How many educated workers do you wish for your economy? Government targets, optimal public spending, and labor market impact: the French case

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Abstract

This paper studies optimal taxation schemes of education in a search-matching model where the labor market is divided between a high-skill and a low-skill sector. Taxing the productivity rise associated with the recruitment of educated workers in high-skill jobs, *i.e.* the productivity gap between the two sectors, follows different public policy targets: maximizing the share of educated workers, maximizing the global employment level, optimizing the social surplus. We calibrate our model using French evidences, and compare our results with the target from the European Lisbon strategy for education achievement. We show that, with the current labor market characteristics, the target decided by the government seems more compatible with the employment maximization objective rather than the social surplus objective.

Keywords: Educational policy, Job search, Matching model, Optimal taxation.

JEL Codes: H21, H52, J21, J64

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1 Introduction

In most European countries, the educational system receives public subsidies. The high level of funding engaged by each government underlines the importance of investing in high quality education. Public spending for student support in tertiary education exists trough different schemes: direct study grants for students, tax relief directly linked to participation in higher education, publicly subsidized and guaranteed loans, subsidized accommodation, meals or transport for students, and sometimes family allowances related to participation in higher education. Such a public system has to be financed by the product of a tax. The question lies therefore on the extent to which governments would put financial efforts, and thus a certain fiscal pressure, in order to respect education policy objectives. Recently, as a result of early financial restraints, Spain and the UK gave their universities the right to increase tuition fees. Public reactions to such modifications proved to which extent populations are attached to the public financing of education.

During the past decades, European policy makers often pointed out the challenging role of improving the education level of citizens, the common view being that more educated individuals would favor the economy. Since the Bologna process of 1999, and the first Lisbon strategy whose results were expected within ten years, education became one of the main primary policy responsibilities of European countries (Keeling 2006) and higher education was modernized by the imposition of some level of standardization in the European education system and by the improvement of students European mobility. More recently, the European Commission restated the importance of education and training, facilitating workers' progression into working life, and playing a crucial role in many issues faced by Europe today and in the future (European Commission, Eurydice report 2013). The new Lisbon strategy 2020 indeed promotes efficient education investment as an important strategy to deliver knowledge-base growth and jobs. Apart from four strategic objectives[2], the Lisbon strategy for education and training fixes five quantitative targets of performance that should be reached by 2020, among which the target that at least 40% of the 30-34 years old age group should attain a tertiary educational level, undergraduate degree or higher (Official Journal of the European Union, 2009). This European average came with individual target proposals by each 27 Nation States. The highest target was set by Ireland who should reach 60% of 30-34 year olds with successful tertiary education, the level of which being of 32% in 2002 and 51,1% ten years later. Italy fixed the lowest target of 26% while the achieved level was only of 13,1% in 2002 and 21,7% in 2012. As for France, on which the calibration of our model is based on, the level of attainment in 2002 and 2012 were respectively of 31.5% and 43.6% for a target of 50% by 2020[3].

In order to achieve these five targets, State Members put strong public financial sup-

[2]Making lifelong learning and mobility a reality, improving the quality and efficiency of education and training, and promoting equity, social cohesion and active citizenship, and enhancing creativity and innovation, including entrepreneurship, at all levels of education and training.

[3]see the Eurostat website at `http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=t2020_41`

port in the educational system, such as investment in education infrastructures, the funding of specific educational programs, and financial support for students. All in all, the total expenditure and budgets for education remained stable between 2007 and 2010 or had a positive trend for a few countries. In 2010, the share of total public expenditure allocated to education was 8,9% in Italy, 9% in Ireland, and 10.8% in France (see European Commission 2013). These public policy choices lead to the issue of optimal taxation for the educational system, and the criteria on which the financing of the education system would be considered as optimal. As far as our economic literature search led us, no research-based defense can be cited to support or exclude the Lisbon criteria. However one can, for instance, consider the optimal level of the share of educated workers. Since employment, especially for young workers, is another leading issue for European countries, the connection between education and employment cannot be avoided. Another issue could therefore be the optimal tax rate corresponding to public spending on education that a government should implement in order to maximize the employment level of the economy. Finally, one could consider that the most important criteria is neither the share of educated workers nor the employment level but the social well-being. The target would thus be the maximization of the social surplus.

The link between education and the labor market is often considered in relation with wages premium and over-education issues but there is no clear study on the impact of an improvement in the average level of education on the labor market composition. We consider the previous targets cited in a specific matching model with a dual labor market in which job search is perfectly directed in each sector, as in Acemoglu (2001). In a search and matching model in which workers have a finite life expectancy (Moen and Rosén 2004, Gavrel *et al.* 2010), educated workers direct their search toward the high-skill sector, while non-educated workers search in the low-skill sector only. The educated status of workers is defined as individuals whose educational attainment is higher than high-school degree, *i.e.* the individual has passed at least the first tertiary education degree. We consider a very specific taxation scheme in which the tax, the product of whom is used to finance education only, is implemented in high-skill firms on the productivity gap between high-skill jobs and low-skill jobs, the high-skill sector being more productive than its counterpart. In such a framework, we derive the optimal tax rate for each target considered: maximization of the share of educated workers in the economy, maximization of the employment level, and optimization of the social surplus. We calibrate our model using French evidences for 2011 and analyse in such a context the rationality of each target. We then compare the results with the French target given as part of the Lisbon strategy.

The paper is organized as follows: Section 2 outlines the analytical framework. We define possible Government targets and the optimal tax that result from them in section 3. Section 4 presents a calibration of the model using French evidences. Finally, section 5 contains some concluding comments.

2 The model: two labor market sectors and a public educational system

The model describes a labor market with two types of jobs constituting the two sectors of this economy: (1) high-skill jobs with high productivity which are occupied only by educated workers; (2) low-skill jobs with lower productivity which are occupied only by non-educated workers. Workers are considered as educated when they succeed in obtaining their first university degree, while workers with high-school degree or less are considered as non-educated. The educational system is public so that the share of educated workers depends, for each age group, on the Government investment in education. The cost of education is assumed to be supported by the product of a tax levied on the most productive firms of the economy.

2.1 An economy with two sectors and perfect directed job-search

Firms are infinitely-lived whereas workers have a finite life expectancy of $1/m$. Time is continuous and parameter m measures the workers' labor market exit rate. Workers who leave the market are replaced with newcomers, a share α of which are educated. The measure of the total labor-force is constant and normalized to one. All agents are risk-neutral and discount future payoffs at rate r ($r \geq 0$).

Sector 1 consists of firms each having a single high-skill job producing output y_1. These firms need educated workers in order to be productive. Sector 2 consists of firms each having a single low-skill job producing output y_2. These firms produce with non-educated workers. We have $y_1 > y_2$.

Job search is perfectly directed, hence high-skilled unemployed workers, noted u_1, apply only to high-skill vacancies. High-skilled unemployed workers are of two types: educated newcomers, and high-skilled workers who separated from their high-skill jobs at rate s_1. The same apply to low-skilled unemployed workers, noted u_2. They apply to low-skill vacancies only and are of two types: non-educated newcomers, and low-skilled workers who separated from their low-skill jobs at rate s_2. When hiring a worker, firms are indifferent between newcomers and workers that separated from their previous jobs. Thus all high-skilled unemployed workers have the same probability of obtaining a high-skill job. The same applies to low-skilled unemployed workers.

Job creation results from the usual assumption of free entry in both sectors. Market frictions in sector-i, with $i = 1, 2$, are summarized in a constant-returns matching function that defines the arrival rate of workers to job vacancies $q_i(\theta_i)$ with $q_i'(\theta_i) < 0$. The arrival rate of job offers to searching workers is $p_i = \theta_i q_i$ with $p_i'(\theta_i) > 0$ where θ_i ($\theta_i = \frac{v_i}{u_i}$, with v_i the share of vacancies in sector i) is the sector tightness. The higher the tightness θ_i, the shorter the unemployment duration for a worker but the longer the job-vacancy duration for a firm. The function $p_i(\theta_i)$ has an elasticity $(1 - \eta_i)$ (where $0 < \eta_i < 1$).

2.2 Educated workers and the financing of the educational system

2.2.1 Educational cost

Newcomers have obtained their degree and are therefore considered as educated in proportion α. A share $(1-\alpha)$ of newcomers remains non-educated. Assuming that the share of educated workers is the same for each age group, α represents the share of educated workers in the economy.

