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Optimal Redistributive Taxation with both Labor Supply and Labor Demand Responses

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Abstract

This paper characterizes the optimal redistributive tax schedule in a matching unemployment framework where (voluntary) nonparticipation and (involuntary) unemployment are endogenous. The optimal employment tax rate is given by an inverse employment elasticity rule. This rule depends on the global response of the employment rate, which depends not only on the participation (labor supply) responses, but also on the vacancy posting (labor demand) responses and on the product of these two responses. For plausible values of the parameters, our matching environment induces much lower employment tax rates than the usual competitive model with endogenous participation only.

JEL-Code: D820, H210, J640.

Keywords: optimal taxation, labor market frictions, unemployment, Kalai solution.

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I Introduction

This paper analyzes the optimal income tax schedule with voluntary nonparticipation and involuntary unemployment. Individuals decide whether they participate in the labor force (the extensive margin). Because of matching frictions *à la* Diamond (1982) and Mortensen and Pissarides (1999), a participating individual may be involuntarily unemployed. The probability for a participant to be recruited is endogenous and depends on the number of vacancies firms find profitable to create (the labor demand margin). Individuals differ both in their skills and their costs of searching for a job. The skill heterogeneity implies that employed workers earn distinct wages. The cost of searching for a job differs across individuals of the same skill level, which accounts for the extensive margin as do Diamond (1980), Saez (2002) or Choné and Laroque (2005, 2011). As the government only observes earnings, it faces a second-best redistribution problem. This paper derives the optimal *employment tax*, defined as the tax the worker pays plus the welfare benefit.¹

Our model encompasses the standard case with only the extensive margin. A higher level of the employment tax reduces the return of participation, thereby inducing some individuals to leave the labor force. The optimal employment tax is inversely related to the elasticity of the labor supply, as in the “extensive response model” of Saez (2002).

We introduce labor demand through skill-specific matching frictions *à la* Diamond (1982) Mortensen and Pissarides (1999). When a worker and a vacancy are randomly matched, a surplus is created. The total surplus is the difference between the overall income the worker and the employer get from the match and what they would get if their search was unsuccessful. The total surplus is shared between workers and employers according to the Kalai solution (Kalai, 1977). This solution is introduced instead of the axiomatic Nash solution because the latter relies on the controversial independence to irrelevant alternatives axiom.² The Kalai solution, which replaces this axiom by a monotonicity axiom, leaves the gains of the players proportional to each other. An increase in the employment tax reduces the total surplus, thereby both the worker’s and the employer’s surplus. Therefore, a rise in the employment tax decreases the net (or after-tax) wage and increases the gross (or pre-tax) wage. Employers thus find less profitable to create vacancies, which decreases the number of taxpayers.³

¹In the literature, the employment tax is traditionally called *participation tax* in the absence of (involuntary) unemployment.

²This axiom states that the outcome of a bargain (in our context, the bargained wage) should remain the same if the set of feasible agreements shrinks and still encompasses the initial solution (L’Haridon, Malherbet and Perez-Duarte (2010)). In the context of a bargaining solutions in wage negotiations, this axiom has been criticized by e.g., McDonald and Solow (1981) and Laroque and Salanié (2004). Conversely, Alexander (1992) and several laboratory controlled experiments mentioned by the latter paper suggest that the Kalai solution might be more relevant than the Nash solution.

³These effects are standard in the matching literature. See Mortensen and Pissarides (1999), Pissarides

In the presence of both extensive supply and labor demand margins, we show that the optimal employment tax is inversely related to the *global* elasticity of employment. The latter is the sum of three terms: the labor supply elasticity, the labor demand elasticity with respect to the firm surplus and the product of these two elasticities. The presence of this product is explained by the fact that any labor demand response to taxation, by changing the job-finding probability, also affects the return to participation. We also numerically investigate how the introduction of the labor demand response affects the optimal employment tax rate. Our matching environment induces much lower employment tax rates than the usual competitive extensive response model. However, when the Hosios (1990) condition⁴ holds and when the *global* elasticity of employment is fixed, optimal employment tax rates are higher (in absolute value) when the labor demand elasticity increases and the labor supply elasticity decreases.

An alternative way of introducing labor demand considerations in the optimal income tax problem consists in assuming imperfect substitution between low and high-skilled labor in a competitive setting. Stiglitz (1982) shows the desirability of a negative marginal tax rate for high-skilled workers. This reduces the inequality in wage rates, thereby relaxing the relevant incentive constraint. This framework has been extended by Allen (1987) and Guesnerie and Roberts (1984, 1987) who show that a minimum wage cannot relax the relevant incentive constraint. In these papers, labor supply responses are concentrated along the intensive margin.

Lee and Saez (2008) consider instead a model with extensive responses. They derive an optimal tax formula in the absence of a minimum wage.⁵ The labor demand elasticity does not enter their formula and the latter is identical to the one obtained with exogenous wages by the usual Diamond and Mirrlees (1971) argument: Given the zero-profit condition, the changes in the various wage levels due to any tax reform cancel out.⁶ Conversely, in our model with matching frictions and surplus sharing, at a given skill level, a rise in the employment tax increases the gross wage through demand side effects. The employment level is then affected by the response of the labor demand, which influences the equity-efficiency tradeoff.

Several papers study the optimal income tax model under search frictions on the labor market. The optimal tax in Boone and Bovenberg (2002) and in Boadway, Cuff and Marceau (2003) acts as a Pigouvian tax to correct the inefficiency that arises from the

(2000). Empirical evidence about the effects of gross wages on employment rates can be found in e.g., Kramarz and Philippon (2001) or Beaudry, Green and Sand (2010).

⁴This condition on the bargaining power guarantees that the decentralized economy is efficient in the absence of taxes, despite the presence of search-congestion externalities.

⁵Their main formula however concerns the case with an optimally chosen minimum wage.

⁶The numerical analysis of Rothstein (2010) however stresses that imperfect substitution between different types of labor has quantitatively important effects.

search-congestion externalities induced by matching frictions. Hungerbühler, Lehmann, Parmentier and Van der Linden (2006) and Lehmann, Parmentier and Van der Linden (2011) consider instead an environment where these externalities are perfectly internalized by the wage setting process in the no-tax economy. Differing from Hungerbühler *et al.* (2006) and Lehmann *et al.* (2011), we depart from the Nash bargaining solution and assume the Kalai solution. This implies that a change in the employment tax affects the bargained wage and that modifying the marginal tax rate does not alter the bargained wage. If we assumed instead a Nash bargain of wages, a rise in the marginal tax rate would discourage workers to claim for higher wages, thereby reducing the gross wage negotiated (and boosting labor demand). Assuming this so-called wage-cum labor demand as well as labor supply responses along the extensive margin, Hungerbühler *et al.* (2006) and Lehmann *et al.* (2011) study the optimal marginal and average tax schedules. However, while empirical evidence points out that gross earnings decrease with marginal tax rates (Saez, Slemrod and Giertz, 2010), on the basis of current empirical evidence, one still ignores whether larger marginal tax rates reduce gross earnings through labor supply responses along the intensive margin, via the wage bargain, via tax avoidance or tax evasion responses. Our model is then able to shed light on the role of the labor demand responses in the optimal employment tax formula without favoring a channel of response to changes in marginal tax rates at the expense of the others.

