacancy. It must be noted that since it is not a directed search model, the firm cannot distinguish among workers *before* filling the vacancy; as agents of type i are heterogeneous in terms of their asset levels (and therefore of their reservation wage), but they are all equally productive, the firm faces an uncertainty with respect to how much it will have to pay a worker (and how many hours he will work for a certain hourly wage). This is the reason that the "average" value of a filled job $\int J_i(a'_{u,i})\frac{P_{u,i}(a)}{u_i}da$ appears in the value of a vacancy.

In equilibrium, the value of opening a vacancy has to be null; setting $V_i = 0 \ \forall i$ implies the following value for the job filling rate:

$$q_i(\theta_i) = \omega_i(1+r)\left(\int J_i(a'_{u,i})\frac{P_{u,i}(a)}{u_i}da\right)^{-1} \tag{2.19}$$

The profit of the firm coming from one matched job pair of type i is given by the production less the costs of capital and labor:

$$\pi_i(a) = F(k_i, z_i h_i) - (r+\delta)k_i - w(a)h_i(a) \tag{2.20}$$

The dividend is paid on the profit net of the vacancy posting cost, which is given by the cost of opening a vacancy (ω_i) multiplied by the number of vacancies (v_i):

$$d_i = \int \pi_i(a) P_{e,i}(a) da - \omega_i v_i \tag{2.21}$$

2.6 Wage bargaining

The wage and hours are fixed through Nash-bargaining between the firm and the worker: the fact that the tax on labor income is progressive has an impact on the bargaining, and therefore on the equilibrium choices, of wage and hours.

The firm and the worker maximise the Nash product of their respective evaluation of the value of the job:

$$\max_{w_i, h_i} (W_i(a) - U_i(a))^\gamma (J_i(a) - V_i)^{1-\gamma}$$

The FOC with respect to the wage gives:

$$\gamma (W_i(a) - U_i(a))^{\gamma-1} \frac{\partial W_i(a)}{\partial w_i} (J_i(a))^{1-\gamma} + (1-\gamma)(J_i(a))^{-\gamma} \frac{\partial J_i(a)}{\partial w_i} (W_i(a) - U_i(a))^\gamma = 0 \tag{2.22}$$

where the derivative of the value for a worker of a higher (hourly) wage is given by:

$$\frac{\partial W_i(a)}{\partial w_i} = \frac{\partial u(c_{e,i}, h_i)}{\partial c_{e,i}} (1-\tau)(1-\lambda)(w_i(a) h_i(a) + ra)^{(-\lambda)} h_i \tag{2.23}$$

If $\lambda = 0$ (a proportional income tax), equation (2.23) takes the form of a traditional expression: the value of an increase in wage is given by the additional (net) consumption it allows, evaluated through its marginal utility. When λ increases, ceteris paribus, the value of an increase in wage for the worker decreases.

The derivative of the value of a filled job for the firm with respect to the wage is given by:

$$\frac{\partial J_i(a)}{\partial w_i} = -h_i(a) \tag{2.24}$$

The expression becomes:

$$\frac{(W_i(a) - U_i(a))}{\left(\frac{\partial W_i(a)}{\partial w_i}\right)} \frac{1-\gamma}{\gamma} = -\frac{J_i(a)}{\frac{\partial J_i(a)}{\partial w_i}} \tag{2.25}$$

and therefore[19]:

[19] By setting $\lambda = 0$ and by considering linear utility, equation (2.26) reverts to to the standard DMP form. In Appendix A, I provide some analytical insight, under the simplifying hypothesis that agents are risk neutral, about the effects that the transfer (the UB) has on wage bargaining; I also analyse the effect of λ in the wage equation.

$$(W_i(a)-U_i(a))\frac{c_{e,i}(a)[w_i(a)h_i(a)+ra]^{\lambda}}{(1-\tau)(1-\lambda)}=\frac{\gamma}{1-\gamma}J_i(a) \tag{2.26}$$

The FOC with respect to hours gives:

$$\gamma\frac{1}{(W_i(a)-U_i(a))}\frac{\partial W_i(a)}{\partial h_i}J_i(a)+(1-\gamma)\frac{\partial J_i(a)}{\partial h_i}=0 \tag{2.27}$$

The derivative of the value function with respect to hours is given by:

$$\frac{\partial W_i(a)}{\partial h_i}=\frac{\partial u(c_{e,i},1-h_i)}{\partial c_{e,i}}w_i(1-\tau)(1-\lambda)(w_ih_i+ra)^{-\lambda}+\frac{\partial u(c_{e,i},1-h_i)}{\partial h_i} \tag{2.28}$$

Similarly to what has been observed for equation (2.23), the effect of more progressive taxation (an increasing value for λ) is to decrease the convenience to work additional hours: when $\lambda\to 1$ (i.e., a situation involving perfect pooling of income and redistribution among agents), the only consequence of working an additional hour would be the disutility of enjoying less leisure time.

The derivative of the value for the firm of an additional hour is given by:

$$\frac{\partial J_i(a)}{\partial h_i}=\tilde{k_i}^{\alpha}-w_i \tag{2.29}$$

Substituting the previous expressions in equation (2.27), it becomes:

$$\frac{(W_i(a)-U_i(a))}{\left(\frac{\partial u(c_{e,i},1-h_i)}{\partial c_{e,i}}w_i(1-\tau)(1-\lambda)(w_ih_i+ra)^{-\lambda}+\frac{\partial u(c_{e,i},1-h_i)}{\partial h_i}\right)}=\frac{\gamma}{1-\gamma}\frac{J_i(a)}{(w_i-\tilde{k_i}^{\alpha})} \tag{2.30}$$

Combining the FOC on hours and wage, I finally obtain the following condition:

$$(1-h_i(a))^{-\nu}=\frac{\tilde{k}_i^{\alpha}}{\sigma_{l,i}}\frac{(1-\tau)(1-\lambda)}{c_{e,i}(a)[w_i(a)h_i(a)+ra]^{\lambda}} \tag{2.31}$$

Once again, by setting $\lambda=0$ the usual hours equation appears; as it has been remarked, the parameter λ has a negative effect on hours, ceteris paribus.

2.7 Government budget constraint

The government runs a balanced budget: it collects taxes which are used to finance its transfers. In addition, the Government finances also a public insurance, in the form of unemployment benefits.

In the numerical simulations, the value of the degree of progressivity (λ) is the policy parameter, while the parameter governing the level of tax revenues (τ) varies endogenously, in order to balance the government budget.

I recall the definition of tax revenues, which consist of the difference between total (pre-tax) income and the disposable (after-tax) income:

$$T(y) = y - y^d = y - (1-\tau)y^{1-\lambda} \tag{2.32}$$

The net taxes (all the tax collected minus the transfers paid by income-poor agents) have to be equal to the Government expenditures in unemployment insurance, which are given by the amount of the unemployment benefit μ, which is paid to a fraction u of the population.

Government budget constraint:

$$\begin{aligned}\Sigma_{i=1}^{3}\psi_i\{(1-u_i)\left[\int(w_ih_i+ra)\frac{dP_{e,i}}{(1-u_i)}-(1-\tau)\int(w_ih_i+ra)^{(1-\lambda)}\frac{dP_{e,i}}{(1-u_i)}\right]+\\ u_i\left[\int(\mu w_ih_i+ra)\frac{dP_{u,i}}{u_i}-(1-\tau)\int(\mu w_ih_i+ra)^{(1-\lambda)}\frac{dP_{u,i}}{u_i}\right]\}=\Sigma_{i=1}^{3}\left(\int\mu w_ih_idP_{u,i}\right)\end{aligned} \tag{2.33}$$

3 Calibration and quantitative results

The model is calibrated for a period of six weeks on the US economy. As anticipated, in line with Lifschitz et al. (2016), I consider a finite number of types of agents ($i = 1, 2, 3$), who differ in terms of skill/productivity levels as well as in terms of labor market characteristics (separation rate and vacancy posting costs). In addition, I also allow for heterogeneity in preferences (taste for leisure and impatience).

