A numerical approach to fiscal policy, unemployment, and growth in Europe*

by

Francesco Daveri and Marco Maffezzoli

Università di Parma and IGIER
daveri@unipr.it

Università "L. Bocconi"
marco.maffezzoli@uni-bocconi.it

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Abstract

We calibrate an infinite-horizon model with endogenous growth and unemployment on actual data from the largest countries in the European Union. Two types of balanced-budget fiscal policy experiments are studied. First, the effects of separately changing the tax rates on capital, labor and subsidies, as well as the replacement rates, are analyzed, assuming offsetting changes in lump-sum transfers. Second, we rule out offsetting transfers and study how effective is the cut in labor taxes when financed either raising capital taxation or reducing unemployment subsidies. We find two main results: *(i)* with lump-sum transfers, reducing labor taxes and unemployment subsidies is beneficial to both employment and growth, while cutting capital taxes is less beneficial; *(ii)* without transfers, cutting labor taxes is more effective when financed by a (modest) cut in unemployment subsidies rather than by a (sizable) increase in capital taxes. Sensitivity analysis shows that our results are robust to changes in a vast range of parameter values.

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1 Introduction

In Europe, growth has slowed down and unemployment risen substantially since the mid seventies. **Figure 1** documents that average per-worker GDP growth in the EU-15 was close to some 4.4% in the sixties, and then, gradually but steadily, declined to 2.7% in the seventies, 2.3% in the eighties and 1.5% in the nineties. In parallel, the average unemployment rate increased from 2.5% in the sixties, to 3.7% in the seventies, to 8.2% in the eighties and 9.8% in the nineties. These trends obtain irrespectively of how growth and unemployment are measured. The rise in unemployment and the growth slowdown were relatively more pronounced in Europe than in the US.

What accounts for these long-run phenomena? As first suggested by Phelps (1968), growth and unemployment may just be unrelated in the long-run. The continued growth slowdown in Europe may be a manifestation of the long-lasting transitional dynamics adjustment to the capital stock destruction brought about by WWII. The rise in European unemployment may, instead, be the outcome of a malfunctioning of labor markets in the first instance unrelated to the dynamic forces driving the process of growth.

Yet the visual correlations in **Figure 1** are puzzling, and may suggest possible alternative explanations. Here, to address this puzzle, we calibrate an infinite-horizon endogenous growth model with equilibrium unemployment. Growth is the result of unintended learning-by-doing and unemployment is caused by monopoly union bargaining in the labor market.[1] In this framework, any permanent increase in the equilibrium unemployment rate feeds into a permanently lower growth rate. Thus, the long-run trends of growth and unemployment may be related, and possibly driven by (at least) one common cause.

Daveri and Tabellini (2000) identify one exogenous shock hitting more severely Europe than the US, *i.e.* the rise in the taxation of labor.[2] **Figure 2** shows that, in the last thirty years, labor taxes - already higher in the sixties - grew more in Europe than in the US (by 15 and 7 points, respectively). Moreover, data on union coverage rates - so much higher in the EU than in other OECD countries in **Table 1** - suggest that equal tax hikes are more likely to be shifted forward

[1] Gali (1996) develops on similar lines a dynamic non-Walrasian framework - comprehensive enough to accommodate various labor-market structures - to justify involuntary unemployment in general equilibrium..

[2] The vast literature on the causes of unemployment in Europe has provided a long list of exogenous shocks in principle all harmful to employment. As emphasized by Ljungqvist and Sargent (1998), the rise of European unemployment was also associated to the expansion of welfare spending, and of unemployment subsidies in particular. Nickell and Layard (1999) report that unemployment is to attribute to the rise in the overall burden of taxation. A recollection of the main results in this strand of literature is in Blanchard (1999).

onto higher labor costs and lower employment in Europe than elsewhere among the Industrial countries (the US, in particular).[3]

In our model, the reduction of employment is associated to diminished growth through learning by-doing effects, such as those emphasized in Lucas (1993). Hence, to account for the correlations in **Figure 1** we emphasizing the link between labor taxes, unemployment and growth. This relation is supposed to hold in Europe, and not in the US, where labor markets are more competitive.

We have a more ambitious goal, however. Even taking for granted its adverse effect, reducing the tax burden on labor does not necessarily deliver employment and growth gains. A crucial aspect in determining the effect of a cut on labor taxes is how this cut is financed.

To analyze these issues, in the second part of the paper, the model is calibrated on actual data from a variety of countries in Europe, which - based on data in **Table 1** - we identify as the closest to our toy model. The numerical model is then used, first to investigate how quantitatively large are the effects of changes in labor and capital taxes, and in the unemployment subsidies, on steady state employment and growth rates. Then, two types of balanced-budget experiments are run. In the first set of experiments, changes in tax and subsidy rates are separately studied, while assuming offsetting changes in lump-sum transfers. In the second set of experiments, we concentrate on the policy questions currently discussed in Europe, namely whether a reduction in labor taxes should be financed through an increase in capital taxes or by cutting spending. In our framework, this implies ruling out offsetting changes in transfers and concentrate on the effects of two, rather than one, policy changes at a time.

The thrust of our numerical results is that the effectiveness of reducing labor taxes for employment creation and growth crucially depends on how this reduction is financed.

Suppose that offsetting transfers are feasible. Then, for each percentage point decrease in the labor tax rate, the employment rate rises by some 0.5 percentage points in Germany and Italy, 0.3 points in Belgium, Spain, and Sweden, and a bare 0.2 in France, the Netherlands, and Finland. Taken at face value, these figures are large. They would attribute a large fraction of the rise in European unemployment to the labor tax increase. Moreover, a one percentage point increase in the taxes on labor would also feed into a growth slowdown ranging between 0.03 and 0.07 percentage points (0.04 on average). At first sight, this might look a rather small figure, but in fact it is not. If multiplied by the actual labor tax increase of some 15 points, this translates into a permanent fall in the yearly growth rate of some 0.45-1.05 percentage points depending on the country. This slowdown cannot be easily dismissed as irrelevant, in the face of an average fall in

[3] The layman's view holds that high labor taxes feed into high labor costs, thus generating low employment. However, if the elasticity of individual labor supply is very low, the burden of a tax on labor income would be almost entirely borne by the workers, with little effect on employment. For taxes to affect employment, then, two conditions have to be met: (i) the wage setting function must be non-vertical; (ii) the tax on labor has to dive a wedge between the utility of being employed and the one of being unemployed. If workers organize themselves into unions, and if the workers' outside option does enjoy a more favorable fiscal treatment than wages, these conditions are met.

the EU growth rate of some 2.8 points. These results are overall consistent, though of a somewhat smaller size, with the econometric findings by Daveri and Tabellini (2000) - in turn, an upper bound among the empirical studies on the relation between labor taxes, unemployment and growth. Furthermore, we also find a strong effect of unemployment subsidies on employment and growth - in most cases even stronger than labor taxes. Finally, capital taxes markedly affect both employment and growth in Scandinavian countries only.

Now suppose, instead, as implied by the Stability Pact, that offsetting transfers are not feasible. Then, the government is left with just two instruments of financing the revenue loss induced by the labor tax cut: raising capital taxes or cutting unemployment subsidies. Our numerical findings suggest that the gains from cutting subsidies over raising taxes are substantial. A EU-wide subsidy decrease of less than one percentage point would suffice to finance a EU-wide one percent reduction in the labor tax rate, while the rise in the capital tax rate would be of 2.7 points. Moreover, employment and growth would rise in the former case, while they would fall or remain roughly unchanged in the latter.