Since the educational system is public, the share of young individuals obtaining their degree is correlated to the expenses granted by the government for educational purpose. We assume that the average cost of educating a young individual (μ) increases with the share of educated newcomers belonging to an age group, α. This assumption lies on the fact that as α gradually increase, the remaining non-educated individuals have less and less aptitude toward education. These individuals therefore require more financial effort from the government. The average cost of education thus depends on the shape of the function $\mu(\alpha)$ which is increasing in α ($\mu' > 0$). Notice that ε is the elasticity of the average cost $\mu(\alpha)$.

Since the labor-force is normalized to 1, there are αm educated newcomers, which represents a global cost of education $\alpha m \mu(\alpha)$. This global cost is increasing in α.

2.2.2 Budget constraint for public education

As stated before, there are two types of firms in the economy. Sector 1 firms, since they are highly productive, are the only ones benefiting from the educational system, as they recruit educated workers only. We therefore assume that they are the only ones participating to the financing of public education. The tax t is imposed on the productivity increase associated with the recruitment of educated workers, that is to say the productivity gap $(y_1 - y_2)$ between high-skill firms and low-skill firms. Each sector 1 firm therefore pays a tax $t(y_1 - y_2)$. The product of this tax corresponds to the financing of the public educational system.

The total revenue induced by the tax depends on the number of high-skill firms, that is to say the number of educated employees (ℓ_1), and on the productivity gap between high-skill jobs and low-skill jobs.

The budget constraint for public education can be written as:

$$t(y_1 - y_2)\ell_1 = \alpha m \mu(\alpha) \tag{1}$$

2.3 High-skill and low-skill job creation

The asset value of a vacancy is denoted V_i. Maintaining a vacant job requires that the firm pays a cost c_i, which gives the firm the opportunity of finding a worker at rate q_i. When the job is filled with a worker, its asset value becomes J_i (for $i = 1, 2$).

$$rV_i = -c_i + q_i(J_i - V_i) \tag{2}$$

The number of high-skill jobs depends on the number of educated workers and on the profitability of high-skill firms whose job is filled. The higher the public expense to education, the higher the number of educated workers searching for a high-skill job. This increases high-skill job creation. However a rise in the tax t, used to finance education, reduces the profitability of high-skill jobs which lowers high-skill job creation. The impact of the tax on high-skill job creation is twofold. This phenomenon is observed only in sector 1 since the tax does not impact low-skill job creation.

The profitability of a firm also depends on the wages, w_i, paid to its unique employee. They are negotiated according to a Nash bargaining game where β is the worker's bargaining power and $(1-\beta)$ that of the firm. When a worker and a firm meet and agree to form a match, the private surplus S_i of this match is shared between the worker and the firm according to their respective bargaining power.

The asset value J_i also takes into account the average duration during which the job remains productive. This duration depends on the exogenous destruction rate s_i, and on the permanent exit rate of the worker from the labor market, m.

For a filled job, the asset values are given by the following Bellman equations:

$$rJ_1 = [(y_1 - y_2)(1-t) + y_2] - w_1 - (m + s_1)(J_1 - V_1) \tag{3}$$

$$rJ_2 = y_2 - w_2 - (m + s_2)(J_2 - V_2) \tag{4}$$

Job creation results from the usual assumption of free entry in each sector so that at steady-state $V_i = 0$. We deduce from equation (2):

$$J_i = \frac{c_i}{q_i} \tag{5}$$

Because of free-entry, we deduce, for sector 1, from equations (2) for $i = 1$, and (3):

$$(r + m + s_1)J_1 = [(y_1 - y_2)(1-t) + y_2] - w_1 \tag{6}$$

And for sector 2, we deduce from the equations (2) for $i = 2$, and (4):

$$(r + m + s_2)J_2 = y_2 - w_1 \tag{7}$$

On the workers' side, the asset value of an employee, W_i, and that of an unemployed worker, U_i are given by:

$$rW_i = w_i - s_i(W_i - U_i) - mW_i \tag{8}$$

$$rU_i = d + p_i(W_i - U_i) - mU_i = d + \beta p_i S_i - mU_i \tag{9}$$

where d is the value for non-market activities of an unemployed worker. From equations (8) and (9), the workers' surplus can be written as:

$$(r + m + s_i)(W_i - U_i) = w_i - d - \beta p_i S_i \tag{10}$$

In sector 1, equations (6) and (10), for $i = 1$, give the surplus of the match between an educated worker and a high-skill firm:

$$(r + m + s_1)(J_1 + W_1 - U_1) = (r + m + s_1)S_1 = (y_1 - y_2)(1 - t) + y_2 - d \tag{11}$$

Knowing that the firm has a share $(1 - \beta)$ of the match surplus, we have: $J_1 = (1 - \beta)S_1$. Combining equations (5), for $i = 1$, and (11) gives the equilibrium equation for job creation in sector 1:

$$\frac{c_1}{q_1} = (1 - \beta)\frac{(y_1 - y_2)(1 - t) + y_2 - d}{(r + m + s_1 + \beta p_1)} \tag{12}$$

Tightness θ_1 decreases with the tax t applied to the productivity gap between the two sectors.

In sector 2, equations (7) and (10) for $i = 2$ gives the surplus of the match between an educated worker and a high-skill firm:

$$(r + m + s_2)(J_2 + W_2 - U_2) = (r + m + s_2)S_2 = y_2 - d \tag{13}$$

Knowing that the firm has also a share $(1 - \beta)$ of the match surplus, we have: $J_2 = (1 - \beta)S_2$. Combining equations (5) for $i = 2$, and (13) gives the equilibrium equation for job creation in sector 2:

$$\frac{c_2}{q_2} = (1 - \beta)\frac{y_2 - d}{(r + m + s_2 + \beta p_2)} \tag{14}$$

This sector 2 equilibrium equation is standard (Pissarides (2000)).

2.4 Labor-force structure

We assume that each age group of workers present on the labor market benefits from the same governmental educational effort. The share of educated workers, α, is therefore homogeneous disregarding the years of experience of workers on the labor market. Let u_1 be the pool of educated unemployed workers, ℓ_1 educated workers employment, u_2 non-educated workers unemployment, and ℓ_2 non-educated workers employment.

In order to establish flows equilibrium of workers in each sector, we present transition frequencies for each possible state of the labor market: educated employees (respectively non-educated employees) who separated from there jobs, and educated (respectively non-educated) newcomers, join the pool of educated (respectively non-educated) unemployed workers; educated (respectively non-educated) workers quit unemployment when they find a high-skill (respectively low-skill) job, or when they definitely quit the labor market. In equilibrium, the number of newcomers equals the number of outgoing individuals for each state of the labor market. The flows equilibrium equations are thus:

$$s_1\ell_1 + \alpha m = (m + p_1)u_1 \tag{15}$$

$$s_2\ell_2 + (1 - \alpha)m = (m + p_2)u_2 \tag{16}$$

A share p_1 (respectively p_2) of unemployed workers finds a job at a given moment. This entry in employment is compensated by the exit of employees from the labor market, and by job separations. We therefore have:

$$p_1 u_1 = (m + s_1)\ell_1 \tag{17}$$

$$p_2 u_2 = (m + s_2)\ell_2 \tag{18}$$

In steady state, employment and unemployment levels are deduced from the flow-equilibrium conditions taking into account a labor-force normalized to 1.

$$u_1 = \frac{\alpha(m + s_1)}{(m + s_1 + p_1)} \tag{19}$$

$$\ell_1 = \frac{\alpha p_1}{(m + s_1 + p_1)} \tag{20}$$

$$u_2 = \frac{(1 - \alpha)(m + s_2)}{(m + s_2 + p_2)} \tag{21}$$

$$\ell_2 = \frac{(1 - \alpha)p_2}{(m + s_2 + p_2)} \tag{22}$$

In each sector a rise in the tightness reduces unemployment, thus favoring a rise in employment. A rise in the share of educated workers α mechanically leads to a shift of the labor-force toward the high-skill sector.