The proxy for skill is the educational attainment, so that agents are divided in three categories: less than high school, high school diploma and college degree or more. The parameter ψ_i indicates the weight in total population. The productivity level z_i is set in order to target the wage premium, expressed as the ratio of the median wage of the different skill types with respect to the low skill.

Agents are heterogeneous in preferences in two dimensions: their taste for leisure, represented by the parameter $\sigma_{l,i}$ differs, as well as their impatience (their discount factor β_i). The heterogeneity in discount factor allows to replicate the stylised fact that agents with higher educational attainment accumulate more assets than low skilled individuals: the target for calibration is in fact given by the median wealth premium, i.e. the ratio between the median wealth of the different skill types with respect tot he low skilled agent. The total amount of capital implies a steady state equilibrium interest rate of 6.5%.

The taste for leisure is set considering the different average levels of labor supply that can be observed in the data. The fact that the hours worked by agents with different education level showed a different evolution in the last decades has been highlighted by some authors, as for ex. Aguiar and Hurst (2007) or Kuhn and Lozano (2005): the conclusion is that today the average hours worked by people with no formal education are lower than those worked by college graduates. I use therefore the evidence from the ATUS data then to calibrate the taste for leisure of the different types of agents, in order to replicate the fact that the average labor supply of skilled workers is higher than that one of workers with lower levels of education[20].

The labor market performance for these categories are very different, as highlighted by Lifschitz et al. (2016): the unemployment risk faced by the unskilled is higher, and I follow the aforementioned paper in calibrating different separation rates.

I allow for different vacancy posting costs in order to target a similar job finding rate for all types of agents: this implies that the vacancy posting costs for skilled workers are higher than for the less skilled, in accordance with some empirical evidence as reported by Lifschitz et al. (2016).

The calibration of the parameter ω_i implies that the recruiting costs, when evaluated in terms of wage bill[21], for the three types of workers amount respectively to $0.21\%, 0.13\%$ and 0.06%: overall therefore the recruiting costs amount to 0.41% of total labor costs. This number is too low with respect to its empirical counterpart: using the 1997 National Employer Survey, Villena-Roldan (2012) concludes that the firms spend 2.5% of their labor costs in recruiting activities.

Table 1: Type specific parameters

Symbol	Interpretation	Low skill	Medium skill	High skill	Target
ψ_i	population share	0.12	0.56	0.32	data
z_i	productivity	0.50	0.77	1.26	wage premium (CPS data)
β_i	discount factor	0.9929	0.9940	0.9946	wealth premium (CPS data)
$\sigma_{l,i}$	leisure preference	0.405	0.310	0.205	labor supply (ATUS data)
s_i	separation rate	0.061	0.037	0.018	data[22]
ω_i	vacancy posting cost	0.05	0.05	0.05	job finding rate[23]
χ_i	matching efficiency	0.77	0.70	0.61	unemployment rate

[20]Some recent papers, as Carroll and Young (2011) or MustredelRio (2015) estimate the preferences parameter for leisure from the data. My approach is much more stylised as I just target the average hours of work supplied by the different skill categories.

[21]For each type of agent i, the ratio of interest is calculated as $((\omega_i V_i)/q_i)/(\text{wage bill of i}) = ((\omega_i V_i)/q_i)/(\psi_i \int w_i(a) h_i(a) P_{e,i}(a)$.

There is a set of parameters which are common to all types of agents. The parameter α in the production function, which gives the capital share, is set to 0.33; the depreciation rate is set to 0.01, which implies an investment output ratio of 0.19 in steady state; the inter-temporal risk aversion is calibrated to the standard value of 1.

I choose to calibrate the elasticity of the matching function with respect to vacancies and the bargaining power of the firm to the same value (0.5), and I fix the matching efficiency in order to target the values of the job-filling rates.

I choose as a 'benchmark economy' in terms of policy parameters a case that can be considered close to the actual state of the US economy: the parameter λ is set to 0.16[24], i.e. the CRIP $(1-\lambda)$ is equal to 0.84[25].

The replacement rate for unemployment insurance is set to the commonly used value of 40%.

In the presence of progressive taxation on labor income, the Frisch elasticity of labor supply is not independent of the parameter that affects the CRIP[26]. The parameter ν implies an elasticity of leisure of 2.86; together with the taste for leisure, $\sigma_{l,i}$, they imply that in the benchmark economy the 'traditional' Frisch elasticity[27] takes the values of $\{0.31, 0.21, 0.14\}$ for the three types of agents respectively[28]: low skill individuals have on average a higher elasticity, however, for every type of agent the elasticity increases as agents accumulate assets. Since labor supply elasticity is a parameter of fundamental importance, I provide in Section 4.1 a sensitivity analysis of the results with respect to the this value.

Finally, in order to assure that the value of working is always higher than that of not working (if not, there would be endogenous separations, which I discard in my modelling choices), I calibrate the value of home production Γ^uso that the condition $W_i(a) - U_i(a) > 0$ is always respected, $\forall i$.

I provide in Tables 3 and 4 the results for the targeted labor market moments for the benchmark economy. The performance of the model in steady state is good for what is

[22] From Lifschitz et al. (2016)

[23] From Lifschitz et al. (2016)

[24] Intermediate value between the estimates obtained by Heathcote et al. (2014), who consider a value of 0.15, and Bakış et al. (2015) who provide an estimate of 0.17.

[25] The OECD reports a value of 0.86 or 0.88 for the elasticity of disposable income (for a married couple with two children, according to their wage income level), see OECD pag. 120.

[26] See Appendix B for the derivation of the Frisch elasticity with progressive taxation.

[27] The Frisch elasticity of agent i, for the adopted separable preferences in consumption and leisure, is given by $\epsilon_i = \frac{1}{\nu} \int \frac{1-\bar{h_i}(a)}{\bar{h_i}(a)}$ where $\bar{h_i}(a) = \int h_i(a) P_{e,i}(a) da$

[28] The empirical estimates about labor supply elasticity have found very different values, but it is not uncommon to find in the literature values as low as 0.1 for the labor supply elasticity of adult men: for an example, see Chetty (2012). Peterman (2016) provides a recent survey justifying the use of different values for elasticity according to the specific model adopted. According to the author, in a case in which the Frisch elasticity refers only to the intensive margin, a reasonable range is considered to be the interval [0.2-0.9].

concerns the labor market moments (unemployment rate and job finding rate), as well as for the median wage and wealth premia. The performance is worse instead for the labor supply aspect: the model in fact implies an average labor supply which is too high for the agents with lower level of skills.

Table 2: Calibrated common parameters

Symbol	Interpretation	Value
α	capital share of income	0.33
δ	depreciation rate	0.01
σ	risk aversion parameter	1
γ	bargaining power	0.5
η	matching elasticity	0.5
λ	level of progressivity	0.16
μ	replacement rate	0.4
ν	inverse leisure elasticity	0.35
Γ^u	home production	0.02

Table 3: Equilibrium benchmark results I

Variable	Low skill	Medium skill	High skill	
u (%)	9.31	5.86	2.81	BLS data (1992-2016)
u (%)	9.41	5.79	2.89	model
job find. rate	0.60	0.60	0.60	Lifschitz et al. (2016)
job find. rate	0.59	0.60	0.60	model
median wage premium	1	1.5	2.5	CPS data (1991-2015)
median wage premium	1	1.5	2.5	model
median wealth premium	1	5	16	CPS data (1991-2015)
median wealth premium	1	6	15.6	model

3.1 Welfare effect of tax progressivity

In this section, I illustrate the first result of the paper: in an economy characterised by the tax and transfer schedule in equation (2.32, as well as by the presence of an unemployment insurance system, there exists a positive optimal level of tax progressivity, measured through the Coefficient of Residual Income Progression[29]. The left panel of Figure 1 shows that the optimal level of progressivity is higher than the one considered as the benchmark case [30].

[29] I remind that the CRIP is given by $(1-\lambda)$.

[30] $(1-\lambda) = 0.84$, while $(1-\lambda^*) = 0.73$, where the closer to the unity the higher is the level of progressivity.