This paper is organized as follows. Section II presents the model. Section III derives the optimal tax formula and contrasts it with the case of a competitive labor market and labor supply responses along the extensive margin. Section IV concludes.

II The general framework

We consider a static model where individuals are risk-neutral and endowed with distinct skill levels denoted by a . The exogenous skill distribution is given by the cumulative distribution $F(a)$, defined on $[a_0, a_1]$, with $0 < a_0 < a_1 \leq \infty$. The size of the population is normalized to 1. Jobs are skill-specific. A worker of skill a produces a units of output if and only if she is employed in a type- a job,⁷ otherwise her production is nil. This assumption of perfect segmentation is made for tractability and is more realistic than the polar one of a unique labor market for all skill levels.

At each skill level, some people choose to stay out of the labor force while some others do participate in the labor market. We integrate this feature by assuming that individuals of a given skill level differ in their cost of searching a job χ . The exogenous distribution of χ

⁷Allowing an agent to work in any occupation which requires a skill below her type opens the possibility of monotonicity constraints and pooling. Choné and Laroque (2011) present sufficient conditions for the absence of pooling at the optimum.

conditional on skill level a is described by the (conditional) c.d.f. $H(\cdot|a)$. This function is defined over the support \mathbb{R}^+ , is strictly positive and admits a continuous partial derivative with respect to $\chi \in \mathbb{R}^+$. The characteristics a and χ may be distributed independently or may be correlated.

Among individuals who participate in the labor market, some fail to be recruited and become unemployed. This involuntary unemployment is due to matching frictions. The number of matches between employers and job seekers on the labor market of skill a is a function denoted $M_a(V_a, U_a)$ of the stock of vacant posts, V_a , and the stock of job seekers, U_a , in the market (Mortensen and Pissarides 1999).

We assume that the government neither observes individuals' types (a, χ) nor the job-search and matching processes.⁸ It only observes worker's gross wage w_a . Therefore, the tax level is only a function $T(\cdot)$ of the gross wage w . The government is also unable to distinguish among the non-employed individuals the (involuntary) *unemployed*, who searched for a job but failed to find one, from the voluntary *non-participants*. Therefore, the government is constrained to give the same level of welfare benefit b to all non-employed agents. Moreover, as our model is static, the welfare benefit cannot differ by past employment histories. Finally, the government does not observe the vacancies created by the firms, so it has no specific instrument to tax or subsidize job creation. The timing of our static model is:

1. The government commits to a tax system defined as a pair $(T(\cdot), b)$ which only depends on the gross wage w and the welfare benefit b for the non-employed.
2. For each skill level a , firms open vacancies. Creating a vacancy of type a costs $\kappa_a > 0$. Each type a -agent decides whether she participates to the labor market of type a .
3. Matching occurs. Once matched, the firm and the worker share the surplus by negotiating the wage.
4. Each worker of skill a produces a units of goods, receives a wage $w = w_a$ and pays taxes or receive transfers. Non-employed individuals get the welfare benefit b . Tax revenue also finances an exogenous amount of public expenditures $R \geq 0$. Agents consume.

II.1 Participation decision

An individual of type (a, χ) can decide to stay out of the labor force, in which case her utility equals the welfare benefit b . Otherwise, she participates. Then, she finds a job

⁸In Appendix C however, we treat the case where (a, χ) is observed.

with an endogenous probability ℓ_a and gets a utility level equals to $w_a - T(w_a) - \chi$ or she becomes unemployed with a probability $1 - \ell_a$ and gets a utility level equals to $b - \chi$.

To participate, an agent of type (a, χ) should expect a higher expected utility $\ell_a(w_a - T(w_a)) + (1 - \ell_a)b - \chi$ than in case of non participation, b . Let $\tau_a = T(w_a) + b$ denote the *employment tax*. We define the expected surplus of a participant of type a as

$$\Sigma_a \stackrel{\text{def}}{\equiv} \ell_a \times (w_a - T(w_a) - b) \quad (1)$$

i.e. the additional income she gets if she finds a job rather than stays unemployed multiplied by the probability of employment. Any individual of skill a chooses to participate if her cost χ of searching a job is lower than the surplus Σ_a she expects from finding a job, i.e. $\chi \leq \Sigma_a$. Let h_a denote the participation rate among individuals of skill a , i.e.:

$$h_a = H(\Sigma_a | a) \equiv \Pr[\chi \leq \Sigma_a | a] \quad (2)$$

The mass of participants of type a equals $U_a = h_a \cdot f(a)$. We now define:

$$\eta_a^P \stackrel{\text{def}}{\equiv} \frac{\Sigma_a}{H(\Sigma_a | a)} \frac{\partial H(\chi = \Sigma_a | a)}{\partial \chi} \quad (3)$$

as the elasticity of the participation rate among individuals of skill a with respect to the expected surplus of a participant, at $\chi = \Sigma_a$. The empirical literature on the participation decisions typically estimates the elasticity of participation with respect to the difference between income in employment and in unemployment, $w_a - \tau_a$. For a given employment probability ℓ_a , η_a^P equals this elasticity.

II.2 Labor demand

If there were no frictions, the number of matches on the labor market of skill a would be determined by the short side of the market and one would get $M_a(V_a, U_a) = \min(V_a, U_a)$. But when job seekers and employers have to engage in a costly and time-consuming process of search to find each other, the matching function captures the technology that brings them together. The matching process is assumed not efficient hence $M_a(V_a, U_a) < \min(V_a, U_a)$. The matching function $M_a(V_a, U_a)$ is twice continuously differentiable on \mathbb{R}_+^2 , increasing and concave in both arguments, verifies $M_a(0, U_a) = M_a(V_a, 0) = 0$ since matches cannot occur unless there are agents on both sides of the market and exhibits constant returns to scale. These assumptions are largely empirically supported as discussed by Petrongolo and Pissarides (2001).

Define market tightness θ_a as the ratio V_a/U_a . The probability of filling a type- a vacancy equals $m_a(\theta_a) \equiv M_a(V_a, U_a)/V_a = M_a(1, 1/\theta_a)$. Due to search-matching externalities, the probability of filling decreases with the number of vacancies (V_a) and increases

with the number of job-seekers (U_a). Since $M_a(V_a, U_a)$ exhibits constant returns to scale, only tightness matters and $m_a(\theta_a)$ is a decreasing function of tightness θ_a . Symmetrically, the probability that a job-seeker finds a job is an increasing function of tightness $\theta_a m_a(\theta_a) \equiv M_a(V_a, U_a)/U_a = M_a(\theta_a, 1)$ with the functions $m_a(\theta_a)$ and $\theta_a m_a(\theta_a)$ defined from \mathbb{R}^+ to $[0, 1)$. Firms and individuals being atomistic, they take tightness θ_a as given.