Our results also relate to the debate on the growth effects of taxes (see, *e.g.*, Rebelo, 1991, Stokey and Rebelo, 1995, and others, including Hendricks, 1999). In line with the mentioned previous studies, we find that capital taxes have a relatively limited effect on growth. A EU-wide one percentage point decrease in the tax rate on capital causes a 0.02 points increase in the long-run growth rate, while the same decrease in the tax rate on labor generates a 0.05 points increase. But this does not imply *per se* that taxes and growth are unrelated. According to our results, the one tax instrument mainly affecting long-run growth is the tax rate on labor - in practice, a tax on human capital accumulation - not that on (physical) capital.

The structure of the paper is as follows: Section 2 presents the set-up of the model, Section 3 describes the calibration procedure, and Section 4 presents our results. Concluding remarks are in Section 5.

2 The model

To study the effect of fiscal policy on employment and growth in Europe, we construct prototype economies mimicking the key features of EU countries in the simplest possible way. The crucial role of unions in the process of wage determination in Europe is captured by introducing monopoly union bargaining - an imperfection in the labor market.

2.1 Basic setup and assumptions

The economy is populated by many identical infinitely-lived households. Households organize themselves into unions. Firms are all alike as well.

2.1.1 *Firms and technology*

Firms are price-takers and produce a homogeneous consumption good using a constant returns to scale technology and can thus be aggregated into a single representative firm, which buys factor services from the owners of physical capital and labor endowments, *i.e.* the households.
The production technology can be summarized by the following CES production function:

$$Y_t = A\left[\alpha K_t^{\eta} + \varphi(n_t E_t)^{\eta}\right]^{\frac{1}{\eta}} \tag{1}$$

where $\eta < 1$, $\alpha > 0$, and $\varphi > 0$; in our notation, Y_t represents the aggregate per-capita output level, K_t the aggregate per-capita stock of physical capital, n_t the employment rate (the ratio between the number of employed households and the number of employable ones - empirically measured as the total population in working age), E_t the aggregate per-capita stock of "learning" - or human - capital, interpreted here as an economy-wide externality, and A a scale parameter. The factor $n_t E_t$ can be interpreted as the amount of labor in efficiency units employed in production. The elasticity of substitution between physical capital and efficient labor is $\xi = 1/(1-\eta)$; unlike the Cobb-Douglas, the CES functional form does not imply a unit-elasticity of substitution between capital and labor. As shown below, this opens the route for *both* capital *and* labor taxes to affect the growth rate, although human capital accumulation is the only growth engine in our economy.

2.1.2 *Unions*

Households find it convenient to organize themselves into unions. The reason is that they confront an asymmetry when supplying labor and capital. The individual supply of capital services is perfectly divisible. The services of physical capital can be sold at the given rental rate in arbitrarily small lots to a large number of firms through a competitive financial market. A competitive and efficient financial market is effectively a "veil" between households and firms.
Individual labor supply is, instead, indivisible. If employed, each household member works only for a fixed number of hours, selling her unit labor endowment to only one firm at a time.
By clearly identifying her job-provider as well as those working with her, any household member perceives the scope for extracting some producer's surplus by forming a firm/sector-specific monopoly union, while remaining price-takers in the market for capital services.[4] In other words, households do not internalize that unions simply increase the labor share in their incomes at the

[4] We do not model explicitly the process of union formation. Within a two-person one-firm game-theoretical framework, Horn and Wolinsky (1988) formally proved that highly substitutable workers have an incentive to form a union when contracting over their wage, while complementary workers don't. In a recent paper, Westermarck (1999) extends the Horn-Wolinsky result to a more general setting, where an arbitrary number of workers and a sequential bargaining structure are allowed. Our assumption of identical households amounts to assuming perfect substitutability among workers.

expenses of the capital share, while decreasing the overall income level relatively to the Pareto-efficient allocation.

By assuming that workers are firm/sector-specific, we actually require that a one to one relation exist between firms and unions, so that each firm is allowed to buy the labor services from one and only one union. This is important for the argument to follow: unions must be small at the level of the entire economy, and take the rental rate as given as households and firms do.

What goals are pursued by each union? In the standard monopoly union model,[5] the union unilaterally sets the wage in order to maximize the average income of its members:

$$n_t W_t (1-\tau^N) + (1-n_t) S_t (1-\tau^S) \tag{2}$$

where n_t is the employment rate, S_t represents the per-capita unemployment subsidy, τ^N the average tax rate on labor income, and τ^S the average tax rate on subsidies. The firm is instead granted the right of setting employment at the preset wage level.[6] This drives up the monopoly wage rate to a level higher than in the competitive model, with the well-known unemployment and deadweight loss consequences.

Following Anderson and Devereux (1988), we extend the standard setting by including the firm's decision as to the demand for physical capital services, under the assumption that neither unions nor firms can credibly commit, respectively, to a sequence of future wage rates and demands for capital services.

As a result of the bargaining process, some members of the union remain unemployed. If employed, a household member supplies her unit of labor and is remunerated at the monopoly wage rate. If unemployed, she receives no wage, but cashes an unemployment subsidy from the government. What prevents wage underbidding on the part of the unemployed? Although being employed or unemployed may be unknown *ex-ante*, the unemployed may well feel uneasy *ex-post* with the bargaining outcome and leave the union. To prevent this outcome, we require the unions

[5] The "monopoly union" model was originally introduced by Dunlop (1944) and Oswald (1982). The monopoly union model is a special case of the so-called "right to manage" model, introduced by Nickell (1982), where both the firm and the union bargain upon the wage, according to their bargaining strength, while the firm sets unilaterally the employment level at a later stage. In turn, the "right to manage" model is alternative to the "efficient bargaining" model, introduced by McDonald and Solow (1981), where the firm and the union bargain *jointly* on both wage and employment. The "right to manage" and the "efficient bargaining" models are both special cases of a most general class of models, known as "sequential bargaining" models, introduced by Manning (1987).

[6] Empirical and theoretical rationales can be advanced to defend the *sequential* structure of our model (see the discussion in Manning, 1987, pp. 122-124). In particular, it is widely observed that collective bargains are usually characterized by a sequential feature, and wages are commonly set in advance of employment. Moreover, there is further evidence that unions have a greater influence over the wage than the employment level, while firms usually retain a unilateral right to vary employment. The monopoly union feature remains a special case, instead, with an advantage in terms of algebraic simplicity *vis-a-vis* the right-to-manage model.

engage in a strategy of egalitarian redistribution over and above grabbing a fraction of the producer surplus. In order to preserve its membership, the union redistributes the wage bill accrued to the employed members of the union among all union members. This extreme form of redistribution - somehow reminiscent of actual union practices[7] - guarantees the same labor income to all, independently of labor market outcomes. As discussed in Pencavel (1985), the unions act as a substitute for complete insurance markets. This also serves the important (technical) purpose of preserving agents' homogeneity over time.[8]

2.2 Union-firm bargaining

Extending one of the equilibrium concepts discussed in Anderson and Devereux (1988), we assume that the sequences of employment rates, wages, and demands for physical capital services are determined in a noncooperative game between the monopoly unions and the firms. The strategic variables are respectively the sequences of wage rates for the unions and demands for capital services for the firms, yet scope for pre-commitment is barred on both sides. In other words, if strategic dominance is the relative power to commit to a strategy, neither party is strategically dominant.[9]

More formally, since both firms and unions are infinitely lived, the union maximizes the discounted flow of future average labor incomes, taking as given the sequences of demanded quantities of physical capital services, rental rates, and human capital stocks:

$$\max_{\{W_j\}_{j=t}^{\infty}} \sum_{j=t}^{\infty} R_t^j [n_j W_j (1-\tau^N) + (1-n_j) S_j (1-\tau^S)] \tag{3}$$

where R_t^j is a time-varying market discount factor, subject to the conditional demand for labor:

$$W_t = A\left[\alpha K_t^{\eta} + \varphi (n_t E_t)^{\eta}\right]^{\frac{1-\eta}{\eta}} \varphi n_t^{\eta-1} E_t^{\eta} \tag{4}$$

[7] For instance, Blau and Kahn (1996) show that wages are more volatile for non-union than for union workers.