Table 4: Equilibrium benchmark results II

Variable	Low skill	Medium skill	High skill	
Average hours per week $\bar{h}_i$	35.9	38.8	41.6	ATUS data (2000-2015)
$\bar{h}_i/\bar{h}_{HS}$	0.85	0.94	1	ATUS data (2000-2015)
$\bar{h}_i/\bar{h}_{HS}$	0.95	0.98	1	model

The optimal level of tax progressivity is obtained adopting an utilitarian welfare criterion: total welfare is obtained by simply summing up the welfare level of each agent, expressed by his value function[31].

$$\text{Welfare} = \Sigma_{i=1}^{3}\psi_i\left(\int W_i(a)P_{e,i}(a)da + \int U_i(a)P_{u,i}(a)da\right) \tag{3.1}$$

This result is in contrast with the conclusions of the literature which analysed the optimal level of progressivity in a similar framework (with incomplete financial markets), but within a perfect labor market: Heathcote et al. (2014) for example find that the social planner would choose a slightly regressive tax and transfer system[32]; Bakış et al. (2015) have the same result, i.e. considering just steady state comparisons, the tax and transfer schedule should be slightly regressive[33].

The right panel of Figure 1 shows that the evolution of aggregate welfare is driven by different forces: while the most unskilled profit from increased progressivity, the high skill prefer a less progressive tax and transfer system.

To evaluate the gains (or losses) of moving along the curve representing welfare in Figure 1, I calculate the equivalence between the welfare levels in terms of average consumption variations Δ. Considering that preferences are separable in consumption and leisure, I define the consumption variation as follows:

$$ln(1+\Delta)\frac{1}{1-\beta} = \Sigma_{i=1}^{3}\psi_i\left(\int \tilde{W}_i\tilde{P_{e,i}}da + \int \tilde{U}_i\tilde{P_{u,i}}da\right) - \Sigma_{i=1}^{3}\psi_i\left(\int W_iP_{e,i}da + \int U_iP_{u,i}da\right) \tag{3.2}$$

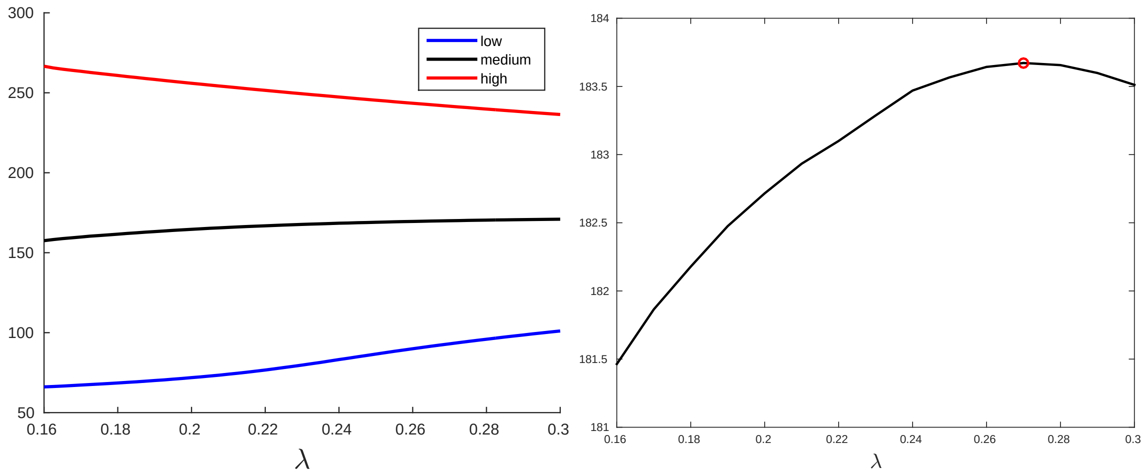
where W_i and $\tilde{W}_i$ (U_i and $\tilde{U}_i$) stand for the value function of the employed (unemployed) of type i in the original and experiment economies.

[31]For the present version, I only consider steady state comparisons and not the transition paths.

[32]Their main explanation however considers factors which I do not include, specifically investment in human capital and valued public goods.

[33]The authors show however that including the transition path tot he new steady state changes the conclusion: a positive level of progressivity is optimal, even if slightly lower than the actual level of the US system.

Figure 1: **Welfare by skill level (left) and aggregate (right): the effects of λ**



In Table 5, I report the values of Δ, where the original economy is the one with $\lambda = 0.16$ and the two experiments are the economies characterised by the optimal level of the parameter ($\lambda = \lambda^* = 0.27$) and $\lambda = 0.30$ respectively: the gains in terms of lifetime consumption are sizeable.

Table 5: **Welfare gains/losses in terms of consumption**

λ	Δ total
0.16	0%
0.27	1.32%
0.30	1.22%

3.1.1 The mechanisms behind the effects of tax progressivity

The effects of λ on the functioning of the economy pass through the wage and hours negotiation, and then through the unemployment rate.

In the context of a representative agent model, Sørensen (1999) summarises the impact of marginal tax rate on the unemployment rate and economic efficiency, in different frameworks characterised by labor market frictions, among which the search and matching model. However, the wage moderating effect of higher progressivity is a widely spread result, from the union model to the effficiency wage models through the directed search model, as recently summarised by Kroft et al. (2015)[34].

Following Sørensen (1999), in a search and matching framework in which wage is bargained over à la Nash, a higher progressive tax implies a lower unemployment rate: since the

[34] See Kroft et al. (2015) pag. 20 footnote 27.

increased progressivity decreases the part of the surplus going to the worker, and makes more costly for the employer to assign part of the surplus to the worker, there is a convergence of interest in lowering wage pressure. This contributes to the decrease of unemployment: if wages are lower, the firm has an interest in posting more vacancies, and unemployment decreases. Parmentier (2006) extends the analysis to a case with search and matching frictions in which hours are elastic, and fixed through Nash bargaining between the worker and the firm[35]. Since hours and wages are bargained at the same time, the resulting equilibrium condition for hours coincides with the walrasian labor supply (that is why this scheme is referred to as 'efficient bargaining'): an increase in tax progressivity then is an incentive to decrease the supply of labor, since it is distorting the marginal revenue of an additional hour of work.

My results are in line with those of Sørensen (1999) and Parmentier (2006)[36]: the numerical simulations show that as the measure of tax progressivity increases, both the negotiated wage and hours worked decrease, for each level of asset.

Both these effects can be seen playing a role in the model by looking at Figure 2. The Figure shows the resulting hours and wage functions for two experiments, one in which $\lambda = 0.16$, and the other in which $\lambda = 0.27$: for all levels of assets, the wage is lower (left panel), while hours worked decrease (right panel) when λ increases[37].

The unemployment rate is decreasing in λ, as it can be seen in the left panel of Figure 1. The overall effect on total labor remains positive, driven by the movement in the rate of unemployment, even if individual hours decrease.

The additional effect that lacks in the model of Sørensen (1999) and Parmentier (2006) regards capital accumulation and its effects on labor productivity. Once agents are allowed to save (and the revenues of savings are taxed), aggregate capital reacts to changes in tax progressivity: in a general equilibrium framework with risk-averse agents and precautionary savings, aggregate capital can be crowded out, if agents have access to other means of insurance, and their capital income is taxed to finance the insurance system.