When a firm creates a vacancy of type a , it fills it with probability $m_a(\theta_a)$. The creation of this vacancy costs $\kappa_a > 0$ to the firm. This fixed cost includes the screening of applicants and the investment in equipments for the extra worker. The firm's expected profit is $m(\theta_a)(a - w_a) - \kappa_a$. For a given number of job-seekers, a rise in the number of vacancies decreases this expected profit because each vacancy is filled with a lower probability. Firms create vacancies until the free-entry condition $m_a(\theta_a)(a - w_a) = \kappa_a$ is met. This pins down the value of tightness θ_a as $m_a^{-1}(\kappa_a/(a - w_a))$.⁹ We define the labor demand $L_a(\cdot)$ as the probability of finding a job $\theta_a m_a(\theta_a)$ in which θ_a is given by the free-entry condition, namely:

$$L_a(a - w_a) \stackrel{\text{def}}{=} \frac{\kappa_a}{a - w_a} \times m_a^{-1}\left(\frac{\kappa_a}{a - w_a}\right) \quad (4)$$

One has $\ell_a = L_a(a - w_a)$ at the equilibrium. The $L_a(\cdot)$ function is a reduced form that captures everything we need on the labor demand side. From the assumptions made on the matching function, $L_a(\cdot)$ is twice-continuously differentiable and admits values within $(0, 1)$. As the wage w_a increases, firms get lower surplus $(a - w_a)$ on each filled vacancy, fewer vacancies are created and tightness θ_a decreases. This explains why the employment probability ℓ_a decreases with the wage w_a . Moreover, due to the constant-returns-to-scale assumption, the probability of being employed depends only on skill and wage levels and not on the number of participants. If for a given wage, there are twice more participants, the free-entry condition leads to twice more vacancies, so the level of employment is twice higher and the employment probability is unaffected. This property is in accordance with the empirical evidence that the size of the labor force has no lasting effect on group-specific unemployment rates. Finally, because labor markets are perfectly segmented by skill, the probability that a participant of type a finds a job depends only on the wage level w_a and not on wages in other segments of the labor market.

We then define the elasticity of the (type- a) labor demand to the surplus of the firm $a - w_a$ as (see Appendix A):

$$\eta_a^D \stackrel{\text{def}}{=} (a - w_a) \frac{L'_a(a - w_a)}{L_a(a - w_a)} = \frac{1 - \mu_a(\theta_a)}{\mu_a(\theta_a)} > 0 \quad (5)$$

⁹ where $m_a^{-1}(\cdot)$ denotes the reciprocal of function $\theta \mapsto m_a(\theta)$, holding a constant.

where (4) has been used and $\mu_a(\theta_a)$ denotes the elasticity of the matching function with respect to the mass of job-seekers U_a evaluated at $\theta_a = m_a^{-1}(\kappa_a/(a - w_a))$. The empirical literature on labor demand is typically concerned with the elasticity of employment with respect to the level of wage. Controlling for participation decisions in our model, the latter elasticity is negative and equals $-\eta_a^D \times (w_a/(a - w_a))$.

II.3 The wage setting

Once a firm and a worker are matched, they share the total surplus, i.e. the sum of the firm's surplus $a - w_a$ and of the worker's surplus $w_a - T(w_a) - b$. In the absence of an agreement, nothing is produced and the worker gets the welfare benefit b . The bargaining process determines how the total surplus $S_a = a - T(w_a) - b$ is shared between the worker and the firm. The result of the bargaining can be viewed as the outcome of the maximization of an objective $\Omega_a(x_a, y_a)$ that is increasing in the firm's $x_a = a - w_a$ and the employee's $y_a = w_a - T(w_a) - b$ surplus. For instance, the generalized Nash bargaining framework consists in maximizing $\Omega_a(x, y) = x^{1-\gamma_a}y^{\gamma_a}$, where $\gamma_a \in (0, 1)$ captures the exogenous bargaining power of workers of skill a . However, the Nash approach has been criticized.¹⁰ For instance, Laroque and Salanié (2004) show that Nash bargaining leads to counterfactual properties in the presence of a legal minimum wage. Moreover, the independence of irrelevant alternatives axiom on which the Nash bargaining is based has been subject to controversy, in particular in the context of wage negotiation. Alexander (1992) lists a number of papers, including controlled experiments in the lab, providing evidence against this axiom and in accord with the alternative axiom of monotonicity that allows players to make interpersonal comparison of gains. Therefore, to replace the property of independence of irrelevant alternatives by the monotonicity property may be very appealing. In this context, the predominant concept is the Kalai solution (Kalai, 1977). The Kalai solution leaves the gains of the players proportional to each other. In this paper, we consider the Kalai (1977) approach which in our context amounts to fixing w_a such that the surplus accruing to the worker be proportional to the one accruing to the firm.¹¹ By analogy with the weights appearing in the above Nash product Ω_a , the exogenous skill-specific coefficient of proportionality is written $(1 - \gamma_a)/\gamma_a$:

$$a - w_a = \frac{1 - \gamma_a}{\gamma_a} (w_a - T(w_a) - b) \quad (6)$$

¹⁰Inside the search and matching literature, there is also a lively debate since the paper of Shimer (2005) about the response of Nash-bargained wages to business cycle conditions. This literature is not central for our purpose.

¹¹If symmetry is required, the Kalai solution becomes the Egalitarian Solution discussed by L'Haridon *et al* (2010) in the context of the search-matching literature.

or:

$$w_a = \gamma_a \cdot a + (1 - \gamma_a) \cdot (T(w_a) + b)$$

which has a unique solution w_a if $T' < 1$. Therefore, the Kalai bargained wage does not depend on the marginal tax rate but on the employment tax. Let $\tau_a = T(w_a) + b$ denote the employment tax for workers of skill a . Then

$$w_a = \gamma_a \cdot a + (1 - \gamma_a) \tau_a \quad (7)$$

If the employment tax τ_a was exogenous, the gross wage w_a would be increasing in τ_a : An increase in the employment tax reduces the employee's surplus hence the employee mitigates her loss by a larger bargained wage w_a . However, the employment tax is a function of the wage, $\tau_a = T(w_a) + b$. The following lemma solves this endogeneity issue.