2.5 Steady-state equilibrium

The repartition of the labor-force gives the number of high-skill productive firms which are taxed in order to finance the public educational system. It therefore determines the share of young workers which will benefit from education. Combining equations (1) and (20) gives the budget constraint for education:

$$t(y_1 - y_2)p_1 = (m + s_1 + p_1)m\mu(\alpha) \tag{23}$$

The share of educated workers α is an increasing function in the tax t and in tightness θ_1.

Definition 1. *An equilibrium of the labor market is a set of variables $(\theta_1^*, \theta_2^*, \alpha^*)$ defined by equations (12), (14), and (23) as a function of t whose value is decided by the decision-maker. Other variables are deducted from the previous ones.*

Note that θ_2, determined by (14), is independent from t and from θ_1. Its value is not affected by a change in the educational policy. However the number of non-educated workers directly depends on such a policy.

Variables θ_1^* and α^* are recursively determined. Equation (12) gives the tightness of the high-skill sector as a function of t. The share of educated workers is then deduced from equation (23) which depends on θ_1^* and t.

3 Government targets and optimal taxation

The decision-maker can link its educational policy to different objectives. The objective that is the most put forward is that of an increase in the share of educated workers amongst young workers. This target corresponds in our work to a maximization in the share α. Such a target has to be justified as being a reasonable (or rational) public policy choice. To this aim we compare this target with two other public policies that could potentially be implemented by the decision-marker: the minimization of unemployment or the maximization of global employment; and the maximization of the social surplus.

3.1 Maximization of the share of educated workers

An increase in the the share of educated workers is the most basic objective in the sense that it is the most popular but also the less economically founded. As we will see in the empirical part of our work, this objective often refers to as quantitative targets fixed by decision-markers in public speeches. As for us, we determine a tax rate likely to maximize the share of educated workers for a specific financing scheme. We will then compare this tax rate with the highest tax rate possible (its upper-bound), and compare the deduced share of educated workers with government objectives.

The direct impact of the tax rate t, targeted on the productivity supplement of high-skill jobs, on the share of educated workers α is measured through the budget constraint of the educational system (equation (23)). The indirect impact goes through the tightness of the high-skill sector θ_1. The value of t which optimizes the share of educated workers is deduced from the following equation:

$$\frac{d\alpha}{dt} = 0 \Leftrightarrow \frac{\partial \alpha}{\partial t} + \frac{\partial \alpha}{\partial \theta_1}\frac{\partial \theta_1}{\partial t} = 0 \tag{24}$$

Terms $\frac{\partial \alpha}{\partial t}$ and $\frac{\partial \alpha}{\partial \theta_1}$ are given by differentiating equation (23). The term $\frac{\partial \theta_1}{\partial t}$ is determined via the equation for job creation in the high-skill sector (equation (12)):

$$\frac{\partial \alpha}{\partial t} = \frac{(y_1 - y_2)p_1}{(m + s_1 + p_1)m\mu'} > 0 \tag{25}$$

$$\frac{\partial \alpha}{\partial \theta_1} = \frac{(1-\eta_1)p_1[t(y_1 - y_2) - m\mu(\alpha)]}{\theta_1(m + s_1 + p_1)m\mu'} \tag{26}$$

From equation (23), one can show that around the equilibrium we have $p_1[t(y_1 - y_2) - m\mu(\alpha)] = (m + s_1)m\mu(\alpha)$. We thus have $\frac{\partial \alpha}{\partial \theta_1} > 0$.

$$\frac{\partial \theta_1}{\partial t} = \frac{-\theta_1(1-\beta)(y_1 - y_2)}{\theta_1(1-\eta_1)\beta c_1 + \eta_1(1-\beta)[(y_1 - y_2)(1-t) + y_2 - d]} < 0 \tag{27}$$

The rise of t has opposite impacts on the revenues obtained trough the tax. It therefore has opposite impacts on the share of educated workers α as well. On the one hand the rise of t increases the withdrawal on high-skill firms whose job is occupied. This leads to a rise in the financing possibilities of the educational system. On the other hand the rise

of t reduces the number of high-skill jobs since it reduces the profitability of high-skill firms. This leads to a reduction in the tax base and therefore in the tax revenues.

Combining equations (24), (25), (26), and (27), leads to the determination of the optimal tax equation, where t^*_α is the optimal tax level:

$$t^*_\alpha = \frac{(1-\beta)(1-\eta_1)m\mu(\alpha) + (1-\eta_1)c_1\beta\theta_1 + (1-\beta)\eta_1(y_1-d)}{(1-\beta)(y_1-y_2)} \tag{28}$$

The optimal tax level t^*_α is positive. The model makes sense so long as the net output of a high-skill job is higher than or equal to that of a low-skill job, that is to say so long as the level of the tax remains below or equal to 1. We study the value of the optimal tax level t^*_α by replacing two terms in equation (28). First, we consider that around the equilibrium c_1 is replaced by its equation in (12). Second, $\mu(\alpha)$ is replaced by its equation in (23). t^*_α can therefore be written as:

$$t^*_\alpha = \frac{(y_1-d)}{(y_1-y_2)} \times \frac{(m+s_1+p_1)[\beta p_1 + \eta_1(r+m+s_1)]}{(m+s_1+p_1)[\beta p_1 + \eta_1(r+m+s_1)] + (1-\eta_1)(m+s_1)(r+m+s_1+\beta p_1)} \tag{29}$$

We deduce from the previous equation that $t^*_\alpha < 1$ if and only if:

$$y_2 \leq \frac{y_1(1-\eta_1)(m+s_1)(r+m+s_1+\beta p_1) + d(m+s_1+p_1)[\beta p_1 + \eta_1(r+m+s_1)]}{(m+s_1+p_1)[\beta p_1 + \eta_1(r+m+s_1)] + (1-\eta_1)(m+s_1)(r+m+s_1+\beta p_1)}$$

If this condition on the relative values of y_1, y_2, and d is not fulfilled, the policy-marker will chose the maximum value possible for t under which the net output of a high-skill job equals that of a low-skill job, that is to say $\tilde{t}_\alpha = 1$.

3.2 Maximization of global employment

The second objective that the decision-marker could implement is the optimization of total employment. Let us note ℓ is sum of employment in the economy $(\ell_1 + \ell_2)$. One can write total employment ℓ as a function of α, θ_1, and θ_2 using equations (20) and (22):

$$\ell = \ell_1 + \ell_2 = \frac{\alpha p_1}{(m+s_1+p_1)} + \frac{(1-\alpha)p_2}{(m+s_2+p_2)} \tag{30}$$

The derivatives of the optimal tax rate t^*_ℓ that maximize global employment is given in Appendix A.1. We have:

$$t^*_\ell = t^*_\alpha - \frac{(1-\eta_1)(m+s_1)(m+s_2+p_2)m\varepsilon\mu(\alpha)}{(y_1-y_2)(p_1(m+s_2)-p_2(m+s_1))} \tag{31}$$

We can compare the two optimal levels of the tax t obtained by the maximization of the share of educated workers t^*_α and obtained by the maximization of the global employment level t^*_ℓ. The comparison depends on the relative value of transition rates to unemployment and employment in the two sectors:

- If $[p_1(m+s_2) - p_2(m+s_1)] > 0$, we have: $t^*_\ell < t^*_\alpha$. We can show that t^*_ℓ remains strictly positive (see Appendix A.1).

- If $[p_1(m+s_2) - p_2(m+s_1)] < 0$, we have $t^*_\ell > t^*_\alpha > 0$, keeping in mind that, as we mentioned previously, the tax rate cannot exceed 1.

None of the two cases can be theoretically ruled out. However we can decide on which case to keep by considering the empirical reality of the labor market: non-educated or less-skilled workers often occupy jobs which are less stable and more precarious than educated and skilled workers (inducing $s_2 > s_1$), moreover they face more difficulties to find a job (*i.e.* $p_2 < p_1$)). These observations lead us to think that $[p_1(m+s_2) - p_2(m+s_1)]$ should be positive. We can therefore think that the tax rate that maximizes the global employment level should be lower than the tax rate that maximizes the share of educated workers.