[8] This extreme form of redistribution is not necessarily desirable in more general settings, though. Had leisure been valued in the workers' utility function, the desirable amount of egalitarianism pursued by the union would be less than full (so as not to penalize those exerting a work effort vis-a-vis the unemployed). Partial egalitarianism would however introduce heterogeneity among the households, with all the related technical difficulties.

[9] In the partial equilibrium models due to Grout (1984) and Van der Ploeg (1987), the firm can commit to its capital stock. It may thus be locked-in by the union, *i.e.* quasi-rents may be extracted from the installed machines by claiming higher wages than agreed *ex-ante*. Note however that, in our framework, if a centralized union were able to take into account the effects of its behavior on the rental rate, it would maximize the average total income of its members, and so full employment would emerge as the only possible solution. In other words, the centralized union would have no role in such a general equilibrium setting, since full employment is the natural competitive outcome.

for given sequences $\{K_j\}_{j=t}^{\infty}$, $\{E_j\}_{j=t}^{\infty}$, and $\{S_j\}_{j=t}^{\infty}$.
Each firm, instead, maximizes the discounted flow of future profits:

$$\max_{\{n_j, K_j\}_{j=t}^{\infty}} \sum_{j=t}^{\infty} R_t^j (Y_j - W_j n_j - r_j K_j) \tag{5}$$

subject to (1), for given sequences $\{W_j\}_{j=t}^{\infty}$, $\{r_j\}_{j=t}^{\infty}$, and $\{E_j\}_{j=t}^{\infty}$.
The sequences of employment rates, wage rates, and demands for capital services, $\{n_j\}_{j=t}^{\infty}$, $\{W_j\}_{j=t}^{\infty}$, and $\{K_j\}_{j=t}^{\infty}$, that jointly solve problems (3) and (5) for given sequences of rental rates, human capital stocks, and unemployment subsidies, $\{r_j\}_{j=t}^{\infty}$, $\{E_j\}_{j=t}^{\infty}$, and $\{S_j\}_{j=t}^{\infty}$, form a Nash equilibrium for the previously described noncooperative game.
Note that unions and firms effectively solve a sequence of independent static games. This is because, *(i)* the services of physical capital and labor are to be purchased at the given prices in each period, since households own both factors of production; *(ii)* pre-commitment is ruled out; *(iii)* unions are small at the level of the entire economy, and take as given the rental price of capital, as well as the set of policy variables. Hence, unions fail to internalize the dynamic consequences of today's wage setting on capital accumulation and wages tomorrow. We restrict then our attention to Markov strategies depending only on the current rental rate, the human capital stock, and the unemployment subsidy.
Given our assumptions, employment, wage and the demand for physical capital services are implied by the following equations:

$$W_t = A\left[\alpha K_t^{\eta} + \varphi (n_t E_t)^{\eta}\right]^{\frac{1-\eta}{\eta}} \varphi n_t^{\eta-1} E_t^{\eta} \tag{6}$$

$$r_t = A\left[\alpha K_t^{\eta} + \varphi (n_t E_t)^{\eta}\right]^{\frac{1-\eta}{\eta}} \alpha K_t^{\eta-1} \tag{7}$$

$$\begin{aligned} & A\left(\alpha K_t^{\eta} + \varphi n_t^{\eta} E_t^{\eta}\right)^{\frac{1-\eta}{\eta}} \varphi \eta n_t^{\eta-1} E_t^{\eta} + \\ & + \frac{1-\eta}{\eta} A\left(\alpha K_t^{\eta} + \varphi n_t^{\eta} E_t^{\eta}\right)^{\frac{1-\eta}{\eta}-1} \varphi \eta n_t^{\eta-1} E_t^{\eta} \varphi n_t^{(\eta-1)+1} E_t^{\eta} = S_t \frac{1-\tau^S}{1-\tau^N} \end{aligned} \tag{8}$$

Equations (6) and (7) are the familiar conditions equalizing the rental rate of each factor to its marginal productivity. Condition (8) obtains from rewriting (2) as:

$$A\left(\alpha K_t^\eta + \varphi n_t^\eta E_t^\eta\right)^{\frac{1-\eta}{\eta}} \varphi n_t^\eta E_t^\eta (1-\tau^N) + (1-n_t) S_t (1-\tau^S) \tag{9}$$

and deriving it partially with respect to n_t.[10] In turn, we may rewrite (9) as:

$$\varphi\left(\frac{A n_t E_t}{Y_t}\right)^\eta \left[\eta + (1-\eta)\varphi\left(\frac{A n_t E_t}{Y_t}\right)^\eta\right] = S_t \frac{1-\tau^S}{1-\tau^N} \frac{n_t}{Y_t} \tag{10}$$

In the Cobb-Douglas case, equation (10) would collapse to:

$$n_t = \frac{s_N^2 (1-\tau^N)}{1-\tau^S} \frac{Y_t}{S_t} \tag{11}$$

Equation (10) defines implicitly the optimal (for the union) employment rate and, together with (6), the corresponding wage. In equilibrium, n_t is smaller than one, so that equilibrium unemployment arises.

2.3 Intertemporal household choice

Under our set of assumptions, all household members are and remain effectively identical at any moment in time. Thus both kinds of household members can be aggregated into a representative household that maximizes an intertemporal utility function:

$$U_t = \sum_{i=t}^{\infty} \beta^{i-t} \frac{\tilde{C}_i^\mu}{\mu} \tag{12}$$

where $\mu < 1$ and a tilde identifies individual-level variables, subject to the following intratemporal budget constraint:

$$\tilde{C}_t + \tilde{I}_t = r_t \tilde{K}_t - \tau^K (r_t - \delta_K) \tilde{K}_t + n_t W_t (1-\tau^N) + (1-n_t) S_t (1-\tau^S) + T_t \tag{13}$$

[10] Once the labor demand function has been taken into account, the choice of the control variable is irrelevant. Since no closed form solution for the labor demand function is available, we simply use the inverse labor demand function and maximize with respect to employment.

where τ^K is the tax rate on the real return on physical capital, δ_K is the physical capital depreciation rate, and T_t the per-capita lump-sum government transfer, and the following accumulation equation:

$$\tilde{K}_{t+1} = (1 - \delta_K)\tilde{K}_t + \tilde{I}_t \tag{14}$$

Equation (13) embodies full tax deductibility of physical capital depreciation. Moreover, the expression $n_t W_t(1 - \tau^N) + (1 - n_t)S_t(1 - \tau^S)$ is the average net-of-tax labor income after the redistribution carried out by the union. Note that the sequences of prices $\{r_t, W_t\}_0^\infty$ and aggregate variables $\{n_t, S_t, T_t\}_0^\infty$ are taken as given by the representative household.
To solve the household's optimal control problem, we plug (13) into (14), construct the Lagrangian, and take partial derivatives with respect to $\tilde{C}_t$, $\tilde{K}_{t+1}$, and λ_t, where the latter represents a present value co-state variable. The first order conditions are the following:

$$\tilde{C}_t^{\mu-1} = \lambda_t \tag{15}$$

$$\lambda_t = \beta \lambda_{t+1}[(r_{t+1} - \delta_K)(1 - \tau^K) + 1] \tag{16}$$

$$\tilde{K}_{t+1} = [(r_t - \delta_K)(1 - \tau^K) + 1]\tilde{K}_t + n_t W_t(1 - \tau^N) + (1 - n_t)S_t(1 - \tau^S) + T_t - \tilde{C}_t \tag{17}$$

together with the standard transversality condition:

$$\lim_{t \to \infty} \beta^t \lambda_t \tilde{K}_{t+1} = 0 \tag{18}$$

Under our assumptions, the first order conditions (15)-(17) and the transversality condition are jointly necessary and sufficient conditions to solve for the representative household's problem.