Lemma 1 *For any differentiable mapping $a \mapsto \tau_a$ such that*

$$-\frac{\gamma_a}{1 - \gamma_a} - \frac{a - \tau_a}{1 - \gamma_a} \frac{\partial \gamma_a}{\partial a} < \frac{\partial \tau_a}{\partial a} < 1 + \frac{a - \tau_a}{\gamma_a} \frac{\partial \gamma_a}{\partial a} \quad (8)$$

There exists a single income tax function $w \mapsto T(w)$ such that employed workers of skill a receive the gross wage w_a given by (7) and pay an amount of tax equal to $\tau_a - b$.

Proof: Given the mapping $a \mapsto \tau_a$, the wage given by (7) is increasing in a only when the first inequality in (8) holds. In this case, Equation (7) can be inverted to express the skill a as a differentiable function denoted $\mathcal{A}(w)$ of the wage. The income tax function has then to satisfy $T(w) \equiv \tau_{\mathcal{A}(w)} + b$, which implies:

$$T'(w) = \frac{\partial \tau_a}{\partial a} \mathcal{A}'(w) = \frac{\frac{\partial \tau_a}{\partial a}}{\gamma_a + (1 - \gamma_a) \frac{\partial \tau_a}{\partial a} + (a - \tau_a) \frac{\partial \gamma_a}{\partial a}}$$

Under this tax function, the condition $T' < 1$ holds only if the second inequality in (8) is verified. \square

According to this Lemma, under (8), the government's problem can be simplified as the design of an employment tax level for each skill level $a \mapsto \tau_a$. In the rest of this paper, we thus adopt a "relaxed" approach. We consider the design of a welfare benefit b and an employment tax for each skill level τ_a that maximize the government's objective subject to the budget constraint. We consider only cases where the solution of this "relaxed" program verifies (8). This optimal allocation can then be decentralized by a tax schedule $w \mapsto T(w)$ that depends only on wages. This relaxed approach is similar in spirit to the first-order-approach adopted in the optimal intensive income tax literature (Mirrlees (1971)) when assuming the monotonicity constraint is slack (thus ruling out bunching). A

similar simplification also holds in the optimal extensive income tax literature when the pooling issue is avoided.¹²

Since $a - w_a = (1 - \gamma_a)(a - \tau_a)$ from (7), the employment probability verifies:

$$\ell_a = L_a [(1 - \gamma_a)(a - \tau_a)] \quad (9)$$

Combining (1) and (7), the expected surplus from participating equals:

$$\Sigma_a = \gamma_a \cdot (a - \tau_a) \cdot L_a [(1 - \gamma_a)(a - \tau_a)] \quad (10)$$

and the skill-specific participation rate equals:

$$h_a = H [\gamma_a \cdot (a - \tau_a) \cdot L_a [(1 - \gamma_a)(a - \tau_a)] | a] \quad (11)$$

Finally, the skill specific employment rate e_a equals the product of the participation rate h_a by the probability ℓ_a for each participant to find a job:

$$e_a = \ell_a \cdot h_a = L_a [(1 - \gamma_a)(a - \tau_a)] \cdot H [\gamma_a (a - \tau_a) L_a [(1 - \gamma_a)(a - \tau_a)] | a] \quad (12)$$

The employment rate responds to tax according to

$$\frac{de_a}{e_a} = - [\eta_a^D + \eta_a^P + \eta_a^D \eta_a^P] \frac{d\tau_a}{a - \tau_a} \quad (13)$$

where we used elasticities defined in (3) and (5). We henceforth refer to the term in brackets in (13) as the *global* elasticity of employment. The product $\eta_a^D \eta_a^P$ enters this formula because any increase in the labor demand increases incentives to enter the labor force and hence reinforces the labor supply. This complementarity between labor demand and labor supply is a key insight of the unemployment matching theory.

II.4 The government

We assume that the government cares about the distribution of expected utilities, namely, $\ell_a \cdot (w_a - T(w_a)) + (1 - \ell_a) \cdot b - \chi = \Sigma_a + b - \chi$ (from (10)) for those who participate and b for nonparticipating individuals. More precisely, the government has the following Bergson-Samuelson social welfare function:

$$\int_{a_0}^{a_1} \left\{ \int_0^{\Sigma_a} \Phi(\Sigma_a + b - \chi) \cdot dH(\chi | a) + \Phi(b) \cdot (1 - H(\Sigma_a | a)) \right\} dF(a) \quad (14)$$

where $\Phi'(\cdot) > 0$, $\Phi''(\cdot) \leq 0$. The stronger the concavity of $\Phi(\cdot)$ the more averse to inequality is the government. Assuming $\Phi''(\cdot) = 0$ corresponds to the Benthamite Utilitarian criterion that sums the individual expected utilities.

¹²the optimal extensive income tax literature neglects the possibility of pooling (e.g., Diamond 1980, Saez, 2002) and we follow this approach. Choné and Laroque (2011) study conditions under which the pooling issue is avoided.

The government faces the following budget constraint

$$\int_{a_0}^{a_1} \tau_a \cdot e_a \cdot dF(a) - b - R = 0 \quad (15)$$

that is written so that the welfare benefit b is provided to all agents in the economy but for each additional worker of skill a , the government saves the welfare benefit b and collects taxes $T(w_a)$ (the sum of these being τ_a). Taking (12) into account, this budget constraint can be rewritten as

$$\begin{aligned} & \int_{a_0}^{a_1} \tau_a \cdot L_a [(1 - \gamma_a)(a - \tau_a)] \cdot H(\gamma_a \cdot (a - \tau_a) \cdot L_a [(1 - \gamma_a)(a - \tau_a)] | a) \cdot dF(a) \\ = & b + R \end{aligned} \quad (16)$$

III The optimal tax policy

Following Lemma 1, the optimal tax problem consists in finding the optimal level of benefit b and employment tax levels τ_a that maximize the social objective (14) subject to the budget constraint (16), taking into (10) account. This problem is solved in Appendix B.

Let λ be the Lagrange multiplier of the budget constraint. We interpret λ as the marginal social cost of the public funds R . Let g_a denote the marginal social welfare weight given to workers of skill a , expressed in terms of public funds, i.e.

$$g_a \stackrel{\text{def}}{=} \frac{\int_0^{\Sigma_a} \Phi'(\Sigma_a + b - \chi) \cdot dH(\chi | a)}{\lambda \cdot h_a} \quad (17)$$

Intuitively, the government is indifferent between giving one more euro to each participant of skill a and giving g_a euros of public funds. Symmetrically, we define

$$g^N \stackrel{\text{def}}{=} \frac{\Phi'(b)}{\lambda} \quad (18)$$

as the marginal social welfare weight of non-participating individuals expressed in terms of public funds. The optimal tax policy is given in the following proposition, which is proved in Appendix B and in the heuristic proof below.