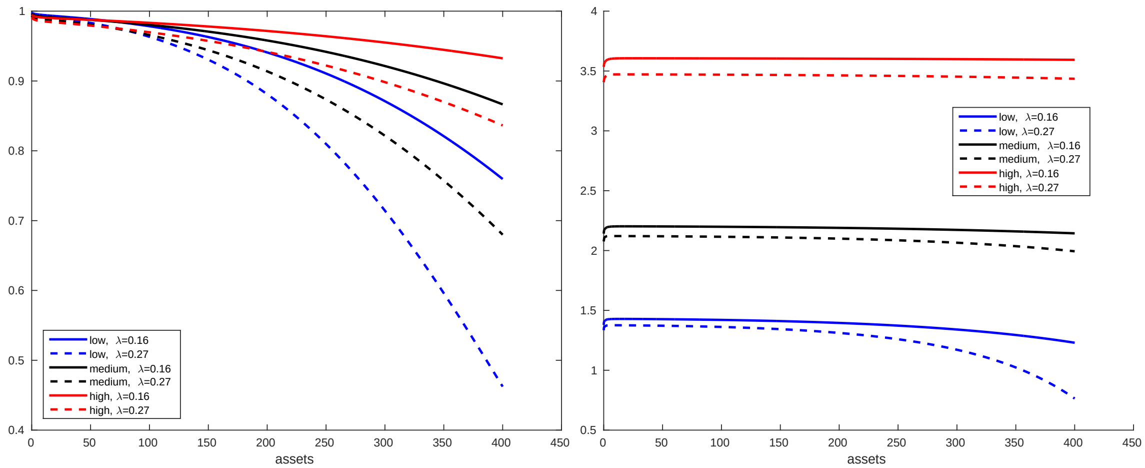
The effects on aggregate welfare come from the trade off between the two main production factors: while it is true, as it is expected, that increased progressivity decreases private

[35]Parmentier (2006) stresses that introducing variable hours implies an ambiguity in the reaction of unemployment, depending on how the utility in unemployment is considered (if instantaneous utility in unemployment is perfectly linked to net wages, through a fixed replacement ratio, or if it is instead fixed and disconnected from net wages), and on the value of some key parameters. Moreover, the effects on economic efficiency are not monotonic. In his numerical simulations, Parmentier (2006) shows that the key parameters affecting the results are the level of utility in unemployment, and labor supply elasticity: in his benchmark economy, unemployment decreases with the increase of marginal tax rate, and economic efficiency has an inverted u-shape.

[36]To have an intuition about the mechanisms, since I do not have analytical results for the complete model, I solve, in Section A of the Appendix, for the wage equation of a model with linear utility.

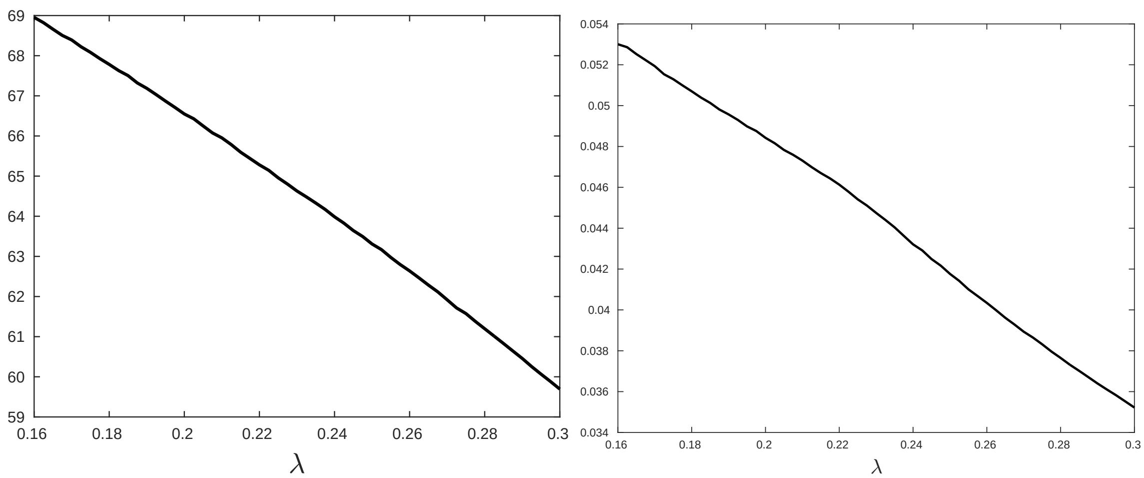
[37]The feature that wage is non monotonically increasing in assets is due to the presence of valued leisure.

Figure 2: **Hours (left) and wage function (right): the effects of λ**



savings (total capital decreases), in a context of a frictional labor market it is also true that the unemployment rate decreases, as progressivity increases, as it is shown in Figure 3.

Figure 3: **Total capital (left) and unemployment rate (right): the effects of λ**



In the evaluation of welfare, the decrease in savings allows to increase consumption, up to a certain level; in addition to consumption, there is also the effect of (increased) leisure time and better job-finding probabilities.

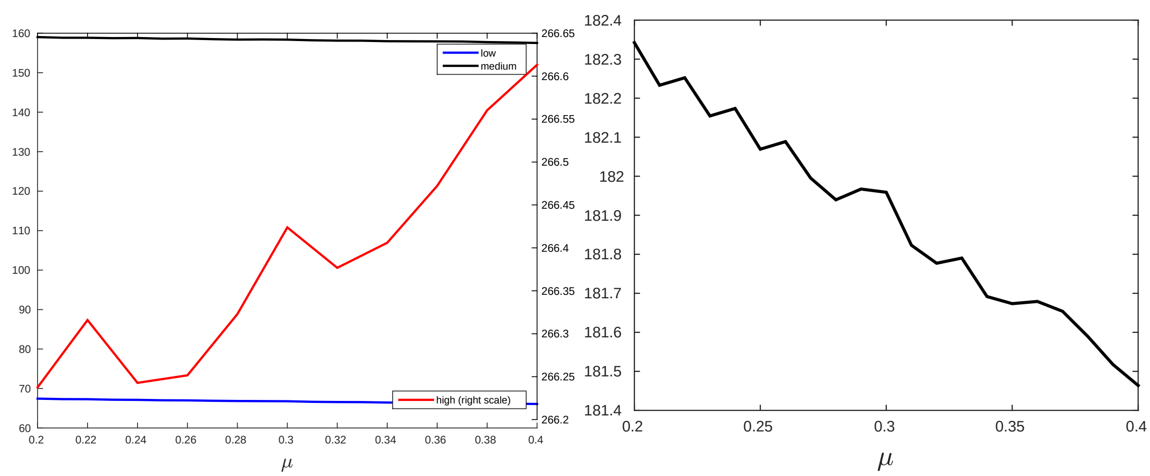
3.2 Welfare effect of unemployment benefits (UB)

Till now I analysed the welfare effects of a progressive tax and transfer system, however since in the model the only risk is linked to the probability of becoming unemployed, it is natural to study the welfare implication of an unemployment insurance scheme, as an instrument to improve consumption smoothing. The question I ask in this section is therefore: which are the welfare effects of unemployment benefits, keeping constant the level of progressivity of the tax and transfer system?

The welfare effects of an unemployment insurance scheme have been analysed, in a framework similar t the one I adopt in this paper, by Krusell et al. (2010), Mukoyama (2013) and recently by Lifschitz et al. (2016). My framework differs from theirs because I add leisure in the utility function, and I allow for variable individual labor supply. The introduction of leisure time, however, does not change qualitatively the results, which are in line with the conclusions expressed by these papers[38] the welfare costs of unemployment insurance outweigh the benefits that can come from improved consumption smoothing.

The consequences in terms of aggregate welfare are that a benevolent social planner would opt for the lowest level of UB (in the graph, I only consider a range for μ between 0.2 and 0.4). Looking at different skill categories (left panel of Figure 4), it appears that in fact only high skilled individuals would benefit from this policy, while the other categories do not see their level of welfare increased: it is particularly important the effect on the middle skill, because they constitute the main group of population. The effect on high skill individuals can be explained by the fact their unemployment risk level is very low, so that a worsening of the labor market is not a major problem.