2.4 Aggregate constraints

Finally a set of aggregate constraints must be satisfied. In each period, the government has to satisfy the following aggregate per-capita budget constraint:

$$\tau^K(r_t - \delta_K)K_t + \tau^N n_t W_t + \tau^S(1 - n_t)S_t = T_t + (1 - n_t)S_t \tag{19}$$

On the left-hand side, total tax revenues are the sum of the revenue from capital and labor income taxes, and from the taxes on the unemployment subsidies. On the right-hand side, total spending consists of two items, lump-sum transfers and unemployment subsidies. Government transfers are there to allow us to separately evaluate the effects of a change in the tax rates from the effects of a change in the subsidy rate.

If the government budget is balanced at any instant, the dynamics of the aggregate per-capita physical capital stock can be described by the following accumulation equation:

$$K_{t+1} = (1 - \delta_K)K_t + Y_t - C_t \tag{20}$$

Finally, we assume that the accumulation of knowledge capital takes place through a learning-by-doing process, more specifically as a by-product of being employed as follows:

$$E_{t+1} = (1 - \delta_E)E_t + Bn_tE_t \tag{21}$$

where δ_E represents the knowledge capital depreciation rate and B a scale parameter.

3 Solution

3.1 Equilibrium

A recursive equilibrium for our economy is the following:

i) a sequence of prices, $\{W_t, r_t\}_0^\infty$;

ii) a sequence of *individual* consumption levels and physical capital stocks, $\{\tilde{C}_t, \tilde{K}_t\}_0^\infty$;

iii) a sequence of *aggregate* consumption levels and physical capital stocks, $\{C_t, K_t\}_0^\infty$;

iv) a sequence of employment rates $\{n_t\}_0^\infty$;

v) a sequence of human capital stocks $\{E_t\}_0^\infty$, unemployment subsidies $\{S_t\}_0^\infty$, and per-capita lump-sum transfers $\{T_t\}_0^\infty$;

such that:

i) the individual quantities $\{\tilde{C}_t, \tilde{K}_t\}_0^\infty$ solve the representative household optimization problem for the given sequences $\{r_t, W_t, n_t, S_t, T_t\}_0^\infty$;

ii) the aggregate quantities $\{n_t, K_t\}_0^\infty$ solve the representative firm's optimization problem for the given sequences $\{r_t, W_t, E_t\}_0^\infty$;

iii) the individual and aggregate quantities are consistent, $\tilde{C}_t = C_t$ and $\tilde{K}_t = K_t$;

iv) the goods market clears, $C_t + K_{t+1} - (1-\delta)K_t = Y_t$;

v) the employment levels $\{n_t\}_0^\infty$ solve the union's optimization problem for the given sequences $\{r_t, S_t, K_t, E_t\}_0^\infty$;

vi) the government budget constraint and the equation of motion for the human capital stock are satisfied.

We use these aggregate consistency conditions, together with the government budget constraint, in the first order conditions (15)-(17), noting that $Y_t = r_t K_t + W_t n_t$. This set of equations, together with (1), (6), (10), and (21), constitutes a system of difference equations that completely describes our economy. Given the linearity in the human capital stock of equation (21), the economy is characterized by endogenous growth as long as $Bn_t > \delta_E$; our dynamic system may thus be non-stationary. To make it stationary, we can normalize it with regard to E_t, and obtain the following normalized first order conditions (small letters identify normalized variables; note that $\tilde{\lambda}_t \equiv \lambda_t E_t^{1-\mu}$):

$$c_t^{\mu-1} = \tilde{\lambda}_t \tag{22}$$

$$\gamma_t^{1-\mu}\tilde{\lambda}_t = \beta\tilde{\lambda}_{t+1}[(r_{t+1} - \delta_K)(1-\tau^K) + 1] \tag{23}$$

$$\gamma_t k_{t+1} = (1-\delta)k_t + y_t - c_t \tag{24}$$

$$\gamma_t = 1 - \delta_E + Bn_t \tag{25}$$

$$\varphi\left(\frac{An_t}{y_t}\right)^{\eta}\left[\eta + (1-\eta)\varphi\left(\frac{An_t}{y_t}\right)^{\eta}\right] = s_t\frac{1-\tau^S}{1-\tau^N}\frac{n_t}{y_t} \tag{26}$$

$$y_t^{\eta} = A(\alpha k_t^{\eta} + \varphi n_t^{\eta}) \tag{27}$$

$$r_t = A^{\eta} y_t^{1-\eta}\alpha k_t^{\eta-1} \tag{28}$$

With respect to the original system, we lost a state variable, E_t, and gained a pseudo-control variable, γ_t, the endogenous growth rate of the knowledge capital stock. Given the initial condition for E_0, the time path for E_t is recursively defined once the path for n_t is given; this guarantees that the original and the normalized systems are homeomorphic.

3.2 Steady-state

The normalized equation system (22)-(28) has a steady state solution whereby all variables stay constant, if and only if the employment rate stays constant over time. Whether employment is constant over time is in turn determined by equation (26), which implicitly defines the level of employment n as a function of a bunch of parameters, the ratio between unemployment subsidies and output, and the factor income shares.[11] Now, factor shares cannot but be constant in the steady state, which makes the left-hand side of equation (26) constant. Hence, a sufficient condition for the system (22)-(28) to bear a steady state solution is that the unemployment subsidy and the level of output share the same steady-state growth rate. If this is the case, then in steady-state the unemployment subsidy is a constant fraction of output, *i.e.* $s = \sigma y$, where $0<\sigma<1$. In what follows, we refer to σ as the subsidy share.

Furthermore, we assume that the tax rate on unemployment subsidies is directly proportional to the tax rate on labor income, *i.e.* that $\tau^S = \phi\tau^N$, with $\phi>0$. As shown below, unemployment subsidies are usually taxed at somewhat lower rates than wages, so that the actual ϕ are less than one. An important consequence of this specification is that any change in the labor tax rate translates immediately in a proportional change in the subsidy tax rate.