Proposition 1 *The optimal tax schedule satisfies:*

$$\int_{a_0}^{a_1} \{g_a \cdot h_a + g_a^N \cdot (1 - h_a)\} \cdot dF(a) = 1 \quad (19a)$$

$$\forall a \in [a_0, a_1] \quad \frac{\tau_a}{w_a - \tau_a} = \frac{1 - g_a \cdot \gamma_a \cdot (1 + \eta_a^D)}{\gamma_a \cdot [\eta_a^D + \eta_a^P + \eta_a^D \eta_a^P]} \quad (19b)$$

Equation (19a) states that the marginal cost of public funds is a weighted average of the social marginal utilities of the workers (g_a) and of the unemployed (g_a^N). Equation (19b) states that the optimal employment tax rate is an inverse elasticity rule: The larger the global elasticity of employment $\eta_a^D + \eta_a^P + \eta_a^D \eta_a^P$, the lower the absolute value of the employment tax rate. Using $w_a - \tau_a = \gamma_a (a - \tau_a)$, (19b) can be rewritten as

$$\frac{\tau_a}{a - \tau_a} = \frac{1 - g_a \cdot \gamma_a \cdot (1 + \eta_a^D)}{[\eta_a^D + \eta_a^P + \eta_a^D \eta_a^P]}$$

so that γ_a does not appear anymore in the denominator of our inverse elasticity rule. Equation (19b) can also be rewritten as

$$\tau_a = \frac{1 - g_a \cdot \gamma_a \cdot (1 + \eta_a^D)}{1 - g_a \cdot \gamma_a \cdot (1 + \eta_a^D) + \gamma_a \cdot [\eta_a^D + \eta_a^P + \eta_a^D \eta_a^P]} w_a \quad (20a)$$

$$\text{or } \tau_a = \frac{1 - g_a \cdot \gamma_a \cdot (1 + \eta_a^D)}{1 - g_a \cdot \gamma_a \cdot (1 + \eta_a^D) + \eta_a^D + \eta_a^P + \eta_a^D \eta_a^P} a, \quad (20b)$$

where the employment tax level τ_a is expressed as function of w_a and as function of a , respectively.

Our general model encompasses two specific cases. First, one can retrieve the pure extensive margin model when the matching function verifies $M_a(V, U) = U$ and $\gamma_a = 1$. When $M_a(V, U) = U$, any job-seeker becomes employed, as in Diamond (1980), Saez (2002) and Choné and Laroque (2005, 2011) and $\eta_a^D = 0$. When $\gamma_a = 1$, Equation (7) leads to the equality between the gross wage w_a and the marginal product a . Under these two assumptions, to which we henceforth refer to as the “pure extensive response” model, Equation (19b) becomes identical to the inverse elasticity rule of Saez (2002) in the absence of intensive response, i.e.

$$\frac{\tau_a}{w_a - \tau_a} = \frac{1 - g_a}{\eta_a^P} \quad (21)$$

where η_a^P measures here the elasticity of participation with respect to $w_a - \tau_a$.

Second, our model also encompasses the polar “pure labor demand response” model with full participation decisions where $h_a = 1$ and $\eta_a^P = 0$. Equations (19a)-(19b) then become:

$$\int_{a_0}^{a_1} g_a \cdot dF(a) = 1 \quad (22a)$$

$$\frac{\tau_a}{w_a - \tau_a} = \frac{1 - g_a \cdot \gamma_a \cdot (1 + \eta_a^D)}{\gamma_a \cdot \eta_a^D} \Leftrightarrow \frac{\tau_a}{a - \tau_a} = \frac{1 - g_a \cdot \gamma_a \cdot (1 + \eta_a^D)}{\eta_a^D} \quad (22b)$$

In the “pure labor demand response”, the optimal employment tax also follows an inverse elasticity rule but the only responses that prevail are the ones from the labor demand side through η_a^D . The intuition behind the numerators of (22b) will be provided in the heuristic proof below.

III.1 Heuristic proof

To derive and interpret Equations (19b), (21) and (22b), we consider a perturbation of the optimal tax function that consists in a small increase¹³ $dT(w_a) > 0$ of the tax liability at wage w_a . For a constant level of benefit b , this increase induces a rise $d\tau_a = dT(w_a)$ in the employment tax τ_a paid by workers of skill level, which implies a “mechanical” effect, an “employment response” effect and a “social welfare” effect that we now describe.

Mechanical effect

Absent any behavioral change, the government levies $d\tau_a$ additional taxes on each job of skill a . As only a fraction e_a of individuals of skill a are employed, the mechanical increase in tax revenue per individual of skill a equals:

$$\mathcal{M}_a = e_a \cdot d\tau_a \quad (23)$$

This effect is identical in our general model, in the pure extensive case and in the pure labor demand case.

Employment response effect

The increase in the employment tax induces a reduction in the employment rate $e_a = \ell_a h_a$ that is given by (13). Using (7), employment changes by:

$$de_a = -\gamma_a \cdot [\eta_a^D + \eta_a^P + \eta_a^D \eta_a^P] \cdot \frac{d\tau_a}{w_a - \tau_a} \cdot e_a$$

This reduction is made of a direct change in participation, a direct labor demand response and the effect of the labor demand response on the incentives to participate. In particular, the term $\eta_a^D \eta_a^P$ captures the complementarity between labor demand and participation responses: Any increase in the labor demand reinforces incentives to enter the labor force and hence boosts the labor supply. The bargaining power γ_a appears because we express the optimal level of the employment tax as a fraction of the gross wage level w_a . This parameter would have been absent if instead we had written the employment tax as a fraction of the skill level a .¹⁴ As each additional worker of skill a increases the government’s revenue by the employment tax τ_a , the employment effect per individual of skill a equals

$$\mathcal{E}_a = -\gamma_a \cdot [\eta_a^D + \eta_a^P + \eta_a^D \eta_a^P] \cdot \frac{\tau_a}{w_a - \tau_a} \cdot e_a \cdot d\tau_a \quad (24)$$

¹³The case where the employment tax decreases is symmetric as only first-order effects need to be considered.