Figure 4: **Welfare by skill level (left) and aggregate (right): the effects of UB**

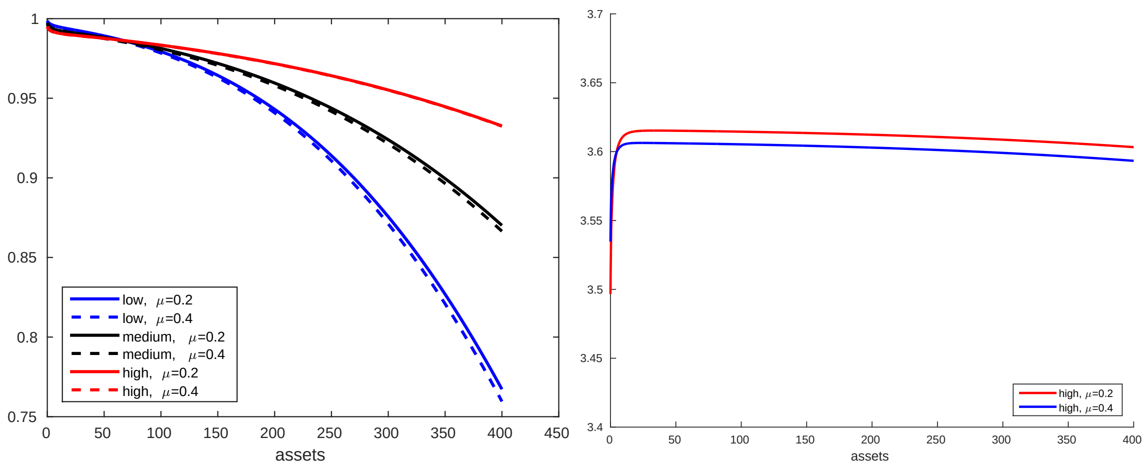


The unemployment insurance scheme, in fact, has detrimental effects on the unemployment rate, as it is standard in a model with search and matching frictions à la Mortensen-Pissarides. This effect is due to the fact that unemployment benefits increase the reservation

[38]Lifschitz et al. (2016) confirm and generalise the results of the other two papers: they analyse a model in which agents are heterogeneous in terms of skill level and labor market risk. They find that the optimal level of unemployment insurance is higher than in the case in which agents are homogeneous in terms of skills, which is basically the framework adopted in Krusell et al. (2010), Mukoyama (2013).

wage, and therefore push up wages, which in turn reduces the profitability of vacancies. However, in a framework with capital accumulation, additional insurance crowds out private savings: capital decreases, so that capital labor ratio is negatively affected[39]. The contribution of the worker of type i for the firm (the term $\tilde{k}_i = K/H_i$ in equation 2.14) decreases, and this puts a downward pressure on wage. Having a lower expected income if unemployed, the agent bargains to work a (slightly) higher amount of hours. Figure 5 shows the overall effects on the hours and wage function of a change in the generosity of the unemployment insurance from $\mu = 0.4$ to $\mu = 0.2$: the dashed lines show that, with a lower replacement rate, hours worked (slightly) increase and the wage barely moves: the wage decreases for the lowest level of wealth and slightly increase for the asset rich agents, and this applies to all skill types.

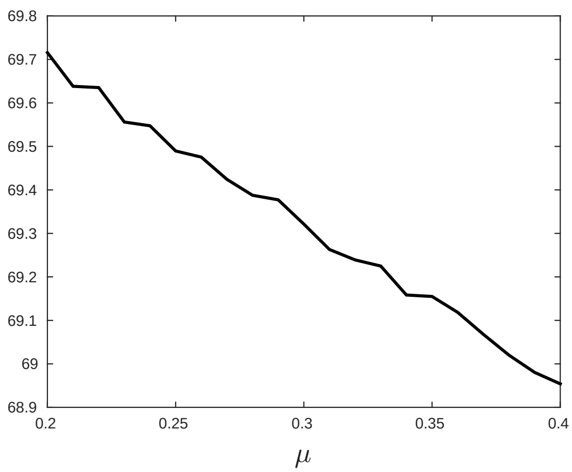
Figure 5: **Hours (left) and wage function (right): the effects of UB**

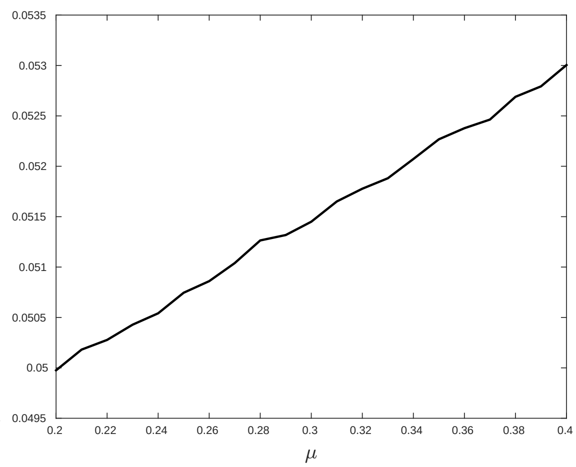


The effects of the generosity of the unemployment insurance scheme on aggregate capital and unemployment rate are shown in Figure 6.

[39]The overall effect on capital labor ratio is due to the fact that both the numerator (total capital) and the denominator (total labor) decrease.

Figure 6: **Total capital (left) and unemployment rate (right): the effects of UB**





3.3 General welfare comparisons: progressive tax and transfer schedule versus UB

To sum up the findings of the previous sections, I showed firstly that a progressive tax and transfer schedule (even if constrained to a specific functional form) can be welfare improving up to a certain level of progressivity (Section 3.1).

Secondly (Section 3.2), I showed that the evaluation in terms of average welfare of the unemployment insurance scheme, keeping fixed the level of progressivity, is always negative: in this case, the costs in terms of efficiency of the publicly provided insurance scheme are overwhelming.

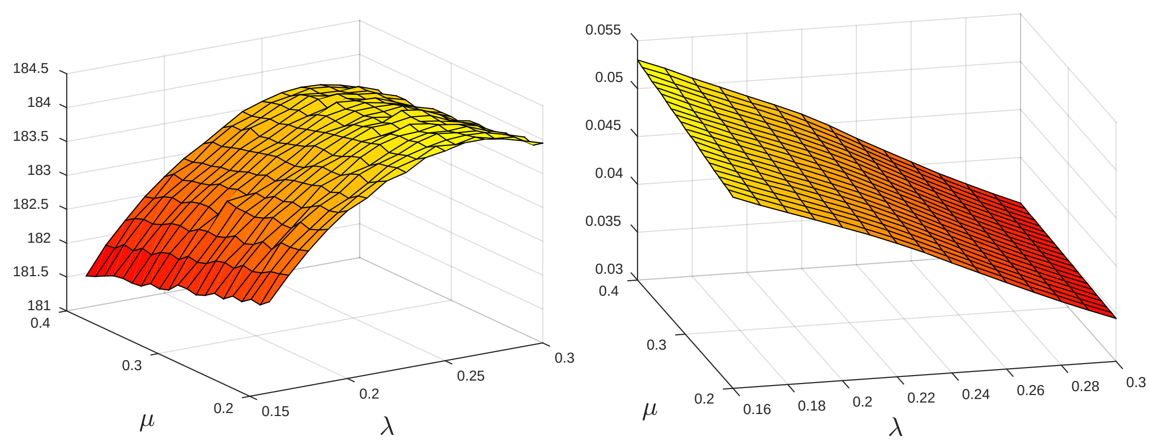
In this Section, I allow for a combination of the previous schemes, i.e. I consider a tax schedule as in equation (2.5), where the CRIP can take values between 0 and 1, and at the same time I allow for changes in the unemployment replacement rates.

This comprehensive experiment is motivated by the fact that it allows to evaluate the relative weight of the effects of progressivity and of the UB on the evolution of welfare: I do expect to find a positive level of progressivity at the optimum, and no need for additional transfers, in the form of UB, but it is important to see the "relative" strength of welfare cost (i.e. the derivative of welfare with respect to the different policy parameters).

The variation of welfare due to changes in the transfer μ is less important than that implied by varying the parameter λ; moreover, for low levels of progressivity, the negative welfare effects of the unemployment benefits are more pronounced.