3.3 Maximization of the social surplus

Here the efficient educational public policy is that which is likely to maximize the social surplus of the economy. The social surplus is measured by the difference between the wealth of the economy (the global output plus the wealth associated with leisure), and the cost faced by the economy (high-skill and low-skill vacancy costs, and the cost of public education). We have:

$$\sigma = \ell_1 y_1 + \ell_2 y_2 + z(u_1 + u_2) - c_1 v_1 - c_2 v_2 - \alpha m \mu(\alpha) \tag{32}$$

where z is the value of leisure. This value of leisure constitutes a share of the value for non-market activities d used as the workers' treat point in wage bargaining. The difference between d and z corresponds to extended unemployment benefits. In order to concentrate on the funding of the educational system we implicitly assume that these benefits are financed by a neutral tax as in Holmlund (1998).

Taking into account flows equilibrium equations at steady-state (equations (19) to (22)), the social surplus is given by the following equation:

$$\begin{aligned} \sigma \;=\; & \frac{\alpha p_1 y_1}{(m+s_1+p_1)} + \frac{(1-\alpha) p_2 y_2}{(m+s_2+p_2)} + (z - c_1\theta_1)\frac{\alpha(m+s_1)}{(m+s_1+p_1)} \\ & + (z - c_2\theta_2)\frac{(1-\alpha)(m+s_2)}{(m+s_2+p_2)} - \alpha m \mu(\alpha) \end{aligned} \tag{33}$$

When taxing the increase of productivity associated with a high-skill job, the public decision-maker has to impose a tax rate equals to the following equation (see proof in Appendix A.2):

$$t^*_\sigma = t^*_\alpha - \frac{\theta_1 Z_1 (m+s_1+p_1) m \mu'}{p_1 Z_\alpha (y_1 - y_2)} \tag{34}$$

where

$$Z_\alpha \equiv \frac{p_1 y_1 + (m+s_1)(z - c_1\theta_1)}{(m+s_1+p_1)} - \frac{p_2 y_2 + (m+s_2)(z - c_2\theta_2)}{(m+s_2+p_2)} - m\mu(1+\varepsilon)$$

and

$$Z_1 \equiv \frac{\alpha(m+s_1)}{(m+s_1+p_1)^2}[(y_1-z)(1-\eta_1)q_1 - c_1(m+s_1+\eta_1 p_1)]$$

We show in Appendix A.2 that:

- If $Z_\alpha > 0$, then $t^*_\sigma < t^*_\alpha$.
- If $Z_\alpha < 0$, then $t^*_\sigma > t^*_\alpha$.

We cannot *a priori* know the sign of Z_α. Therefore we cannot know the relative value of t^*_α and t^*_σ, so we cannot compare the tax rates that maximize the employment level and the social surplus. However the targets studied in this section and the associated optimal tax rates can be calibrated. We therefore perform a calibration of our model using French evidences. This calibration enables us to determine the level at which the decision-maker should finance the public educational system depending on the favored target.

4 Calibration based on French evidences

Since the end of 1980s, education has always been at stake for the successive French governments. In the French political context, education has been considered qualitatively but also quantitatively, one of the main objectives being an increase in the share of education workers in the economy.

The first objective, 80% of an age group obtaining the high-school degree, was set by the 1989 orientation law for education. During the Chirac mandate, in 2005, the Senate added the objectives of 100% of young workers exiting the educational system with a well recognized diploma or qualification, and 50% of an age group with a higher education degree[4]. The European Lisbon strategy 2020 for education, dated 2009, specified that a European average of at least 40% of the 30-34 years old age group should have a higher education degree by 2020[5]. The Sarkozy government strengthen this criteria by wishing 50% by 2012[6]. This figure was not reached and the recent Holland government once again advocated the objective of 50% altogether with political measures aiming at improving the success of the "greatest number of students"[7].

Employment has also been a major issue for the successive French governments. An increase in the education level of age groups has always been considered as being positive for the labor market disregarding the induced potential negative impact of the public taxation scheme.

In this section we present a calibration of the model using empirical evidences for France. We consider the economic situation in 2011 as corresponding to the baseline

[4] http://www.senat.fr/rap/a04-239/a04-2391.pdf

[5] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2009:119:0002:0010:EN:PDF

[6] http://www.enseignementsup-recherche.gouv.fr/cid51080/objectif-50-de-diplomes-du-superieur-en-2012.html

[7] Law project dated July 9, 2013 studied at the National Assembly: http://www.assemblee-nationale.fr/14/ta/ta0180.asp

scenario where a level of public policy for education already exists. We then compare this scenario with the three different objectives that the government could consider.

4.1 Baseline calibration

We consider that the non-educated group (or low-educated) is constituted of individuals whose educational attainment is below or equal to the high-school diploma. The educated group is therefore composed of individuals with a higher education degree. The unemployment rates u_1 and u_2 are given by the number of educated unemployed workers and non-educated unemployed workers in the overall labor-force divided by the total labor-force. The figures are given by INSEE (Institut National de la Statistique et des Etudes Economiques) for 2011. Regarding the share of educated workers, we choose to consider the percentage of the overall population aged 30-34 who have successfully completed university or university-like (tertiary-level) education with an education level ISCED 1997 (International Standard Classification of Education) of 5-6 given by Eurostat. The share was 43.3% for 2011. With this figure, we can directly compare the results of our model with the French Lisbon strategy target of 50% of educated workers. Note that the share is a little lower in the overall population than in the labor-force since the less educated workers are those who are more likely not to participate in the labor market. Since our model does not display non-participation, assimilating the total population figure with that of the labor-force remains meaningful.

The monthly probability of leaving permanently the labor market (dying) is fixed at $m = 0.001749$ which represents about 41.5 years in the labor-force. This figure corresponds to the French duration of pension contribution. The rate is derived from Ljungqvist and Sargent (1998) where 42.7 years in the labor-force corresponds to a twice a month rate of 0.0009. The discount rate is fixed to an annual rate of 4% which represents a monthly rate of 0.33%. The job finding elasticity as well as the bargaining power are fixed standardly to 0.5.

We assume that the separation rates s_1 and s_2 correspond to the monthly transition rates from employment to unemployment, for educated and non-educated workers respectively. The INSEE gives the annual separation rates in 2011, that is to say the probability of becoming unemployed in 2011 while being employed in the previous year, by aggregated socio-professional categories. We approximate the educated workers' separation rate as being that of skilled workers and executive workers (0.00027431 annually), and non-educated workers' separation rate as being that of unskilled workers (0.00108362 annually). We then reconstruct monthly rates by considering the probability of not separating within a year, which is equal to 1 minus the annual separation probability.

The French economic literature gives some evidences regarding the wages in low-skill firms. Low-skill workers earn 44% less than the average (see Jauneau 2009). In 2011, the INSEE gives an average net wage of 2 130 current euros per month. These informations allows us to set a system of two equations with two unknowns: $2130 = 0.2w_2 + 0.8w_1$ and $w_2 = [1 - 0.44] \times [0.2w_2 + 0.8w_1]$, giving the values of wages in the two sectors.

Finally we distinguish between the value of non-market activities d, and the value

of leisure z. The first is obtained by considering the income perceived by unemployed workers, that is to say the amount of unemployment benefits, the amount of minimum income (named RSA socle), and the amount of social public allocations weighted by the number of recipients. These figures are given by multiple sources. The income and monthly rate of unemployment compensation for unemployed workers dated December 31, 2011, are given by Pole Emploi[8]. The number of RSA recipients at the same date, and the average amount of RSA and social allocations perceived are given by the CAF[9]. Regarding the second, since we do not have any European measure of the value of leisure, it is defined according to the US literature. According to Hall and Milgrom (2008), non-market activities represent a share 0.71 of the average productivity which includes unemployment benefits and the value for leisure. Shimer (2007) uses a rate of 0.4 including unemployment benefits only. We then deduce the value for leisure of the two previous sources by subtracting 0.4 from 0.71. This gives a share of productivity of 0.31 that we decide to align on the productivity of the low-skill sector.

Table 1 sums up the values fixed by empirical evidences and by the literature.