¹⁴As $w_a - \tau_a = \gamma_a (a - \tau_a)$ from (7), we would have instead $de_a = [\eta_a^D + \eta_a^P + \eta_a^D \eta_a^P] \cdot \frac{dw_a}{a - \tau_a} \cdot e_a$

There are two differences with the pure extensive case. First, the global elasticity of employment $\eta_a^D + \eta_a^P + \eta_a^D \eta_a^P$ matters instead of the sole labor supply elasticity η_a^P . Second, the employment response effect is multiplied by the fraction γ_a of the surplus that accrues to the worker. In the pure extensive case, one has $\gamma_a = 1$ and $w_a = a$.¹⁵

In the pure labor demand response case, the global elasticity of employment $\eta_a^D + \eta_a^P + \eta_a^D \eta_a^P$ is reduced to the sole labor demand elasticity η_a^D since only the labor demand response prevails.¹⁶

Social welfare effect

We now describe how the reform affects the social welfare function (14). Given our assumption that the government cares about the distribution of expected utilities, one should determine how the reform modifies the expected surplus Σ_a defined in (1). On the one hand, there is a direct effect on the surplus $w_a - \tau_a$ extracted by the worker. From (7), this change amounts to

$$d(w_a - \tau_a) = -\gamma_a \cdot d\tau_a$$

On the other hand, the labor demand response implies a reduction in the job-finding probability ℓ_a . From (5) and (9), this term equals

$$d\ell_a = -\eta_a^D \cdot \frac{1}{a - \tau_a} \cdot \ell_a \cdot d\tau_a$$

Combining these two effects, the expected surplus is reduced by

$$d\Sigma_a = -\gamma_a \cdot (1 + \eta_a^D) \cdot \ell_a \cdot d\tau_a$$

This reduction induces some individuals to stop participating. However, these pivotal individuals are indifferent between participating or not, so the change in their participation decisions has no first-order effect on the social objective. Recall that g_a is the marginal social welfare weight given to workers of skill a , expressed in terms of public funds (see (17)). The social welfare effect per individual of skill a equals:

$$\mathcal{W}_a = -g_a \cdot \gamma_a \cdot (1 + \eta_a^D) \cdot \ell_a \cdot d\tau_a \quad (25)$$

¹⁵The above distinction between expressing the employment tax as a fraction of the wage or as a fraction of the skill then becomes meaningless.

¹⁶Appendix C considers the optimal tax problem when the government observes also the cost of searching χ . The optimal employment tax is then inversely related to the labor demand elasticity only. Intuitively, in such a case, the government can condition taxation on the cost of searching to enforce individuals' participation decisions without distorting labor supply. The labor supply elasticity then does not appear in the optimal tax formula. However, the labor demand elasticity remains for two reasons. First, the government cannot influence the matching process. Second, the government has no tax instrument to influence the number of vacancies created on each labor market.

In the pure extensive response model where $\gamma_a = 1$ and $\eta_a^D = 0$, the term $\gamma_a (1 + \eta_a^D)$ of the welfare effect (25) simplifies to 1. In the general model, the term $\gamma_a (1 + \eta_a^D)$ equals 1 only when:

$$\frac{1 - \gamma_a}{\gamma_a} = \eta_a^D \quad (26)$$

From (5), this restriction amounts to the equality between the worker's share γ_a of the total surplus and the elasticity μ_a of the matching function with respect to unemployment. This equality is known in the matching literature as the Hosios (1990) condition. In an economy without taxes and transfers, it ensures that the total surplus generated by a match is shared in such a way that the congestion externalities are internalized. There is no particular reason why the Hosios condition should be satisfied, since it “relates a parameter of the resolution of bargaining conflict to a parameter of the technology of matching” (Pissarides (2000, page 198)).

In our model, when the Hosios condition (26) is not met, the tax instrument cannot be used to correct for congestion externalities, as it cannot modify the fraction of the surplus that each party receives through the wage bargain. Still, a deviation from the Hosios condition affects the optimal tax for tax incidence reasons. Workers only pay a fraction γ_a of a tax increase from (7). The latter affects the expected surplus through a direct effect on net earnings and an indirect one on the probability of finding a job. The term $\gamma_a (1 + \eta_a^D)$ therefore captures the incidence of a tax increase on the welfare of a participant of skill a .

A small change in the employment tax must imply no first-order effect. Adding (23), (24) and (25) and rearranging terms gives (19b). Rearranging terms again lead to the optimal employment tax rates given in (20a).

III.2 Sign of the optimal employment tax

The sign of the employment tax rate is given by the difference between the mechanical (23) and the social welfare effects (25). Therefore, as shown by (19b), the employment tax is positive for workers whose weights g_a are lower than $1/[\gamma_a (1 + \eta_a^D)]$ and negative for the others.

In the pure labor demand case, the weighted average of social welfare weights $\int_{a_0}^{a_1} g_a \cdot dF(a)$ equals 1 (see (22a)). Under a concave social welfare function $\Phi(\cdot)$, the social welfare weights g_a are decreasing in the skill levels a under the plausible assumption that the expected surplus Σ_a is increasing in the skill level. Therefore, if one also assumes that the Hosios condition (26) holds, the employment tax on the least skilled workers is negative, a case that Saez (2002) defines as an Earned Income Tax Credit (EITC).

In the pure extensive case and in the general model, the welfare of nonparticipants has to be taken into account. From (17) and (18), one has $g_N > g_a$ whenever the social welfare function $\Phi(\cdot)$ is concave. In particular, when the social welfare function is close to a Maximin objective, one typically obtains $g^N > 1 > g_a$. If the Hosios condition holds in the general model, an EITC is then ruled out, since the numerator of (19b) simplifies to $1 - g_a$.

III.3 Quantitative insights

In this section, we numerically investigate how introducing the labor demand response affects the optimal employment tax rates τ_a/w_a . For this purpose, we use (20a) to compute optimal employment tax rates for different calibrated values of η_a^P , η_a^D , γ_a and g_a .

We take three values for η_a^P , namely 0, 0.25, and 0.5. These values are plausible lower bound, average and higher bound estimates for η_a^P , according to Immervoll *et alii* (2007) and Meghir and Phillips (2008), among others. To calibrate the elasticity η_a^D of the job-finding probability with respect to the firm surplus $a - w_a$, we use (5) and the estimates of the matching function surveyed by Petrongolo and Pissarides (2001). We take $\mu = 0.5$, thereby $\eta_a^D = 1$ as a benchmark. However, we also consider the pure extensive case where the labor demand is unresponsive ($\eta_a^D = 0$) and an intermediate case, namely $\eta_a^D = 0.5$.

g_a	0			0.5		
η_a^D	0	0.5	1	0	0.5	1
γ_a	1	2/3	0.5	1	2/3	0.5
η_a^P						
0	100%	75.0%	66.7%	100%	60.0%	50.0%
0.25	80.0%	63.2%	57.1%	66.7%	46.2%	40.0%
0.5	66.7%	54.5%	50.0%	50.0%	37.5%	33.3%