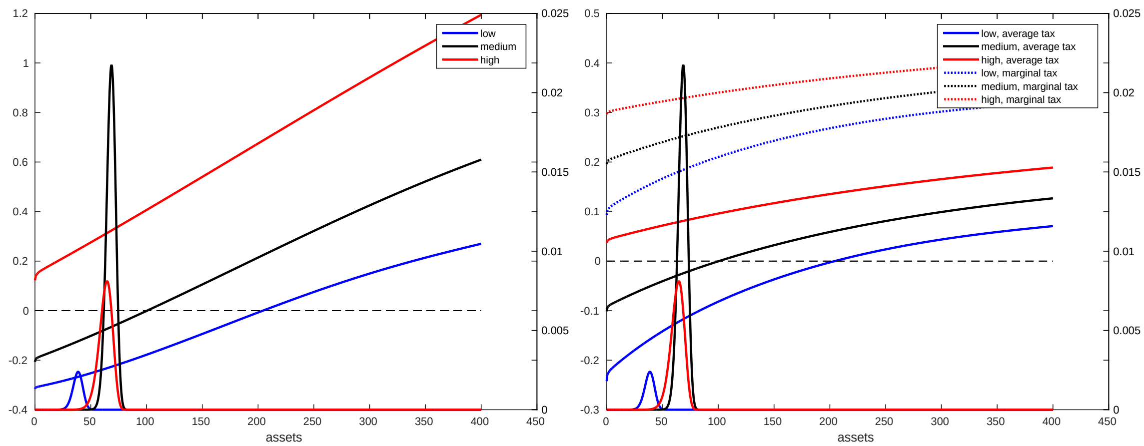
The right panel of Figure 7 sums up the effects of the policy parameters on the unemployment rate: the marginal effect of the degree of progressivity seems to be more important than that one of the level of unemployment benefit, similarly to what has been observed for average welfare.

Figure 7: **Utilitarian welfare (left) and unemployment rate (right)**



The optimal combination of policies, in the space of parameters considered for this economy, would call for the lowest possible level of unemployment replacement rate ($\mu = 20\%$) and a level of progressivity $1 - \lambda^* = 0.73$:.The implied tax and transfer schedule is showed in Figure 8: in the left panel it can be seen that total taxes paid by the low and middle skill employed are negative, i.e. these categories of agents receive transfers; the right panel confirms that the fiscal system is progressive: marginal tax rates are always higher than the average tax rates and these are increasing in assets.

Figure 8: **Employed: total taxes (left) and marginal tax rates (right)**



In terms of inequality, the level of progressivity has the strongest impact: Table 6 reproduces the wealth distribution in the model for the baseline calibration (when $\lambda = 0.16$ and $\mu = 40\%$), and for two policy alternatives: i) when $\lambda = 0.27$ (keeping μ constant at 40%); ii) when $\mu = 20\%$, keeping the level of progressivity constant at $\lambda = 0.16$[40].

Table 6: **The effect of policies on wealth inequality**

Share % of assets by:	Baseline ($\lambda = 0.16$, $\mu = 0.4$)	Alternative 1 ($\lambda = 0.27$, $\mu = 0.4$)	Alternative 2 ($\lambda = 0.16$, $\mu = 0.2$)	Data [41]
Q1	5.77	14.82	6.15	-0.90
Q2	13.22	20.21	13.99	0.80
Q3	15.17	21.69	16.04	4.4
Q4	28.00	23.77	27.15	13.0
Q5	37.83	19.50	36.67	82.7

[40]The model is not able to replicate the skewed wealth distribution we observe in the data, as it is the common case for all simplified models which do not include overlapping generations, bequest motives, wage shocks etc.

[41]Net worth from PSDI 2006, from Table 1 in Krueger et al. (2016).

4 Sensitivity analysis - WORK IN PROGRESS

In this section, I check the robustness of the model's predictions to alternative calibration choices. In particular, I consider the results in relation to: *(i)* the value of the labor supply elasticity; *(ii)* the consequences of calibrating the bargaining power of workers to a different value than the elasticity of the matching function with respect to unemployment.

4.1 Labor supply elasticity

In this section, I check the effects of allowing hours to vary more or less.

My conclusions are in line with Sørensen (1999): the higher the variability of hours, the lower the optimal value of progressivity (i.e. the closer the optimal CRIP is to the unity). This result comes from the fact that the higher the elasticity, the stronger is the reaction of agents in decreasing labor supply, when tax progressivity is increased. The crowding out effect of labor supply implies a lower total labor input, and therefore production, which cannot be compensated by the increased utility coming from leisure time.

I report the values for the optimal level of the parameter λ for two alternative calibrations of the model in terms of the parameter ν, which represents the inverse of Frisch elasticity of leisure: the lower the value of ν, the higher the Frisch elasticity of labor supply[42]. I remind that, being hours a (decreasing) function of assets, the elasticity takes a different value at each value of wealth; moreover, each agent of type i has a different hours supply function. in Table 7, I report the average value for the elasticity, computed using the average hours: $\bar{h} = \Sigma_{i=1}^{3} \psi_i \int h_i(a) P_{e,i}(a) da$.

Table 7: **Optimal level of progressivity for different levels of labor supply elasticity**

	Baseline ($\nu = 0.35$)	Higher elasticity ($\nu = 0.30$)
Frisch elasticity of hours[43]	0.20	0.22
Optimal λ^*	0.27	0.25

[42]To avoid confusion, I measure hours elasticity for the case in which $\lambda = 0$, so that elasticity $= \left(\frac{1-h}{h}\right)\frac{1}{\nu}$, as reported in Table 4. In Appendix B, I detail the definition of labor supply elasticity in the presence of progressive taxation.

[43]The Frisch elasticity is computed as $\frac{1-\bar{h}}{\bar{h}}\frac{1}{\nu}$, with $\lambda = 0$

4.2 When $\gamma \neq \eta$

In calibrating the baseline economy, I made the assumption that the bargaining power of the workers (γ) is equal to the value of the elasticity of the matching function with respect to unemployment (η).

The importance of the value assigned to the bargaining power of the workers has been widely analysed in the literature about labor market fluctuations. The choice of calibration of the two parameters has important consequences also in terms of efficiency: in a standard representative agent model, it is known that the decentralised equilibrium is efficient if the Hosios condition is respected, i.e. if $\gamma = \eta$[44].

As Krusell et al. (2010) state, the respect of the Hosios condition does not guarantee, however, that the equilibrium is constrained efficient, because of the externality coming from capital accumulation, as it has been stated by Dávila et al. (2012).

If the bargaining power of the worker is lower (higher) than the elasticity of the matching function, the equilibrium unemployment rate is lower (higher) than in the benchmark case of equality. The value of optimal tax progressivity goes in the direction of "correcting" the distortion: therefore, as it can be seen in Table 8, when the parameter γ is lower (higher) than η, the optimal value of λ is lower (higher).

Table 8: **Optimal tax policy values when $\gamma \neq \eta$**

	$\gamma = 0.4 < \eta$	Baseline $\gamma = 0.5 = \eta$	$\gamma = 0.6 > \eta$
Unempl. rate ($\lambda = 0.16$)	4.56%	5.79%	6.17
Optimal λ^*	0.265	0.27	0.28

5 Conclusion

This paper studies the impacts of tax progressivity as well as of unemployment insurance on macroeconomic aggregates and welfare.

I consider a framework in which agents are *ex ante* heterogeneous in terms of skills and preferences, and *ex post* heterogeneous in terms of assets, as a result of their specific sequence of employment/unemployment spells[45]. In particular, I consider a framework in which agents have different levels of education, and the most skilled are the most patient as well as the agents who dislike the least hours of work. Financial markets are incomplete, so that agents

[44] The Hosios condition is derived in a context in which there are no unemployment benefits and the interest rate tends to zero.

[45] Agents are subject only to idiosyncratic unemployment risk, there is no aggregate uncertainty.

cannot perfectly insure against unemployment risk, and the functioning of the labor market is characterised by searching frictions.

This framework allows to highlight different effects of a progressive tax and transfer schedule: on the one hand, progressivity has a beneficial effect on the unemployment rate and job-finding probability, since as it has been stressed in the labor market literature, progressivity implies a general downward pressure on wages. On the other, progressivity reduces individual labor supply and crowds out savings, as it has been stressed in the literature on consumption/savings decisions and Walrasian labor markets. Within this framework I can therefore analyse numerically the different effects of progressivity on both production factors (capital and labor).