Since $s_N = \varphi(An/y)^\eta$, we can evaluate (26) at the steady-state and rewrite it as:

$$s_N[1-(1-\eta)s_K] = \sigma n \frac{1-\phi\tau^N}{1-\tau^N} \tag{29}$$

In the calibration procedure to be described in the next section, equation (29) is solved for σ as a function of s_N, n, and some other parameters. It will be useful to obtain also an equation expressing the steady-state employment rate n as a function of deep parameters alone. It is easy to show that:

$$s_N = 1-\alpha\left[\frac{(1-\delta_E+Bn)^{1-\mu}-\beta[1-(1-\tau^K)\delta_K]}{\beta\alpha(1-\tau^K)}\right]^{\frac{\eta}{\eta-1}} \tag{30}$$

Substituting (30) into (29) we get:

[11] Note that $(w_t n_t)/y_t = \varphi(A n_t/y_t)^\eta$.

$$\left\{1-\alpha\left[\frac{(1-\delta_E+Bn)^{1-\mu}-\beta[1-(1-\tau^K)\delta_K]}{\beta\alpha(1-\tau^K)}\right]^{\frac{\eta}{\eta-1}}\right\}\times$$

$$\times\left\{1-(1-\eta)\alpha\left[\frac{(1-\delta_E+Bn)^{1-\mu}-\beta[1-(1-\tau^K)\delta_K]}{\beta\alpha(1-\tau^K)}\right]^{\frac{\eta}{\eta-1}}\right\}=\sigma n\frac{1-\phi\tau^N}{1-\tau^N} \qquad (31)$$

Equation (31) relates the steady-state employment rate to the deep parameters of the model, and, being highly non-linear, has to be solved numerically.

3.3 Calibration

To perform any numerical experiment with our model, we need to parameterize it carefully. First of all, it is desirable that our results do not depend on unobservable cross-country differences in preferences, technology and depreciation parameters. Thus, we assume that the elasticity of intertemporal substitution, the intertemporal discount factor, the elasticity of substitution between capital and efficient labor, and the depreciation rates (for physical and knowledge capital) are equal across countries to:

$$\mu=-1\ ,\quad \beta=0.96\ ,\quad \xi=0.70\ ,\quad \delta_K=10\%\ ,\quad \delta_E=6\%$$

These are all standard values, except for the depreciation rate of knowledge capital - a somewhat less usual figure to be plugged in. Empirical estimates of the yearly depreciation rate of human capital lie in the 1.5%-7% range: we chose a value equal to 6%. An elasticity of substitution between capital and labor equal to 0.7 corresponds to the benchmark value adopted by Pissarides (1998); the implied value for η is -0.43.

The remaining parameters are all country-specific. They are either taken from other studies or calibrated. We borrow the 1960-1995 average effective tax rates on labor and capital[12], τ^N and τ^K, from the data set employed by Daveri and Tabellini. Moreover, using data on gross and net replacement rates[13] provided by the *OECD Jobs Study* (1994, ch. 8, Annex 8.13), we can recover an (admittedly crude) estimate of the effective tax rate on employment subsidies, and indirectly of the parameter $\phi=\tau^S/\tau^N$.

The size of the parameter ϕ is crucial to determine the ultimate effect of a tax on labor income on employment (and growth). If ϕ is equal or very close to one, this means that the tax rates on

[12] The data on effective tax rates have been computed by Mendoza et al. (1994) and filled by Daveri and Tabellini for a few observations.

[13] Replacement rates are usually defined as the ratio between he unemployment subsidy and the previous labor income, *i.e.* s/w in steady-state. The replacement rates employed here are the OECD summary measures of "entitlement benefits" (an average of the replacement rates for different categories of unemployed).

wages and unemployment subsidies are very similar. Therefore, a change in τ^N leaves the equilibrium value of n unaffected. Our results are summarized in **Table 2**.
The implied average value of ϕ is quite low in Italy and Germany, close to 0.5 in Finland and Spain, and fairly high (some 0.75) in France, Belgium, the Netherlands, and Sweden. This implies that the unemployed enjoy a relatively more favorable tax treatment in Italy, Germany, Finland and Spain, than in France, Belgium, the Netherlands and Sweden. Cutting labor taxes is thus more likely effective in the former rather than in the latter group of countries.
Now we are left with a set of parameters, in principle hard to estimate. In particular, we need values for α, the parameter of the CES related to the capital income share, B, the scale parameter in the equation of accumulation for human capital, and σ, the subsidy share.
Empirical estimates of the employment rate, n, the long-run growth rate, γ, and of the steady-state investment-output ratio, s_i, are readily obtained.[14] A little manipulation of the first order conditions gives:

$$\frac{k}{y} = \frac{s_i}{\delta_K - 1 + \gamma} \tag{33}$$

Furthermore, some further manipulation leads to:

$$r = \frac{\gamma^{1-\mu} - \beta[1 - (1 - \tau^K)\delta]}{\beta(1 - \tau^K)} \tag{34}$$

Since $s_K \equiv rK/Y$, clearly $s_K = r \cdot k/y$. Evaluating (7) at the steady-state and solving it for α gives:

$$\alpha = s_K \left(\frac{k}{y} \right)^{-\eta} \tag{35}$$

Evaluating (25) at the steady-state, and solving for B we obtain:

$$B = \frac{\gamma - 1 + \delta_E}{n} \tag{36}$$

[14] We measure n as the ratio between civilian employment and total population in working age, s_i as the share of gross fixed investment over GDP, and γ as the yearly growth rate of GDP per worker.

Finally, σ can be explicitly derived from equation (29). **Table 3** presents the long-run properties we aim at replicating (column 1 through 3), together with the implied values for the calibrated parameters σ, α, and B (column 4 through 6).
The calibrated values for the parameters α and B are all strictly positive, and this is all we can say about them. The implied steady-state labor income shares and capital-output ratios are fairly close to their measured counterparts. The values of σ implied by our calibration procedures can be contrasted with those computed from a transformation of National Accounts data. The procedure is the following. Given the OECD gross replacement rates, one can compute the labor income shares from National Accounts data. This is enough to recover the implied value for the parameter σ from the following expression:

$$\sigma = \frac{s}{y}\frac{n}{n}\frac{w}{w} = \frac{s}{w}\frac{s_N}{n} \tag{37}$$

The σs computed from this indirect procedure are compared in **Table 4** with those implied by the calibration in **Table 3.** The correlation coefficient between the two series is 0.75. Most coefficients are very similar, one important exception being Italy.[15]
Table 5 reports some endogenously determined long-run features of the model, and in particular the labor shares and capital-output ratios (columns 4 and 5), together with the ratios between the tax revenues from capital, labor and subsidies, and output. **Table 6** instead summarizes the complete parameterization used in our experiments. Columns [1] to [5] show parameters that are constant across countries; columns [6] to [8] show the calibrated parameters; columns [9] to [11] show the empirically observed fiscal policy parameters.

4 Policy experiments

In this section, we present the methodology and the main results from some policy experiments conducted to explore the steady-state properties of our model.
We study the effects of fiscal policy on the steady-state employment rate and the long-run growth rate. In the first set of experiments, the government budget is kept balanced by offsetting changes in the level of lump-sum transfers. As, for instance, the labor tax is cut, this creates a budget deficit, to be bridged by reducing transfers. One may interpret the implied changes in transfers as the budgetary implications of the examined policy. In the second set of experiments, instead,

[15] The OECD measure of replacement rates most likely underestimates the actual protection granted to the unemployed in Italy, for the *Cassa Integrazione Guadagni*, *i.e.* the mechanism though which firms in financial distress were allowed not to fire redundant workers until the 1991 reform, is not accounted for.

offsetting transfer changes are ruled out. If the labor tax rate is reduced, the fall in tax revenues is made up for by either appropriate changes in the capital tax rate or in the unemployment benefits. These experiments are more akin to the content of current policy discussions in Europe, for two reasons. First, fiscal policy in EU countries is to be balanced on average under the Stability Pact. This strongly reduces the scope for offsetting transfer changes. Second, in the wake of the 1990 liberalization of capital movements, the European Commission has advocated and actively pursued a strategy of tax policy coordination in Europe with the goal of shifting the tax burden from labor to capital. We provide a framework to formally evaluate and quantify the likely effects of such policies, albeit in a closed economy framework.