Table 1: Optimal employment taxes τ_a/w_a under the Hosios condition

We consider in Table 1 cases where the bargaining power is adjusted to fulfill the Hosios condition (26). Hence $\gamma_a \cdot (1 + \eta_a^D)$ remains equal to 1. The first and fourth columns give τ_a/w_a in the pure extensive response model (where $\eta_a^D = 0$) while the first row provides values of τ_a/w_a in the pure labor demand model (where $\eta_a^P = 0$). Increasing the labor demand elasticity implies two effects on the optimal employment tax rates. First, the global elasticity of employment $\eta_a^D + \eta_a^P + \eta_a^D \eta_a^P$ increases, which tends to reduce the magnitude of the employment tax rates. Second, according to (20b), the reduction in γ_a that takes place to keep the Hosios condition does not change the ratio of the optimal employment tax τ_a to the skill level a . However, it reduces the ratio of the wage w_a to the skill a , hence it tends to increase the employment tax rate τ_a/w_a . The overall effect is

negative under the Hosios condition.¹⁷ This effect is quantified in Table 1. A larger labor demand elasticity substantially reduces the optimal employment tax. For instance, when $\eta_a^P = 0.25$, τ_a/w_a shrinks by 23 percentage points (from 80% to 57%) under Maximin and by 33 percentage points (from 67% to 40%) with a marginal social welfare weight g_a equals to 0.5.

g_a	0			0.5		
η_a^D	0	0.5	1	0	0.5	1
γ_a	1	2/3	0.5	1	2/3	0.5
$\eta_a^D + \eta_a^P + \eta_a^D \eta_a^P$						
0.5	66.7%	75.0%	×	50.0%	60.0%	×
0.75	57.1%	66.7%	×	40.0%	50.0%	×
1	50.0%	60.0%	66.7%	33.3%	42.9%	50.0%

Table 2: Optimal employment taxes τ_a/w_a under the Hosios condition

The empirical literature on labor taxation typically distinguishes an intensive margin and an extensive margin of the labor supply. In estimating the latter, the controls for changes in job-finding probabilities are typically lacking. Hence, it is unclear whether the responses of employment to taxation identify the sole participation elasticity η_a^P , or the global employment elasticity $\eta_a^D + \eta_a^P + \eta_a^D \eta_a^P$. Consequently, in each row of Table 2, the global elasticity of employment remains constant (at respectively 0.5, 0.7 and 1). As the labor demand elasticity increases, the participation elasticity shrinks. Some cells in Table 2 are empty since η_a^P cannot be negative. Moreover, the bargaining power γ_a is again adjusted to fulfill the Hosios condition (26). Increasing η_a^D requires to reduce γ_a to keep the Hosios condition satisfied. Therefore, from (20a) with $g_a < 1$, the optimal employment tax rate increase with η_a^D , the global elasticity being constant. Increasing η_a^D from 0 to 0.5 increases the employment tax τ_a by about 8 or 10 percentage points when $g_a = 0$. Employment tax rates are lower when $g_a = 0.5$ and increase in η_a^D by a similar extent. Hence, for a given global elasticity of employment, optimal employment tax rates are substantially higher when labor demand responses contribute more (thereby participation responses contribute less) to the global elasticity of employment.

Finally, Table 3 studies the impact of deviating from the Hosios condition (26). In each row, we vary the worker's share γ_a of the total surplus, while we keep η_a^D at its benchmark value of 1. A low ($\gamma_a = 0.3$) and a high ($\gamma_a = 0.7$) value are taken to illustrate the

¹⁷Under the Hosios condition (26), Equation (20a) simplifies to

$$\frac{\tau_a}{w_a} = \frac{1 - g_a}{1 - g_a + \gamma \cdot [(1 + \eta_a^D)(1 + \eta_a^P) - 1]} = \frac{1 - g_a}{1 - g_a + 1 + \eta_a^P - \frac{1}{1 + \eta_a^D}}$$

where we use again the Hosios condition (26) to get the second equality. Hence, optimal employment tax rates in absolute value decreases with the labor demand elasticity.

g_a	0			0.5		
η_a^D	1			1		
η_a^P γ_a	0.3	0.5	0.7	0.3	0.5	0.7
0	76.9%	66.7%	58.8%	70.0%	50.0%	30.0%
0.25	69.0%	57.1%	48.8%	60.9%	40.0%	22.2%
0.5	62.5%	50.0%	41.7%	53.8%	33.3%	17.6%

Table 3: Optimal employment tax rates τ_a/w_a when the Hosios condition is violated

consequences of a deviation from the Hosios condition (the central value being $\gamma_a = 0.5$). According to (19b), a rise in γ_a has two effects on the optimal employment tax rate τ_a/w_a . First, the employment tax rate is the product of the ratio of the employment tax to the skill level τ_a/a times the ratio of the skill level to the gross wage a/w_a . When $g_a = 0$, the first term is unaffected by a rise in γ_a , while the second shrinks. Hence the optimal employment tax rate decreases when $g_a = 0$. Second, a given increase of the employment tax τ_a has a larger impact on the welfare of the workers when γ_a is higher. Therefore, the optimal employment tax decreases with γ_a . Table 3 highlights that the quantitative impact of γ_a is substantial. For instance, when $g_a = 0$, increasing the worker's share γ_a from 0.3 to 0.7 reduces the optimal employment tax rate by approximately one third. When $\eta_a^P = 0.25$ and $g_a = 0.5$, increasing γ_a from 0.3 to 0.7 divides the employment tax rate by nearly 3.

IV Conclusion

The optimal tax schedule derived in the optimal tax model with labor supply along the extensive margin is drastically modified when labor demand is taken into account in a search-matching economy where the empirically relevant Kalai bargaining solution is assumed. The employment tax is still an inverse elasticity rule however the elasticity term encapsulates not only labor supply responses (as in the standard model) but also labor demand responses and the interaction effects between labor demand and labor supply, the latter two being neglected in the standard framework. For plausible values of the parameters, matching frictions induce much lower employment tax rates than the ones found in the usual competitive model with endogenous participation decisions.

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Appendices

A Link between the elasticity of the labor demand and the elasticity of the matching function

Let $\mu_a(\cdot)$ denote the elasticity of the matching function $M_a(\cdot, \cdot)$ with respect to the mass of job-seekers U_a . Because the matching function is increasing in both arguments and exhibits constant returns to scale, μ_a depends only on the level of tightness and one has $\mu_a(\theta) \in (0, 1)$ for all θ . From $m_a(\theta) = M_a(1, 1/\theta)$, the elasticity of the probability of filling a vacancy to the tightness level (i.e. $(\theta_a/m_a)(\partial m_a(\theta)/\partial \theta_a)$) equals $-\mu_a(\theta)$. Hence the elasticity of the reciprocal $m_a^{-1}(\cdot)$ equals $-1/\mu_a(m_a^{-1}(\cdot))$. The log-differentiation of the L_a function (4) with respect to the firm's surplus $a - w_a$ gives:

$$\frac{dL_a}{L_a} = \left(-1 + \frac{1}{\mu_a(\theta_a)} \right) \cdot \frac{d(a - w_a)}{a - w_a}$$

which leads to the second equality in (5). The inequality holds because $\mu_a(\theta) \in (0, 1)$.