Table 1: Parameters and variables whose value is fixed

Name	Description	Value	Source
β	worker's bargaining power	0.5	Pissarides (2000)
η_1	elasticity high-skill sector	0.5	Pissarides (2000), Hosios (1990)
η_2	elasticity low-skill sector	0.5	Pissarides (2000), Hosios (1990)
m	permanent exit rate	0.001749	*see text*
r	monthly discount rate	0.0033	
d	non-market activities	1004	*see text*
α	share of educated workers	0.433	*see text*
u_1	educated unemployment	0.01745679	*see text*
u_2	non-educated unemployment	0.07454711	*see text*
w_1	wages in high-skill sector	2364.3	*see text*
w_2	wages in low-skill sector	1192.8	*see text*
s_1	educated separation rate	0.00117422	*see text*
s_2	non-educated separation rate	0.00470310	*see text*

Other variables and parameters are deduced using equations of the model. Equations (19) and (21) can then be used to retrieve the average monthly job finding rates p_1 and p_2. The tax rate imposed on high-skill firms in order to finance the educational system is

[8]DIRECTION ETUDES, STATISTIQUES ET PRÉVISIONS, Nadine Courty-Morelle, Département Gestion des Sources Statistiques sur le Marché du travail, 9 juillet 2012.

[9]l'e-essentiel, Publication électronique de la Caisse nationale des Allocations familiales, Direction des statistiques, des études et de la recherche, n°120-mars 2012, and Études sur le revenu de solidarité active (RSA), Evolutions et caractéristiques des bénéficiaires -Éléments sur leurs trajectoires - mise en place dans les caisses d'Allocations familial, Sophie Cazain - Pauline Domingo - Violaine Fernandez - Magali Le Tic - Isabelle Sigure, Octobre 2012, Dossier d'Etude n°156.

assimilated to the average French corporate tax on profits of 33%. Here profits come from the difference between the productivity and wages $(y_1 - w_1)$. We assume $t = \frac{1}{3}\frac{y_1 - w_1}{y_1 - y_2}$. With this equation in mind, outputs y_1 and y_2 are deduced by the equation defining the wages in the two sectors: $y_1 = \frac{3}{2}\frac{w_1(r+m+s_1+\beta p_1)-d\beta(r+m+s_1)}{(1-beta)(r+m+s_1+p_1)} - \frac{1}{2}w_1$ and $y_2 = \frac{w_2(r+m+s_2+\beta p_2)-\beta d(r+m+s_2)}{(1-\beta)(r+m+s_2+p_2)}$. The tax rate estimated in the baseline scenario is much lower than the French corporate tax rate since the difference between productivity and wages in sector 1 is much lower than the sectors' productivity gap $(y_1 - y_2)$.

Since we do not have any estimation for France, the cost of a vacancy is fixed in proportion of the output in each sector, using empirical findings from Hagedorn and Manovskii (2006) on US data. According to them the capital cost of a vacancy corresponds to 0.474 times the average productivity, and the labor cost of a vacancy equals 0.11 times the average productivity. All in all, the total cost of a vacancy therefore corresponds to a share 0.584 of the productivity in each sector. Private surpluses are derived from equations (11) and (13). The values for q_i are then retrieved from equilibrium equations (12) and (14). Sector tightness θ_i is obtained from its definition $\theta_i = p_i/q_i$. We assume the matching functions to be Cobb-Douglas with matching parameter M_i, so that $h_i = M_i v_i^{\eta_i} u_i^{1-\eta_i}$ is the matching function prevailing in each sector i. As a consequence, we have $M_i = \frac{p_i}{\theta_1^{(}1-\eta_1)}$. Employment levels are directly obtained via equations (20) and (22). Vacancy rates are deduced from $v_i = u_i\theta_i$. The value for μ is obtained from the budget constraint (23). We assume the elasticity of the average cost of education, denoted by ε, to be of the shape $\varepsilon = \alpha x$ where the parameter x is defined as $x = \frac{\log(\mu)}{\alpha}$. Finally the value for the social surplus σ is obtained from its equation.

Baseline values are given in the first column of Table 2. The high-skill employment level corresponds to about 41.5% of the labor-force while the low-skill employment level reaches 49.2%.

4.2 Policy results: optimal taxation, and Lisbon strategy

We now test the three different policies that the policy-maker could implement. This time, all parameters of the model are fixed and variables are defined according to equations of the model.

4.2.1 Share of educated workers

Let us start with the most politically popular measure, that is to say the maximization of the share of educated workers in an age group, that we assimilate to an increase in α. Results are presented in the second column of Table 2. In the framework of our model, the maximal value for the share of educated workers in the economy is about 56.3%. This share is much higher than the current level faced by the French economy (43.3% among 30-34 years old) and higher than the advocated Lisbon strategy policy of 50% of an age group. That being said, this optimization implies a tax rate higher than one (about 1.07) inducing a lower net output in the high-skill sector than in the low-skill sector. Such a

policy is therefore not feasible, the policy-maker would hence choose the maximum tax rate possible, that is to say $\tilde{t} = 1$ (see section 3.1). Results are given in the third column of Table 2. Notice that such a scenario cannot be considered as fully realistic since low-skill wages are higher than high-skill wages. It however constitute a limit to the public funding system which deserves to be investigated. For such a unitary tax rate the share of educated workers does not vary much, being still close to 56%. The unemployment rates vary notably: we observe an important rise of unemployment in the high-skill sector (from about 1.7% in the baseline scenario to about 6.1%) together with a smaller reduction in the low-skill sector (from 7.4% to 5.7%). The rise of unemployment, together with a resulting strong increase in the educational cost, lead to a reduction in the social surplus. The current characteristics of the French labor market are not in favor of the high share of educated workers (about 56%) obtained with this unitary-tax scenario. Actually the level of educated workers advocated by the French is of 50% only. Let us investigate the financing need, the employment level, and the social well-being corresponding to this last figure.

The European Lisbon strategy 2020 can be studied in our model framework. We fix a share of educated workers of $\alpha = 0.5$ and let the tax rate t adjusts to this value. Results are given in the last column of Table 2. Here wages remain much higher in the high-skill sector than in the low-skill sector. The unemployment level are much closer to the baseline scenario (respectively 2.2% and 6.6% in the high-skill and low-skill sector) associated with a much important tax rate of about 21%. Overall employment improves compared to the baseline scenario but social the well-being deteriorates. Next sections study employment and social well-being levels as priority targets for the government. We will then compare the share of educated workers obtained for each objective with that of the Lisbon strategy.

Table 2: Calibration: baseline and policy values 1

		Baseline	t^*_α	$\tilde{t}=1$	$\alpha=0.5$ (Lisbon Strategy)
y_1	High-skill output	2.531805E+3	2.531805E+3	2.531805E+3	2.531805E+3
w_1	High-skill wages	2.364300E+3	1.106317E+3	1.189606E+3	2.152447E+3
y_2	Low-skill output	1.227955E+3	1.227955E+3	1.227955E+3	1.227955E+3
w_2	Low-skill wages	1.192800E+3	1.192800E+3	1.192800E+3	1.192800E+3
d	non-market activities	1.004000E+3	1.004000E+3	1.004000E+3	1.004000E+3
β	bargaining power	0.50000000	0.50000000	0.50000000	0.50000000
c_1	Vacancy cost 1	1.478574E+3	1.478574E+3	1.478574E+3	1.478574E+3
c_2	Vacancy cost 2	7.171255E+2	7.171255E+2	7.171255E+2	7.171255E+2
r	discount factor	0.00330000	0.00330000	0.00330000	0.00330000
m	LF exit rate	0.00174900	0.00174900	0.00174900	0.00174900
Vac_1	Days of vacancy 1	3.493668E+2	-	-	-
Vac_2	Days of vacancy 2	1.357497E+2	-	-	-
η_1	Elasticity 1	0.50000000	0.50000000	0.50000000	0.50000000
η_2	Elasticity 2	0.50000000	0.50000000	0.50000000	0.50000000
p_1	Job finding rate 1	0.06958464	0.01704912	0.02389647	0.06369562
p_2	Job finding rate 2	0.04262212	0.04262216	0.04262216	0.04262216
θ_1	High-skill tightness	0.84448278	0.05069534	0.09959368	0.70759244
θ_2	Low-skill tightness	0.21425171	0.21425213	0.21425213	0.21425213
v_1	Vacancy rate 1	0.01474196	0.00417806	0.00610015	0.01552450
v_2	Vacancy rate 2	0.01597185	0.01230750	0.01233934	0.01408453
q_1	Worker find. rate 1	0.08239912	0.33630546	0.23993967	0.09001738
q_2	Worker find. rate 2	0.19893480	0.19893460	0.19893460	0.19893460
M_1	Matching tech. 1	0.07572128	0.07572128	0.07572128	0.07572128
M_2	Matching tech. 2	0.09208161	0.09208161	0.09208161	0.09208161
S_1	Surplus in sector 1	3.588810E+4	8.793042E+3	1.232455E+4	3.285086E+4
S_2	Surplus in sector 2	7.209654E+3	7.209661E+3	7.209661E+3	7.209661E+3
s_1	Separation rate 1	0.00117422	0.00117422	0.00117422	0.00117422
s_2	Separation rate 2	0.00470310	0.00470310	0.00470310	0.00470310
u_1	Unemployment 1	0.01745679	0.08241498	0.06125035	0.02193989
u_2	Unemployment 2	0.07454711	0.05744400	0.05759262	0.06573813
ℓ_1	Employment 1	0.41554321	0.48066960	0.50070382	0.47806011
ℓ_2	Employment 2	0.49245289	0.37947141	0.38045320	0.43426187
ℓ	Global employment	0.90799610	0.86014102	0.88115703	0.91232198
t	Tax rate	0.04282309	1.07230674	1.00000000	0.21255443
α	Educated share	0.43300000	0.56308459	0.56195417	0.50000000
σ	Social surplus	1.635354E+3	1.049134E+3	1.109392E+3	1.611441E+3
μ	cost of education	3.063685E+4	6.823856E+5	6.642290E+5	1.515027E+5
x	cost of educ. param.	23.85671801	23.85671801	23.85671801	23.85671801
spread3	-	1.303850E+3	-	-	-
ε	cost of educ. elast.	-	13.43335023	13.40638224	11.92835901
Z_1	-	-	-	-	-
Z_α	-	-	-	-	-