In the first set of policy experiments, we separately change each policy parameter by one percentage point. The policy variables, whose effect is being evaluated, are four: the tax rates on capital and labor incomes; the parameter relating the differential tax treatment of the unemployment subsidies and wages; the subsidy share (in symbols: τ^K, τ^N, ϕ, and σ).

For example, we ask what happens to long-run employment and growth as the capital tax rate drops in Germany from its initial, long-run value of 28% to 27%, while holding the other parameters constant. Equation (31) is solved numerically to find the new steady-state employment rate. The long-run growth rate is then computed from $\gamma = 1 - \delta_E + Bn$.

Employment and growth effects are summarized in **Table** 7. In column [1] and [2], the benchmark steady state values of the endogenous variables of interest (employment, growth) are reported for comparison purposes. Next, column [3] through [10] show the steady state changes occurring to the same variables, as a result of a one percentage point change in the tax rates on capital and labor incomes, on unemployment benefits, and of the replacement rate. As the value of a policy variable is changed, the other policy variables constant, but for the level of the lump-sum transfers, whose change is necessary to keep the budget balanced. To ease comparisons, policy experiments involving employment and growth *gains* are reported in **Table** 7.

Results suggest that a reduction in unemployment benefits produces the largest employment and growth gains among all policy variables. In **Table** 7, one learns that a drop of one percentage point in the parameter σ increases the employment rate by more than one percentage point in Germany, France, Italy, Sweden, and Finland, and by slightly less in the remaining countries (see column [9] and [10]). This is qualitatively in accordance with the econometric evidence in Layard, Nickell and Jackman (1991), and the numerical findings in Ljungqvist and Sargent (1998), although the size of the effects is much larger in size.

As shown in column [5] and [6] in the same Table, labor taxes produce sizable employment and growth effects, too. Reducing the tax rate on labor by one percentage point raises the employment rate by some 0.5 points in Germany and Italy, by 0.3 in Belgium, Spain, and Sweden, and by 0.2 in France, the Netherlands, and Finland. Daveri and Tabellini's estimated coefficients of labor taxes in their unemployment regressions were equal to some 0.30-0.35 for Continental Europe as a whole, and not statistically different from zero for Scandinavian countries (Norway, Sweden and Finland). These are fairly large numbers. If taken at face value, and associated to the actual labor tax increase of 15 points experienced in Europe in the last thirty years, these figures would account for a large fraction of the total decline in the employment rates.

In our framework, more employment creation has an immediate counterpart: a rise in long-run growth. Thus, we also have that (see column [6]) the rate of growth of per-capita GDP goes up as well, by some figures in between 0.03 (France, Sweden) and 0.07 (Italy).

At first sight, these growth effects might look small, but in fact they are not. This is seen by considering that the actual increase of 15 percentage points in labor taxes translates into a permanent fall in the growth rate of some 0.45-1.05%, depending on the country. Such reductions in the growth rate cannot be easily dismissed as irrelevant, in the face of the actual growth slowdown of 2.8 points experienced by Europe as a whole.

There is another feature of our results which bears some similarity with previous studies. In line with Rebelo (1991), Stokey and Rebelo (1995) and others, the results in **Table 7** show that capital taxes produce smaller effects on employment and growth than both labor taxes and unemployment subsidies in countries in Continental Europe, while the differences are less sensible in Scandinavian countries. In a model with growth driven by learning-by-doing and Cobb-Douglas technology, we would expect no effect whatsoever of capital taxes on employment and growth. This is not the case here, because we have adopted a CES production function with elasticity of substitution different from one.

In the other studies in the applied literature on growth and taxes, the inefficacy of capital taxes in influencing the growth rate was taken as definitive evidence that growth is exogenous.[16] In our framework , we have two results, really. Capital taxes are (relatively) ineffective in affecting the growth rate of the economy (in most countries in Continental Europe). The unimportance of capital taxes does not necessarily imply that taxes and growth are unrelated, however. If growth is driven by learning-by-doing, as assumed here, taxing labor does not just bring down the employment rate, but also feeds into a permanently lower rate of human capital accumulation and economic growth. To sum up, in most countries in our sample, capital taxes do not have a strong influence on the growth rate of the economy, but labor taxes do.

Finally, **Table 7** also report results concerning the changes in ϕ, *i.e.* the parameter that determines how favorable is the tax treatment of benefits compared to wages. As ϕ approaches one, wages and benefits become taxed at the same rate, which neutralizes any labor market effects of labor taxes. If, however, income when employed and when unemployed are taxed at different rates, a rise in ϕ reduces the net-of-tax reservation wage and thus the cost of labor to the firm. This produces higher employment and growth. Notably, in some countries (particularly in France, the Netherlands, and Sweden), the employment and growth effects of changing this tax parameter are as large as those due to a change in the labor tax rate itself.

[16] The argument being: growth rates do not trend anywhere, while taxes manifestly trend up, thus taxes must be unrelated to growth. See Jones (1995).

Finally, as emphasized above, all of the policy experiments described so far are balanced-budget experiments, if and only if one assumes the feasibility of lump-sum transfers large enough to bridge any budgetary gap. It is instructive to check whether the described policy experiments imply offsetting transfers of similar entities. The budgetary implications of reducing taxes and unemployment when offsetting transfers are available are reported in **Table 8**. A one percentage point reduction in the unemployment benefits is more beneficial to the budget (about +0.6 points, on average, with Italy and Germany improving their budget by more than 0.7 points) than increasing taxes. In turn, a one point increase in the labor tax rate is also more beneficial to the government budget than raising the capital tax rate. A 1%-fall in the tax rate on labor, capital, or benefits brings to the government an average reduction in the budget deficit of, respectively, 0.56, 0.22 and 0.10 points. These results are crucially determined by the different tax bases of each tax instrument - smaller for the taxation of capital income and unemployment subsidies, and instead bigger for the taxes on labor.

Yet, presumably, European governments face an even harder choice. Under the Fiscal Stability Pact, each government is severely constrained in its ability to borrow. Hence the hot policy issue is *not* which fiscal policy tool delivers the highest employment and growth gains - something addressed in the Tables presented above. Rather, *the* policy issue in today's Europe is: would a reduction in labor taxes still retain its employment-enhancing features, once it has to be financed by either raising other revenue items or cutting social spending ?

Answers to these questions arise from our second set of experiments, where lump-sum transfers are ruled out. Results are reported in **Table 9** and **10**.

The first exercise in this set of experiments is the following. Suppose that labor taxes are cut by one percentage point. Unlike in previous Tables, the transfers-output ratio is held constant. Suppose, instead, that the government is inclined to raise the capital tax rate so as to balance the budget. As mentioned above, this exercise is probably more appropriate to gain a sense of the effects of a feasible tax reform in Europe, where countries, upon entering the EMU, have also agreed on a Stability Pact, *i.e.* an institutional device preventing them from running positive long-run fiscal deficits. **Table 9** reports the effects of such experiment.

It turns out that, to keep the budget balanced, capital tax rates must be adjusted upwards by some 2.7 percentage points on average, for each percentage point reduction in the labor tax. As a result, the combined effect of the mild decrease in labor taxation and of the parallel sharp increase in capital taxation is no longer necessarily positive in terms of employment and growth. Although some countries would still gain (notably, Italy and Germany), the EU employment rate would fall on average by slightly less than one quarter of a point, and the EU growth rate would slightly fall by 0.03 percentage point.