The first set of result concerns the desirability of a positive level of progressivity, measured by the Coefficient of Residual Income Progression; the tax and transfer schedule takes a specific functional form, as in Sørensen (1999), Heathcote et al. (2014) and Bakış et al. (2015). A utilitarian welfare criterion calls for a positive level of progressivity which is higher than the actual one estimated for the US economy. The results in terms of aggregate welfare however come from the the composition of the welfare effects on the different types of agents: while the most skilled always loose form progressivity, the most unskilled always prefer higher levels of redistribution.

The second set of results in the paper shows that the losses in terms of efficiency, caused by the unemployment insurance scheme, are much more important than those implied by the previously considered progressive tax schedule. Therefore a benevolent social planner would opt for redistributing and providing insurance through a progressive tax and transfer system, without using any additional unemployment insurance scheme.

I also illustrate some robustness results: I illustrate that the higher is the labor supply elasticity, the lower is the optimal level of progressivity. Finally, I analyse the consequences of calibrating the bargaining power of workers to a different value than the elasticity of matching function: the higher the level of distortions which are present prior to Government intervention, the higher the optimal level of tax progressivity.

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Appendix

A Some analytical insights: risk-neutral agents

In order to provide some analytical insight about the different effects implied by the introduction of progressive taxation, and the unemployment benefit, I simplify the model and assume that agents are risk-neutral[46]. I derive the expression of the "wage equation", for the two cases, in order to provide some intuition about the effects, in a *partial equilibrium* setting, of the various parameters.

A.1 The effects of progressivity

In this section I focus on the effects of progressivity on the wage bargaining, while keeping linear utility in consumption. For simplicity, I assume that only wage income (and not interest rate income) is taxed, to remain comparable to the previous literature, in particular to Parmentier (2006).

The problem of the agent is:

$$max \sum \beta^t (c_t + \Gamma^z) \tag{A.1}$$

$$\text{s.t.} \quad c + a' = a(1+r) + z$$

where

$$\Gamma^z = \begin{cases} \Gamma^e = \sigma_l \frac{(1-h)^\nu}{(1-\nu)}, & \text{if employed} \\ \Gamma^u, & \text{if unemployed} \end{cases}$$

The disposable income definition is given by:

$$z = \begin{cases} (1-\tau)(wh)^{1-\lambda}, & \text{if employed} \\ (1-\tau)\mu^{1-\lambda}, & \text{if unemployed} \end{cases}$$

Because of linear utility, I can write that:

1. $\beta = \frac{1}{1+r}$;

2. $a' = a$

and therefore without loss of generality: $c = (1-\tau)(wh)^{1-\lambda}$ for the employed and $c = (1-\tau)\mu^{1-\lambda}$ for the unemployed.

[46] Chéron (2002), Parmentier (2006) and Krusell et al. (2010) assume risk neutral agents to obtain analytical results.

The expressions for the value functions are therefore:

$$
\begin{aligned}
W &= (1-\tau)(wh)^{1-\lambda}+\frac{1}{1+r}\left[(1-s)W+sU\right] && \text{(A.2)}\\
U &= (1-\tau)\mu^{1-\lambda}+\frac{1}{1+r}\left[f(\theta)W+(1-f(\theta))U\right] && \text{(A.3)}\\
J &= (y-w)h+\frac{1}{1+r}\left[(1-s)J+sV\right] && \text{(A.4)}\\
V &= -\omega+\frac{1}{1+r}\left[q(\theta)J+(1-q(\theta))V\right] && \text{(A.5)}
\end{aligned}
$$

where the term y refers to the (fixed) productivity of one hour of labor.
In equilibrium $V=0$, so that I can write:

$$
\begin{aligned}
\frac{J}{1+r} &= \left(\frac{(y-w)h}{(r+s)}\right) && \text{(A.6)}\\
\frac{J}{1+r} &= \frac{\omega}{q(\theta)} && \text{(A.7)}
\end{aligned}
$$

Solving for the value functions I obtain:

$$
W-U=\left[(1-\tau)[(wh)^{1-\lambda}-\mu^{1-\lambda}]+\Gamma^u-+\Gamma^e\right]\frac{(1+r)}{(r+s+f)}
$$

The sharing rule in the actual framework is given by[47]:

$$
\frac{W-U}{\gamma}\frac{(wh)^{\lambda}}{(1-\tau)(1-\lambda)}=\frac{J}{1-\gamma} \tag{A.8}
$$

By substituting the expressions for the value functions, the sharing rule becomes:

$$
\frac{(1-\gamma)}{(r+f+s)}\left[(1-\tau)[(wh)^{1-\lambda}-\mu^{1-\lambda}]+\Gamma^u-+\Gamma^e\right]\frac{(wh)^{\lambda}}{(1-\tau)(1-\lambda)}=\frac{\gamma}{(r+s)}(y-w)h
$$

The expression for the wage bill is then given by:

$$
wh=\frac{(1-\lambda)}{(1-\gamma\lambda)}\gamma(yh+\omega\theta)+\frac{(1-\gamma)}{(1-\tau)}\frac{(wh)^{\lambda}}{(1-\lambda)}\left[(1-\tau)\mu^{1-\lambda}+\Gamma^u-\Gamma^e\right]
$$

The wage equation takes the usual form: when $\lambda=0$, the expression comes back to the standard form, as it can be found in Pissarides (2000).

[47]See equation (2.26) in the main text.

The hours equation is given by[48]:

$$\sigma_l(1-h)^{-\nu} = y(1-\tau)(1-\lambda)(wh)^{-\lambda} \tag{A.9}$$

The factor $\frac{(wh)^{\lambda}}{(1-\lambda)}$ in the wage equation can be substituted, by using the expression of the hours equation, to obtain:

$$wh = \frac{(1-\lambda)}{(1-\gamma\lambda)}\gamma(yh+\omega\theta) + \frac{(1-\gamma)}{(1-\tau)}\frac{y(1-\tau)(1-h)^{\nu}}{\sigma_l}\left[(1-\tau)\mu^{1-\lambda} + \Gamma^u - \Gamma^e\right] \tag{A.10}$$

Regarding the first multiplicative factor on the right side of equation (A.10):

$$\frac{\partial \frac{(1-\lambda)}{(1-\gamma\lambda)}}{\partial\lambda} = -\frac{(1-\gamma)}{(1-\gamma\lambda)^2} < 0 \quad \text{since} \quad 0 < \gamma \leq 1 \tag{A.11}$$

The effect of the level of progressivity λ is then to decrease the part of the surplus coming from the firm and appropriated by the worker.

By looking at the second term on the rhs of eq. (A.10), an opposite force intervenes; by looking at the multiplicative factor, it can be seen that:

$$\frac{y(1-\tau)(1-h)^{\nu}}{\sigma_l} > 1 \leftrightarrow h < 1 - \left(\frac{\sigma_l}{y(1-\tau)}\right)^{\frac{1}{\nu}} \tag{A.12}$$

moreover,

$$\frac{\partial\mu^{1-\lambda}}{\partial\lambda} = -ln(\mu)\mu^{1-\lambda} > 0 \leftrightarrow \mu < 1 \tag{A.13}$$

i.e. under certain parameters restrictions ($h < 1 - \left(\frac{\sigma_l}{y(1-\tau)}\right)^{\frac{1}{\nu}}$ and $\mu < 1$), a higher progressivity (higher λ) puts a upward pressure on wage. Regarding the hours worked, considering the wage rate w as fixed, it can be seen that the factor λ has a negative effect on labor supply:

$$\frac{dh}{d\lambda} = -\frac{y(1-\tau)[w^{-\lambda} + (1-\lambda)\lambda w^{-\lambda-1}]}{\lambda h^{\lambda-1}(1-h)^{-\nu} + h^{\lambda}\nu(1-h)^{-\nu-1}} < 0$$

In conclusion, there is at least one force pushing down the wage as λ increases, for every level of hours[49].

[48]See equation (2.31) in the main text.