4.2.2 Global employment

The second column of Table 3 gives the results for the maximization of global employment. Such an objective leads to a share of educated workers of about 51%, corresponding of a

tax level of about 27%. This figure is surprisingly close to the Lisbon strategy scenario, giving some favorable defense to this French policy.

It is associated with a level of global employment of about 91.2% compared to about 90.8% at baseline. The level of high-skill unemployment is a little higher here (about 2.3%) than in the baseline calibration (about 1.7%), and the level of low-skill unemployment is a little lower (about 6.4% against about 7.4%). However, as it could have been anticipated from our previous results, such an additional investment in the educational system does not lead to a rise in the social surplus compared to its initial value.

4.2.3 Social surplus

The last policy considered is the optimization of the social surplus. Results are given in the last column of Table 3. The share of educated workers observed is about 3 percentage point higher than that at baseline (about 46.2% against 43.3%) for a tax rate that doubles (about 8.53% against 4.28%). Global employment is a little higher than at baseline (91% against 90.8%) but lower than for the employment maximization target (91% against 91.2%).

A rise in employment of about 0.2% (maximal rise possible of employment compared to the scenario that maximizes the social surplus) requires the tax rate and the average educational cost to be multiplied by three. This is the reason why, in the current scenario, the social well-being corresponds to to a share of educated workers much lower than what we would expect with the employment maximization objective.

Nevertheless the quality of jobs is affected by the share of educated workers reached by the investment in the educational system. With 51% of educated workers (corresponding to t_ℓ^*), more than 53% of jobs are highly productive. These jobs are less than 49% when α is 46% (corresponding to t_σ^*). With the first figure, benefits associated with the wealth increase does not compensate for the costs associated with the use of resources for the educational system founding. This assessment underlines the trade-off faced by the government in terms of educational choices.

Table 3: Calibration: baseline and policy values 2

		Baseline	t^*_ℓ	t^*_σ
y_1	High-skill output	2.531805E+3	2.531805E+3	2.531805E+3
w_1	High-skill wages	2.364300E+3	2.082127E+3	2.311190E+3
y_2	Low-skill output	1.227955E+3	1.227955E+3	1.227955E+3
w_2	Low-skill wages	1.192800E+3	1.192800E+3	1.192800E+3
d	non-market activities	1.004000E+3	1.004000E+3	1.004000E+3
β	bargaining power	0.50000000	0.50000000	0.50000000
c_1	Vacancy cost 1	1.478574E+3	1.478574E+3	1.478574E+3
c_2	Vacancy cost 2	7.171255E+2	7.171255E+2	7.171255E+2
r	discount factor	0.00330000	0.00330000	0.00330000
m	LF exit rate	0.00174900	0.00174900	0.00174900
η_1	Elasticity 1	0.50000000	0.50000000	0.50000000
η_2	Elasticity 2	0.50000000	0.50000000	0.50000000
p_1	Job finding rate 1	0.06958464	0.06162258	0.06815401
p_2	Job finding rate 2	0.04262212	0.04262216	0.04262216
θ_1	High-skill tightness	0.84448278	0.66228349	0.81011547
θ_2	Low-skill tightness	0.21425171	0.21425213	0.21425213
v_1	Vacancy rate 1	0.01474196	0.01529153	0.01538815
v_2	Vacancy rate 2	0.01597185	0.01380802	0.01515896
q_1	Worker find. rate 1	0.08239912	0.09304563	0.08412876
q_2	Worker find. rate 2	0.19893480	0.19893460	0.19893460
M_1	Matching tech. 1	0.07572128	0.07572128	0.07572128
M_2	Matching tech. 2	0.09208161	0.09208161	0.09208161
S_1	Surplus in sector 1	3.588810E+4	3.178170E+4	3.515026E+4
S_2	Surplus in sector 2	7.209654E+3	7.209661E+3	7.209661E+3
s_1	Separation rate 1	0.00117422	0.00117422	0.00117422
s_2	Separation rate 2	0.00470310	0.00470310	0.00470310
u_1	Unemployment 1	0.01745679	0.02308910	0.01899501
u_2	Unemployment 2	0.07454711	0.06444754	0.07075288
ℓ_1	Employment 1	0.41554321	0.48672700	0.44286305
ℓ_2	Employment 2	0.49245289	0.42573636	0.46738905
ℓ	Global employment	0.90799610	0.91246336	0.91025211
t	Tax rate	0.04282309	0.26903813	0.08531772
α	Educated share	0.43300000	0.50981610	0.46185807
σ	Social surplus	1.635354E+3	1.585157E+3	1.646451E+3
μ	cost of education	3.063685E+4	1.914801E+5	6.098710E+4
x	cost of educ. param.	23.85671801	23.85671801	23.85671801
ε	cost of educ. elast.	-	12.16253894	11.01841763
Z_1	-	-	-	9.56168158
Z_α	-	-	-	15.75363768

From the social surplus point of view, the education target advocated by the French government, that should be achieved by 2020 according to the Lisbon strategy, seems excessive. We can nevertheless postulate that when fixing this objective, the government takes into account the possible evolution of the characteristics of the French labor market. Let us consider a possible positive evolution of the skill-bias between high-skill and low-skill workers. Appendix A.3 presents the calibration results of each targets (maximization

of the share of educated workers, of employment, of the social surplus, and the Lisbon strategy) when taking into account a rise of 10% in the skill-bias.

We observe an increase in the share of educated workers in the economy with both the employment maximization target and the social well-being target. However this increase is very limited. More particularly the social well-being target justifies a share of educated workers of about 46.5% which is much lower than the 50% advocated by the French public decision-maker. However if employment is the priority target, then the Lisbon strategy choice is fully justified. The French objective of 50% of educated workers would coincide with the social well-being target only for substantial change in the French economy that would potentially reached far later than 2020.

5 Conclusion

In France the tertiary educational system is largely financed by public subsidies. During the past years, and in spite of the economic and financial crisis, funding for tertiary education has not been reduced whereas other civil services faced a strong reduction in their endowments. Such a stable financing of the higher educational system is explained by the government desire to increase the share of educated workers so that newcomers on the labor market would be more adapted to firms needs. They would thus integrate more easily the labor market. Our results show that the government target almost coincides with an employment optimization objective but induced educational costs may lower the social well-being.

These results lies on a specific founding scheme of the educational system where subsidies to education are financed by a tax implemented only in firms benefiting from education, *i.e.* high-skill firms, and levied on the productivity gap between high-skill and low-skill jobs. It is however worth comparing possible objectives for different European economies In such a framework, in such a framework. This extension is the purpose of further research.