The stringent requirements imposed by the Fiscal Stability Pact pose another obstacle to raising employment and growth. Results in **Table 9** can be taken to support the view of those claiming that the *feasible* employment and growth gains of reducing the tax burden on labor are far from guaranteed. As we can see, this is in particular the case if the labor tax reduction is run by shifting the burden of taxation from one factor (labor) to another (capital), at least in our closed economy framework.

In the second exercise, the one-point reduction in the taxation of labor is financed by a parallel reduction in the income share of the unemployment benefits. The results from this other experiment are in **Table 10**.

To keep the budget balanced, the subsidy shares have to be adjusted downwards by slightly more than 0.6 percentage points on average, for each percentage point reduction in the labor tax. The model suggests that the combined effects of reducing labor taxation and the subsidy share have a markedly positive effect on both employment creation and growth. On average, the EU employment rate would increase by 1.5 points, and the growth rate by some 0.2 points per year.

The overall effect of these experiments on the total amount of tax revenues is obviously different, as shown in **Table 11**. As a result of the increase in capital taxes, fiscal revenues would slightly go up on average - more clearly so in Belgium, France and Finland - for the rise in revenues from capital taxes by 0.5-1.0% depending on the country more than offsets the revenue loss from labor taxes (with no action taking place on the unemployment benefit side). In the countries actually experiencing an employment reduction (Italy and Germany), total revenue falls, instead, though by a tiny amount. The revenue effects are more apparent when unemployment benefits are reduced.

Finally, to concisely summarize our main results, we re-calibrated the model to reproduce the long-run properties of an artificial European aggregate, obtained as a weighted average of the countries in our sample, where the weights are simply the 1960-95 average ratios between the working age population in each country and the corresponding total figure.[17] We then reproduce the previously described experiments. Findings are in **Table 12**. Our conclusions are confirmed: an increase in both tax rates with offsetting transfers has a negative effect on employment and growth, and this effect is more pronounced when the tax rate on labor increases. The shift of taxation from labor to capital without offsetting transfers has again a slightly negative average effect on both employment and growth, while the decrease of both the tax rate on labor and the subsidy share has a dramatically positive effect on the same variables.

5 Sensitivity analysis

In order to check the robustness of our results, we adapt the evaluation procedure proposed by Canova (1995) to our needs.

[17] The weights are respectively 0.257, 0.213, 0.234, 0.056, 0.041, 0.145, 0.034, and 0.02. The weighted long-run properties for the European aggregate are equal to $n = 0.61$, $s_i = 0.23$, and $\gamma = 1.024$, while the weighted policy parameters are equal to $\tau^K = 0.26$, $\tau^N = 0.39$, and $\phi = 0.47$. The implied calibrated parameters are $\alpha = 0.46$, $\sigma = 0.39$, and $B = 0.14$.

Canova's procedure is based on the assumption that the proposed model is almost surely false in a statistical sense. The procedure consists of simulating the model very many times randomizing over the parameters, which are each time drawn from a set of Bayesian prior distributions. These distributions summarize all available cross-sectional information. If no prior information is available, the priors should simply be distributed uniformly on a given range. The validity of the model is then judged by checking its ability to reproduce, in a probabilistic sense, the stylized facts one happens to be interested in.

Our particular goal is more limited. We want to check whether the results described in the previous Section are representative of the "average" model's behavior, or are instead due to the particular parameterization we happened to choose. To reach this goal, we repeatedly perform the experiments described in the previous Section, using each time a different parameterization randomly drawn from what we take as a useful approximation of the global parameters' support. In order to maintain the highest degree of generality, and to avoid any bias in favor of our results as much as possible, we obtain this approximation by simply assuming that the observed parameters and the long-run properties used to calibrate the remaining parameters are uniformly distributed, abstracting this way from any prior information other than a wide interval of variation.

This procedure can be used under two simplifying assumptions, which should be made clear at this stage. First, we omit considering that the available empirical evidence may support a different prior distribution. For instance, Canova and Ortega (1996) suggest that the prior information available for the risk aversion coefficient implies a prior distribution equal to a truncated χ^2 with mean -1 and bounds (-9,1). Second, we do not consider that the joint prior distribution may not simply be the Cartesian product of all marginal distributions. For instance, the applied growth literature suggests a positive correlation between the steady-state investment share and the long-run growth rate, but this is not accounted for in our sensitivity analysis framework. To sum up, then, our approximation implies that the same a priori likelihood is assigned to all points in the parameters' support, even if the available empirical evidence suggests that some of them are less likely than others.

Note however that the parameters have to satisfy a set of constraints in order to generate a consistent parameterization steady-state solution. Inconsistencies arise whenever any calibrated parameter lies outside its definition range, or any variable reaches a value incompatible with a steady state situation (*e.g.* when the employment rate takes negative values). In this sense, then, the global parameterization support differs from the simple Cartesian product of the support of each single parameter, and of course the prior joint distribution is different from the product of all prior marginal distributions. We leave the task of selecting the parameters compatible with the constraints to the solution algorithm. In particular, we check that: $\sigma \in (0,1)$, $\alpha > 0$, $B > 0$, $s_K \in (0,1)$, $n \in (0,1)$, and $\gamma > 0$.

Table 13 summarizes the prior marginal distributions used in our simulations. As far as the policy parameters, the employment rate, the growth rate, and the investment share are concerned, the upper and lower bounds were set in order to accommodate the empirical evidence described in

Table 2 and **3**. Then, following Canova and Ortega (1996), we let the risk aversion parameter μ, equal to one minus the inverse of the intertemporal elasticity of substitution in consumption, range from -9 to 1. The variation range for the parameter η, equal to one over the elasticity of substitution between effective labor and physical capital, goes from -3 to 0, implying an elasticity of substitution that ranges from -0.33 to 1 (a value of one being the Cobb-Douglas case). The interval of values for the yearly depreciation rate of human capital is chosen large on purpose, and goes from a minimum of 1% to a maximum of 10%. Finally, the yearly physical capital depreciation rate and the intertemporal discount factor range respectively between 5% and 15%, and between 0.93 and 0.99.

We perform 10,000 drawings, calculating the steady-state effects of alternative fiscal policies on employment and growth in each round, with and without offsetting transfers. The empirical distribution (over the 10,000 drawings) of fiscal policies on employment and growth when transfers are available are summarized in **Table 14**, and graphically described in **Figure 3** and **4**. The effects of a cut in labor taxes financed by either an increase in capital taxes or a decrease in the subsidy share are instead reported in **Table 15** and **16**, and graphically described respectively in **Figures 5** and **6**.

From **Table 14** we learn that the effect of a one percentage point decrease in the average effective tax rate on capital on the steady-state employment rate is equal on average to 0.32 percentage points (with a standard deviation of 0.40 and a median of 0.24), while the effect on the steady-state growth rate is equal on average to 0.04 (with a standard deviation of 0.05 and a median of 0.03). As far as the employment effect is concerned, the range of variation goes from 0 to 16.9 points. Yet **Figure 3**, and **Figure 4** in more detail, show clearly that the upper bound is an outlier, since more than 90% of the observations lie between 0 and 0.7 points.

Furthermore, we note that, on average, the employment effect of a one percentage point decrease in the average effective tax rate on labor is equal to 0.55 points (with a standard deviation of 0.37 and a median of 0.51), while the growth effect is equal on average to 0.07 (with a standard deviation of 0.05 and a median of 0.06). Again, the variation range for the employment effect goes from 0 to 1.96 points. **Figure 3** shows that the bulk of the observations clusters between 0 and 1.