B Proof of Proposition 1

The Lagrangian of the optimal tax problem is

$$\int_{a_0}^{a_1} \mathcal{L}(\tau_a, b, \lambda) \cdot dF(a) - \lambda b - \lambda R$$

where

$$\begin{aligned} \mathcal{L}(\tau_a, b, \lambda) \stackrel{\text{def}}{=} & \int_0^{\gamma_a \cdot (a - \tau_a) \cdot L_a[(1 - \gamma_a)(a - \tau_a)]} \Phi(\gamma_a \cdot (a - \tau_a) \cdot L_a[(1 - \gamma_a)(a - \tau_a)] + b - \chi) \cdot dH(\chi|a) \\ & + \Phi(b) \cdot (1 - H(\gamma_a \cdot (a - \tau_a) \cdot L_a[(1 - \gamma_a)(a - \tau_a)]|a)) \\ & + \lambda \cdot \tau_a \cdot L_a[(1 - \gamma_a)(a - \tau_a)] \cdot H(\gamma_a \cdot (a - \tau_a) \cdot L_a[(1 - \gamma_a)(a - \tau_a)]|a) \end{aligned}$$

The first-order condition with respect to b is:

$$\int_{a_0}^{a_1} \left\{ \int_0^{\gamma_a \cdot (a - \tau_a) \cdot L_a[(1 - \gamma_a)(a - \tau_a)]} \Phi'(\Sigma_a + b - \chi) \cdot dH(\chi|a) + \Phi'(b) \cdot (1 - h_a) \right\} dF(a) = \lambda$$

Using (17) and (18) gives (19a). The first-order condition with respect to τ_a writes $0 = \frac{\partial \mathcal{L}}{\partial \tau_a}(\tau_a, b, \lambda)$. Using (3) and (5), this leads to:

$$0 = -\gamma_a \cdot (1 + \eta_a^D) \cdot \ell_a \cdot \left(\int_0^{\Sigma_a} \Phi'(\Sigma_a + b - \chi) \cdot dH(\chi | a) \right) \\ + \lambda \left\{ 1 - \frac{\tau_a}{a - \tau_a} \eta_a^D - \frac{\tau_a}{a - \tau_a} (1 + \eta_a^D) \cdot \eta_a^P \right\} \ell_a \cdot h_a$$

Dividing both sides by $\lambda h_a \ell_a = \lambda e_a$, using (17) and $w_a - \tau_a = \gamma_a (a - \tau_a)$ (from (7)) gives (19b).

C The government observes (a, χ)

This appendix derives the optimal tax schedule when the government observes individuals' characteristics (a, χ) but not their search activity. In this framework, the utility of agents who do not search for a job is $b_{a,\chi}$, the utility of those who search but do not find a job is $b_{a,\chi} - \chi$ while those who obtain a job obtain $w_{a,\chi} - \tau_{a,\chi} + b_{a,\chi} - \chi$. The worker's surplus is then $w_{a,\chi} - \tau_{a,\chi}$ and the firm's surplus is $a - w_{a,\chi}$. The bargained wage (7) becomes

$$w_{a,\chi} = \gamma_a \cdot a + (1 - \gamma_a) \tau_{a,\chi}$$

hence the probability of having a job for a participating individual states as $\ell_{a,\chi} = L_a [(1 - \gamma_a) (a - \tau_{a,\chi})]$. This allows to write the participation constraints as

$$L_a [(1 - \gamma_a) (a - \tau_{a,\chi})] \cdot \gamma_a \cdot (a - \tau_{a,\chi}) \geq \chi$$

We denote $1_{a,\chi} = 1$ when this constraint is satisfied and $1_{a,\chi} = 0$ otherwise. This allows to write the budget constraint as

$$R = \iint \langle \tau_{a,\chi} \cdot 1_{a,\chi} \cdot L_a [(1 - \gamma_a) (a - \tau_{a,\chi})] - b_{a,\chi} \rangle dH(\chi | a) dF(a)$$

and we denote $\lambda \geq 0$ the Lagrangian multiplier associated to this constraint. The Lagrangian can be formulated as

$$\mathcal{L} = \iint \langle 1_{a,\chi} \cdot \Phi[\gamma_a \cdot (a - \tau_{a,\chi}) \cdot L_a [(1 - \gamma_a) (a - \tau_{a,\chi})] + b_{a,\chi} - \chi] + (1 - 1_{a,\chi}) \cdot \Phi[b_{a,\chi}] \\ + \lambda \cdot \{ 1_{a,\chi} \cdot L_a [(1 - \gamma_a) (a - \tau_{a,\chi})] \cdot \tau_{a,\chi} - b_{a,\chi} \} \rangle dH(\chi | a) dF(a)$$

First, we state the first-order condition for people who participate and next for non-participants. If $1_{a,\chi} = 1$, the first-order condition with respect to $\tau_{a,\chi}$ is:

$$\{ L_a[\cdot] + (1 - \gamma_a) \cdot (a - \tau_{a,\chi}) \cdot L'_a[\cdot] \} \cdot \gamma_a \cdot \frac{\Phi'[\cdot]}{\lambda} = \{ L_a[\cdot] - (1 - \gamma_a) \cdot \tau_{a,\chi} \cdot L'_a[\cdot] \}$$

Using (5) and simplifying by $L_a[\cdot]$, we obtain:

$$\frac{\tau_{a,\chi}}{a - \tau_{a,\chi}} = \frac{1 - (1 + \eta_a^D) \cdot \gamma_a \cdot \frac{\Phi'[\cdot]}{\lambda}}{\eta_a^D} \quad (27)$$

which is equivalent to (22b) except that $\Phi'[\cdot]/\lambda$ stands instead of g_a . The first-order condition with respect to $b_{a,\chi}$ is:

$$1_{a,\chi} \cdot \Phi'[\gamma_a \cdot (a - \tau_{a,\chi}) \cdot L_a[(1 - \gamma_a)(a - \tau_{a,\chi})] + b_{a,\chi} - \chi] + (1 - 1_{a,\chi}) \Phi'[b_{a,\chi}] = \lambda \quad (28)$$

This condition implies that all expected utilities are equalized across individuals, whatever their participation decision. Denote z the common value for the expected utilities, with $\Phi'[z] = \lambda$. The expected utility of people of type (a, χ) is

$$\ell_{a,\chi} (w_{a,\chi} - \tau_{a,\chi}) + b_{a,\chi} - \chi = z \quad (29)$$

The optimality condition with respect to $1_{a,\chi}$ implies that individuals of type (a, χ) participate if and only if:

$$\ell_{a,\chi} \cdot \tau_{a,\chi} \geq 0$$

which can be rewritten, using (29), as:

$$\ell_{a,\chi} \cdot w_{a,\chi} \geq \chi + z - b_{a,\chi}$$

Finally, equation (28) allows to rewrite (27) as

$$\frac{\tau_{a,\chi}}{a - \tau_{a,\chi}} = \frac{1 - (1 + \eta_a^D) \cdot \gamma_a}{\eta_a^D}$$