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A Appendix

A.1 Derivation of t^*_ℓ

The evolution of global employment following a change in the tax rate t, defined by equation (30), takes into account the impact of the tax rate on the high-skill sector tightness θ_1, and on the share of educated workers α:

$$\frac{d\ell}{dt} = \frac{\partial \ell}{\partial t} + \frac{\partial \ell}{\partial \alpha}\frac{d\alpha}{dt} + \frac{\partial \ell}{\partial \theta_1}\frac{\partial \theta_1}{\partial t} = 0$$

Direct impacts on ℓ of a change in t, α, and θ_1 are:

$$\begin{aligned}
\frac{\partial \ell}{\partial t} &= 0 \\
\frac{\partial \ell}{\partial \alpha} &= \frac{p_1}{(m+s_1+p_1)} - \frac{p_2}{(m+s_2+p_2)} \\
\frac{\partial \ell}{\partial \theta_1} &= \frac{\alpha(m+s_1)p_1'}{(m+s_1+p_1)^2} = \frac{\alpha(m+s_1)(1-\eta_1)p_1}{\theta_1(m+s_1+p_1)^2}
\end{aligned}$$

Combining those results with global impacts of t on α and θ_1 gives:

$$\begin{aligned}
\frac{d\alpha}{dt} &= \frac{p_1(y_1-y_2)[\theta_1(1-\eta_1)\beta c_1 + \eta_1(1-\beta)[(y_1-y_2)(1-t)+y_2-d]]}{(m+s_1+p_1)m\mu'[\theta_1(1-\eta_1)\beta c_1 + \eta_1(1-\beta)[(y_1-y_2)(1-t)+y_2-d]]} \\
&\quad - \frac{p_1(y_1-y_2)(1-\eta_1)(1-\beta)(t(y_1-y_2)-m\mu(\alpha))}{(m+s_1+p_1)m\mu'[\theta_1(1-\eta_1)\beta c_1 + \eta_1(1-\beta)[(y_1-y_2)(1-t)+y_2-d]]} \\
\frac{\partial \theta_1}{\partial t} &= \frac{-\theta_1(1-\beta)(y_1-y_2)}{\theta_1(1-\eta_1)\beta c_1 + \eta_1(1-\beta)[(y_1-y_2)(1-t)+y_2-d]}
\end{aligned}$$

We have:

$$\frac{d\ell}{dt} = \frac{p_1(y_1-y_2)\times\psi}{(m+s_1+p_1)^2(m+s_2+p_2)m\mu'\big[\theta_1(1-\eta_1)\beta c_1 + \eta_1(1-\beta)[(y_1-y_2)(1-t)+y_2-d]\big]}$$

where

$$\begin{aligned}
\psi &= [p_1(m+s_2)-p_2(m+s_1)]\big[\theta_1(1-\eta_1)\beta c_1 + \eta_1(1-\beta)[(y_1-y_2)(1-t)+y_2-d]\big] \\
&\quad -[p_1(m+s_2)-p_2(m+s_1)](1-\eta_1)(1-\beta)(t(y_1-y_2)-m\mu(\alpha)) \\
&\quad -(m+s_1)(1-\eta_1)(1-\beta)(m+s_2+p_2)m\alpha\mu'
\end{aligned}$$

The value of t^*_ℓ is obtained by equalizing ψ to zero. We have:

$$\begin{aligned}
t^*_\ell &= \frac{(1-\beta)(1-\eta_1)m\mu(\alpha) + (1-\eta_1)c_1\beta\theta_1 + (1-\beta)\eta_1(y_1-d)}{(1-\beta)(y_1-y_2)} \\
&\quad - \frac{(1-\eta_1)(m+s_1)(m+s_2+p_2)m\varepsilon\mu(\alpha)}{(y_1-y_2)(p_1(m+s_2)-p_2(m+s_1))}
\end{aligned}$$

That is to say:

$$t_\ell^* = t_\alpha^* - \frac{(1-\eta_1)(m+s_1)(m+s_2+p_2)m\varepsilon\mu(\alpha)}{(y_1-y_2)(p_1(m+s_2)-p_2(m+s_1))}$$

When the second term is negative, *i.e.* when $(p_1(m+s_2)-p_2(m+s_1))>0$, the sign of t_ℓ^* is indeterminate. The uncertainty can be removed by replacing $m\mu(\alpha)$, in the second term of the previous equation, by its value obtained from equation (23). We have:

$$\begin{aligned} t_\ell &= \frac{(1-\beta)(1-\eta_1)m\mu(\alpha)+(1-\eta_1)c_1\beta\theta_1+(1-\beta)\eta_1(y_1-d)}{(1-\beta)(y_1-y_2)} \\ &\quad -\frac{(1-\eta_1)(m+s_1)(m+s_2+p_2)\varepsilon t_\ell p_1}{(m+s_1+p_1)(p_1(m+s_2)-p_2(m+s_1))} \end{aligned}$$

For simplification purpose, the previous equation can be written under the following generic form:

$$t_\ell = \frac{X_1}{X_2} - \frac{X_3}{X_4}t_\ell$$

where the terms corresponding to X_1, X_2, and X_3 are always positive, whereas the term X_4 has the sign of $[p_1(m+s_2)-p_2(m+s_1)]$. We can thus write t_ℓ^* as follows:

$$t_\ell^* = \frac{X_1}{X_2}\frac{X_4}{(X_3+X_4)}$$

If $[p_1(m+s_2)-p_2(m+s_1)]$ and X_4 have positive values, then t_ℓ^* is below $t_\alpha^* = \frac{X_1}{X_2}$, but remains positive.

A.2 Derivation of t_σ^*

The evolution of the social surplus (equation (33)) following a change in the tax rate t, takes into account two indirect effects: the effect of the tax rate on tightness θ_1, and on the share of educated workers α:

$$\frac{d\sigma}{dt} = 0 \Leftrightarrow \frac{\partial\sigma}{\partial t} + \frac{\partial\sigma}{\partial\alpha}\frac{d\alpha}{dt} + \frac{\partial\sigma}{\partial\theta_1}\frac{\partial\theta_1}{\partial t} = 0$$

The direct impact on σ of a change in t is equal to zero:

$$\frac{\partial\sigma}{\partial t} = 0$$

The impacts of a variation of α and θ_1 on σ are given by:

$$\frac{\partial\sigma}{\partial\alpha} = \frac{p_1y_1+(m+s_1)(z-c_1\theta_1)}{(m+s_1+p_1)} - \frac{p_2y_2+(m+s_2)(z-c_2\theta_2)}{(m+s_2+p_2)} - m\mu(1+\varepsilon)$$

$$\frac{\partial\sigma}{\partial\theta_1} = \frac{\alpha(m+s_1)}{(m+s_1+p_1)^2}[(y_1-z)(1-\eta_1)q_1 - c_1(m+s_1+\eta_1p_1)]$$

In order to lighten the mathematical writing we now use the variables Z_α and Z_1 for respectively the terms $\frac{\partial\sigma}{\partial\alpha}$ and $\frac{\partial\sigma}{\partial\theta_1}$. Notice that these two terms do not depend on t. We have:

$$Z_\alpha \equiv \frac{p_1y_1+(m+s_1)(z-c_1\theta_1)}{(m+s_1+p_1)} - \frac{p_2y_2+(m+s_2)(z-c_2\theta_2)}{(m+s_2+p_2)} - m\mu(1+\varepsilon)$$

$$Z_1 \equiv \frac{\alpha(m+s_1)}{(m+s_1+p_1)^2}[(y_1-z)(1-\eta_1)q_1 - c_1(m+s_1+\eta_1 p_1)]$$