[49]Equation (A.10) recalls equation (9) in Parmentier (2006); as the author puts to evidence, to know the overall effect of the marginal tax rate on the equilibrium wage it is necessary to take into consideration also the reaction of hours as well, but it is not my interest to obtain such a general equilibrium result.

A.2 The effects of UB

In this section I focus on the effects of UB in the wage bargaining. For simplicity I assume that taxes are raised through a flat income tax.

The problem of the agent is therefore as before:

$$max \sum \beta^t (c_t + \Gamma^z) \tag{A.14}$$

$$\text{s.t.} \quad c + a' = a(1+r) + z$$

where

$$\Gamma^z = \begin{cases} \Gamma^e = \sigma_l \frac{(1-h)^\nu}{(1-\nu)}, & \text{if employed} \\ \Gamma^u, & \text{if unemployed} \end{cases}$$

and

$$z = \begin{cases} wh(1-\tau), & \text{if employed} \\ \mu(1-\tau), & \text{if unemployed} \end{cases}$$

Because of linear utility, I can write that:

1. $\beta = \frac{1}{1+r}$;

2. $a' = a$

and therefore, without loss of generality: $c = wh(1-\tau)$ for the employed and $c = \mu(1-\tau)$ for the unemployed.

The expressions for the value functions are exactly as in previous section.

The sharing rule takes the simple form:

$$\frac{W-U}{\gamma(1-\tau)} = \frac{J}{1-\gamma} \tag{A.15}$$

which by substituting for the expression of the value functions becomes:

$$\frac{(1-\gamma)}{(r+f+s)(1-\tau)} \left[(wh-\mu)(1-\tau) + \Gamma^u - \Gamma^e\right] = \frac{\gamma}{(r+s)}(y-w)h$$

By substituting the expression for the value function of the firm, I obtain again the well known expression for the wage bill:

$$wh = \gamma(yh + \omega\theta) + \frac{(1-\gamma)}{(1-\tau)}\left[\mu(1-\tau) + \Gamma^u - \Gamma^e\right] \tag{A.16}$$

I report the hours equation, obtained by computing the FOC with respect to hours and by using the wage equation (see eq. 2.31 in the main text):

$$\sigma_l(1-h)^{-\nu} = y(1-\tau) \tag{A.17}$$

In this simplified version of the model, the effect of an increase of the unemployment benefit is an upward pressure on wages. The differences with respect to the complete model come from: *(i)* the fact that labor productivity is fixed and equal to y, while in the model with capital accumulation is endogenous and it depends on the level of aggregate capital; *(ii)* in the complete model, marginal utility affects the evaluation of the value of unemployment.

B Frisch elasticity with progressive taxation

I compute the Frisch elasticity of labor supply starting from the FOCs of the Lagrangian for the consumer as in a Walrasian market:

$$L = \sum \beta^t u(c_t, 1-h_t) + \zeta_t[(1+r_t)a_t + (1-\tau)(w_t h_t + r_t a_t)^{(1-\lambda)}] \tag{B.1}$$

FOC wrt consumption:

$$\zeta_t = \frac{\partial u(c, 1-h)}{\partial c_t} \tag{B.2}$$

FOC wrt hours:

$$-\frac{\partial u(c, 1-h)}{\partial h_t} = \zeta_t(1-\lambda)(1-\tau)w_t(w_t h_t + r_t a_t)^{(-\lambda)} \tag{B.3}$$

I derive the two conditions wrt to the wage w_t to obtain the following (I discard the time subscript):

$$\begin{cases} u_{cc}\frac{\partial c}{\partial w} + u_{ch}\frac{\partial h}{\partial w} = 0 \\ -u_{ch}\frac{\partial c}{\partial w} - u_{hh}\frac{\partial h}{\partial w} = \zeta(1-\lambda)(1-\tau)[(wh+ra)^{-\lambda}(1-\lambda wh(wh+ra)^{-1})] \end{cases} \tag{B.4}$$

I substitute the expression for $\frac{\partial c}{\partial w}$ in the second equation to obtain:

$$\frac{\partial h}{\partial w} = \frac{u_h}{\left(u_{hh} - \frac{u_{ch}^2}{u_{cc}}\right)\frac{1}{w}(1-\lambda\frac{wh}{(wh+ra)})} \tag{B.5}$$

The elasticity of hours with respect to (pre-tax) wage is thus given by:

$$\epsilon_{h,w} = \frac{\partial h}{\partial w}\frac{w}{h} = \frac{u_h}{h * \left(u_{hh} - \frac{u_{ch}^2}{u_{cc}}\right)}\left(1 - \lambda \frac{wh}{(wh + ra)}\right) \tag{B.6}$$

If $\lambda = 0$ (flat tax schedule), the expression comes back to the standard expression for Frisch elasticity; with the chosen function for instantaneous utility $u(c, 1-h) = ln(c) + \sigma_l \frac{(1-h)^{(1-\nu)}}{(1-\nu)}$, the expression becomes:

$$\epsilon_{h,w} = \left(\frac{1-h}{h}\right)\frac{1}{\nu} \tag{B.7}$$

C Algorithm

In this section, I briefly describe the algorithm used to solve the model with labor supply. Note that solving the model amounts to solving a fixed functional problem, because we are not looking for single values of wage and hours, but for empirical functional forms $w = w(a), h = h(a)$.

1. Use a grid of N=1000 points, for asset levels $a \in [0, 400]$; this is a log linearly spaced in order to have more points at the bottom of the distribution.

2. Guess a level of the interest rate, labor income tax rate, labor market tightness, and wage and hours functions $w = w(a), h = h(a)$.

3. **Inner loops (savings and wage function)** Given the previous values, solve for the consumer problem to find the savings decision rules $a'_e = g_e(a, w)$ and $a'_u = g_u(a)$ and the value functions when employed and unemployed; compute the value of the firm implied by the Nash bargaining on wage in eq. (2.26). Compute the the wage $w = w(a)$ implied by the value function for the firm in eq. (2.14). Compare the implied wage function to the initial guess; if the distance is bigger than the tolerance value, update the initial guess to a new value $w_{i+1} = \xi_w w_i + (1 - \xi_w) w_{implied}$, where the subscript $(i+1)$ refers to the $(i+1)^{th}$ iteration.

4. **First intermediate level loop (hours function)** Once the saving and wage functions have been found, look for the hours function implied by the FOC on hours in eq.(2.31): this is the very same equation that in a Walrasian labor market. Iterate until convergence, updating the guess for the labor market tightness in a similar way as that of the wage function.

5. **Second intermediate level loop (tightness)** Once the wage and hours equation are obtained (given the guessed tightness, tax rate and interest rate), check the implication for the value of filling a job (and therefore for the labor market tightness, since $\theta = q^{-1}(\theta)$), using the value function of a vacancy in eq. (2.19); if the distance between the guessed and the implied tightness is bigger than the tolerance level, update the guess for the labor market tightness in a similar way as for the wage function: $\theta_{i+1} = \xi_\theta \theta_i + (1 - \xi_\theta)\theta_{implied}$.

6. **Third intermediate level loop (tax rate)** Using the condition that government budget constraint must be in equilibrium, i.e. eq. (**??**), look for the equilibrium tax rate.

7. **Outer loop (interest rate)** Once the model is solved, check the interest rate implied by the aggregation of all savings: for agent i, the total asset is given by $\int a_i di = \int k_i di + p \int x_i di$, where $\int k_i di = \bar{K}$ and $\int x_i di = 1$. Since aggregate savings can be computed as $\int a_i di$, compare the implied interest rate (which is a function of the implied $\bar{K}$, as it is shown in eq. (2.17) to the initial guess, and update it.

The algorithm to solve the model without labor supply is the same as the previous one with one difference: I keep hours fixed (in particular I set $h = \bar{h} = 1$ and therefore I switch off the loop which uses the FOC for hours. I start with guesses on interest rate, tax rate, tightness, and the wage function; after having solved for the policy and wage function, I proceed with the second and third intermediate loops before continuing to the outer loop.