The optimal tax rate t_σ^* can therefore be deduced from the following equation:

$$Z_\alpha \frac{d\alpha}{dt} + Z_1 \frac{\partial \theta_1}{\partial t} = 0$$

Replacing $\frac{d\alpha}{dt}$ and $\frac{\partial \theta_1}{\partial t}$ by their equation (given in Appendix A.2), we can rewrite the previous equation as follows:

$$\begin{aligned} Z_\alpha p_1(y_1-y_2) \quad & \left[\frac{\theta_1(1-\eta_1)\beta c_1 + \eta_1(1-\beta)[(y_1-y_2)(1-t)+y_2-d]}{(m+s_1+p_1)m\mu'[\theta_1(1-\eta_1)\beta c_1 + \eta_1(1-\beta)[(y_1-y_2)(1-t)+y_2-d]]}\right. \\ & \left. -\frac{(1-\eta_1)(1-\beta)(t(y_1-y_2)-m\mu(\alpha))}{(m+s_1+p_1)m\mu'[\theta_1(1-\eta_1)\beta c_1 + \eta_1(1-\beta)[(y_1-y_2)(1-t)+y_2-d]]}\right] \\ -Z_1 \quad & \frac{\theta_1(1-\beta)(y_1-y_2)}{\theta_1(1-\eta_1)\beta c_1 + \eta_1(1-\beta)[(y_1-y_2)(1-t)+y_2-d]} = 0 \end{aligned}$$

After simplification we deduce:

$$\begin{aligned} & p_1(y_1-y_2)Z_\alpha\big[\theta_1(1-\eta_1)\beta c_1 + \eta_1(1-\beta)(y_1-d) + (1-\eta_1)(1-\beta)m\mu(\alpha)\big] \\ & -\theta_1(1-\beta)(y_1-y_2)Z_1(m+s_1+p_1)m\mu' = p_1(y_1-y_2)Z_\alpha t(1-\beta)(y_1-y_2) \end{aligned}$$

Finally we have:

$$\begin{aligned} t_\sigma^* = \quad & \frac{(1-\beta)(1-\eta_1)m\mu(\alpha) + (1-\eta_1)c_1\beta\theta_1 + (1-\beta)\eta_1(y_1-d)}{(1-\beta)(y_1-y_2)} \\ & -\frac{\theta_1 Z_1(m+s_1+p_1)m\mu'}{p_1 Z_\alpha(y_1-y_2)} \end{aligned}$$

We can show by replacing c_1 by its equation deduced from (12) that, around the equilibrium (under the Hosios condition $\beta = \eta_1$), Z_1 is always positive. The sign of Z_α remains however indeterminate.

A.3 Skill-bias calibration results

Table 4: Calibration: skill-bias of 10% of $(y_1 - y_2)$ over y_1

	Baseline Skill-bias	t^*_α	$\tilde{t} = 1$	$\alpha = 0.5$	t^*_ℓ	t^*_σ
y_1	2.662190E+3	2.662190E+3	2.662190E+3	2.662190E+3	2.662190E+3	2.662190E+3
w_1	2.364300E+3	1.112286E+3	1.189606E+3	2.277786E+3	2.164684E+3	2.426727E+3
y_2	1.227955E+3	1.227955E+3	1.227955E+3	1.227955E+3	1.227955E+3	1.227955E+3
w_2	1.192800E+3	1.192800E+3	1.192800E+3	1.192800E+3	1.192800E+3	1.192800E+3
d	1.004000E+3	1.004000E+3	1.004000E+3	1.004000E+3	1.004000E+3	1.004000E+3
β	0.50000000	0.50000000	0.50000000	0.50000000	0.50000000	0.50000000
c_1	1.478574E+3	1.478574E+3	1.478574E+3	1.478574E+3	1.478574E+3	1.478574E+3
c_2	7.171255E+2	7.171255E+2	7.171255E+2	7.171255E+2	7.171255E+2	7.171255E+2
r	0.00330000	0.00330000	0.00330000	0.00330000	0.00330000	0.00330000
m	0.00174900	0.00174900	0.00174900	0.00174900	0.00174900	0.00174900
η_1	0.50000000	0.50000000	0.50000000	0.50000000	0.50000000	0.50000000
η_2	0.50000000	0.50000000	0.50000000	0.50000000	0.50000000	0.50000000
p_1	0.06958464	0.01761524	0.02389647	0.06723932	0.06404984	0.07123101
p_2	0.04262212	0.04262216	0.04262216	0.04262216	0.04262216	0.04262216
θ_1	0.84448278	0.05411794	0.09959368	0.78851636	0.71548446	0.88491661
θ_2	0.21425171	0.21425213	0.21425213	0.21425213	0.21425213	0.21425213
v_1	0.01474196	0.00436604	0.00614352	0.01642619	0.01607789	0.01623890
v_2	0.01597185	0.01220198	0.01222680	0.01408453	0.01366667	0.01505609
q_1	0.08239912	0.32549724	0.23993967	0.08527321	0.08951954	0.08049461
q_2	0.19893480	0.19893460	0.19893460	0.19893460	0.19893460	0.19893460
M_1	0.07572128	0.07572128	0.07572128	0.07572128	0.07572128	0.07572128
M_2	0.09208161	0.09208161	0.09208161	0.09208161	0.09208161	0.09208161
S_1	3.588810E+4	9.085017E+3	1.232455E+4	3.467851E+4	3.303355E+4	3.673722E+4
S_2	7.209654E+3	7.209661E+3	7.209661E+3	7.209661E+3	7.209661E+3	7.209661E+3
s_1	0.00117422	0.00117422	0.00117422	0.00117422	0.00117422	0.00117422
s_2	0.00470310	0.00470310	0.00470310	0.00470310	0.00470310	0.00470310
u_1	0.01745679	0.08067646	0.06168580	0.02083177	0.02247133	0.01835077
u_2	0.07454711	0.05695149	0.05706736	0.06573813	0.06378778	0.07027278
ℓ_1	0.41554321	0.48615409	0.50426348	0.47916823	0.49236287	0.44715895
ℓ_2	0.49245289	0.37621795	0.37698336	0.43426187	0.42137802	0.46421750
ℓ	0.90799610	0.86237204	0.88124684	0.91343010	0.91374089	0.91137645
t	0.04282309	1.06093810	1.00000000	0.19278444	0.27521170	0.08447117
α	0.43300000	0.56683055	0.56594928	0.50000000	0.51483420	0.46550972
σ	1.692703E+3	1.053649E+3	1.109485E+3	1.674968E+3	1.633115E+3	1.705215E+3
μ	3.063685E+4	7.461759E+5	7.306519E+5	1.515027E+5	2.158317E+5	6.653838E+4
x	23.85671801	23.85671801	23.85671801	23.85671801	23.85671801	23.85671801
ε	-	13.52271670	13.50169242	11.92835901	12.28225439	11.10553415
Z_1	-	-	-	-	-	8.62247082
Z_α	-	-	-	-	-	15.52679106

Table 5: Impact of skill-bias. variation in percentage

-	-	Baseline Skill-bias	t^*_α	$\tilde{t}=1$	$\alpha=0.5$	t^*_ℓ	t^*_σ
y_1	High-skill output	5.15	5.15	5.15	5.15	5.15	5.15
w_1	High-skill wages	-	0.54	-	5.82	3.97	5.00
p_1	Job finding rate 1	-	3.32	-	5.56	3.94	4.51
θ_1	High-skill tightness	-	6.75	-	11.44	8.03	9.23
v_1	Vacancy rate 1	-	4.50	0.71	5.81	5.14	5.53
v_2	Vacancy rate 2	-	-0.86	-0.91	-	-1.02	-0.68
q_1	Worker find. rate 1	-	-3.21	-	-5.27	-3.79	-4.32
S_1	Surplus in sector 1	-	3.32	-	5.56	3.94	4.51
u_1	Unemployment 1	-	-2.11	0.71	-5.05	-2.68	-3.39
u_2	Unemployment 2	-	-0.86	-0.91	-	-1.02	-0.68
ℓ_1	Employment 1	-	1.14	0.71	0.23	1.16	0.97
ℓ_2	Employment 2	-	-0.86	-0.91	-	-1.02	-0.68
ℓ	Global employment	-	0.26	0.01	0.12	0.14	0.12
t	Tax rate	-	-1.06		-9.30	2.29	-0.99
α	Educated share	-	0.67	0.71	-	0.98	0.79
σ	Social surplus	-	0.43	0.01	3.94	3.03	3.57
μ	cost of education	-	9.35	10.00	-	12.72	9.10
ϵ	cost of educ. elast.	-	0.67	0.71	-	0.98	0.79
Z_1	-	-	-	-	-	-	-9.82
Z_α	-	-	-	-	-	-	-1.44