Lastly, we focus on the employment and growth effects of a one percentage point decrease in σ, finding that the employment effect is on average equal to 2.05 (with a standard deviation of 2.27 and a median of 1.48), while the growth effect is on average equal to 0.25 (with a standard deviation of 0.30 and a median of 0.18). As far as the employment effect is concerned, the range of variation goes from 0.14 to 34.9. Once again, the upper bound is clearly an outlier, since the bulk of the observations in **Figure 3** falls between 0 and 2 points. **Figure 4** shows in more detail the frequency of the observations in the finer (0,6) range.

Table 15 and **16** (and the Figures attached to these Tables) serve the same purpose. **Table 15** shows that the employment effect of a one percentage point reduction in the tax rate on labor, financed by an increase in the tax rate on capital, is equal on average to -1.39 percentage points, with a standard deviation of 4.42 and a median of -0.43. The variation range goes from -64.2 to 30.6 percentage points. The growth effect is equal on average to -0.14, with a standard deviation of 0.59, a median of -0.05, a minimum of -13 and a maximum of 7.7. The increase in the tax rate on capital that counterbalances a one point decrease in the labor tax is on average equal to 4.92 points, with a standard deviation of 8.04 and a median of 3.01. The range of variation extends from -45.7 to 73.6. **Figure 5** shows that all these upper and lower bounds are outliers, since the bulk of the observations lies between 1 and -1 points for the employment effect, -0.5 and 0.2 for the growth effect, and from 0 to 5 for the increase in capital taxation. Note however that these experiments tend to produce a larger discrepancy between the mean and the median estimated values of the tax changes than previous exercises.

Finally, **Table 16** tells us that the employment effect of a one percentage point reduction in the average effective tax rate on labor, this time financed by a decrease in the subsidy share, is equal on average to 1.95 percentage points, with a standard deviation of 1.53 and a median of 1.58, with a minimum of -9.4 and a maximum of 24.4 percentage points. The growth effect is instead equal on average to 0.24, with a standard deviation of 0.18 and a median of 0.19, with an interval of values ranging from -1.00 to 3.5. The variation in the subsidy share necessary to counterbalance the decrease in the tax rate on labor is equal on average to -1.11, with a standard deviation of 0.75 and a median of -0.96, and a variation range that goes from-7.0 to 3.4. Again, **Figure 6** shows that all of these upper and lower bounds are outliers.

In the end, our sensitivity analysis drives us to conclude that the results described in **Tables 7-12** are not the output of a special parameterization, but can be taken as largely representative of the model's "average" behavior. Our findings exhibit a remarkable robustness to changes in the parameterization that span over a extremely wide range of values.

6 Conclusions

In this paper we have worked out and studied the numerical steady-state properties of an infinite-horizon endogenous growth model with equilibrium unemployment. The model was calibrated to reproduce some observed long-run properties of eight countries in Europe. The calibrated model has then been used to investigate the effects of a variety of balanced-budget fiscal policy experiments on employment and growth.

Whether or not the budget is kept balanced by some binding fiscal constraints is crucial for our results. If the budgetary implications of the tax reform are not important, say because some other items in the budget can be appropriately adjusted upwards or downwards, we find that, for each percentage point rise in the labor tax rate, the employment rate falls on average by some 0.34 percentage points, and the long-run growth rate by some 0.05. These numerical results are overall consistent with the econometric findings in other previous studies.

If the size of the government budget is exogenously constrained, the capital tax rate increase necessary to keep the budget balanced is enough to fully offset the beneficial employment and growth effects of a reduction in labor taxes. If, instead, the labor tax reduction is financed by a reduction in the unemployment subsidies, this sizably reinforces the employment and growth enhancing effects of the decrease of the labor tax. In particular, the reduction in the unemployment subsidy share necessary to keep the budget balanced is about one fourth of the implied rise in the capital tax rate.

We interpret our results as a contribution to reshape the discussion over welfare reform in Europe on the firm ground provided by numerical methods, in the same spirit as Ljungqvist and Sargent (1998).

7 References

Anderson, S. and M. Devereux (1988), Trade Unions and the Choice of Capital Stock, *Scandinavian Journal of Economics*, 90, 27-44

Blanchard, O. J. (1999), *European Unemployment: Shocks and Institutions*, Paper for the Baffi Lecture, Rome, Bank of Italy

Blau, F. D. and L. M. Kahn, (1996), International Differences in Male Wage Inequality: Institutions vs. Market Forces, *Journal of Political Economy*, 104, 791-837

Canova, F. (1995), Sensitivity Analysis and Model Evaluation in Simulated Dynamic General Equilibrium Economies, *International Economic Review*, 36, 477-501

Canova, F. and E. Ortega (1996), Testing Calibrated General Equilibrium Models, in: *Simulation Based Inference in Econometrics: Methods and Applications*, ed. by R. Mariano, T. Schuermann, and M. Weeks, Cambridge University Press, forthcoming

Danthine, J. P. and J. B. Donaldson (1990), Efficiency Wages and the Business Cycle Puzzle, *European Economic Review*, 34, 1275-1301

Daveri, F. and G. Tabellini (2000), Unemployment, Growth and Taxation in Industrial Countries, *Economic Policy*, 30, forthcoming

Dunlop, J. T. (1944), *Wage Determination Under Trade Unions*, New York, MacMillan

Gali, J. (1996), Unemployment in Dynamic General Equilibrium Economies, *European Economic Review*, 40, 839-845

Grout, P. A. (1984), Investments and Wages in the Absence of Legally Binding Labour Contracts, *Econometrica*, 52, 449-60

Hendricks, L. (1999), Taxation and Long-run Growth, *Journal of Monetary Economics*, 43, 411-34

Horn, H. and A. Wolinsky (1988), Worker Substitutability and Patterns of Unionization, *Economic Journal*, 98, 484-97

Jones, C. I. (1995), Time Series Tests of Endogenous Growth Models, *Quarterly Journal of Economics*, 110 (2), 495-525

King, R. and S. Rebelo (1993), Transitional Dynamics and Economic Growth in the Neoclassical Model, *American Economic Review*, 83(4), 908-931

Layard, R., S. Nickell and R. Jackman (1991), *Unemployment: Macroeconomic Performance and the Labour Market*, Oxford, Oxford University Press

Ljungqvist, L. and T. Sargent (1998), The European Unemployment Dilemma, *Journal of Political Economy*, 514-550

Lucas, R. E. Jr. (1993), Making a Miracle, *Econometrica*, 61, 251-272

McDonald, I. M. and R. M. Solow (1981), Wage Bargaining and Employment, *American Economic Review*, 71, 96-101

Manning, A. (1987), An Integration of Trade Union Models in a Sequential Bargaining Framework, *Economic Journal*, 97, 121-39

Mendoza, E., A. Razin, and L. Tesar (1994), Effective Tax Rates in Macroeconomics: Cross-country Estimates of Tax Rates on Factor Incomes and Consumption, *Journal of Monetary Economics*, 34, 297-323

Nickell, S. J. (1982), *A Bargaining Model of the Phillips Curve*, Center for Labour Economics Discussion Paper, 130

Nickell, S.J. and R. Layard (1999), Labor Market Institutions and Economic Performance, in O. Ashenfelter and D. Card (eds.), *Handbook of Labor Economics*, vol. III

OECD (1994), *The OECD Jobs Study*, Paris, OECD

Oswald, A. J. (1982), The Microeconomic Theory of the Trade Union, *Economic Journal*, 92, 269-83

Phelps, E.S. (1968), Money-wage Dynamics and Labor Market Equilibrium, *Journal of Political Economy*, 76, 678-711

Pissarides, C. A. (1998), The Impact of Employment Tax Cuts on Unemployment and Wages; The Role of Unemployment Benefits and Tax Structure, *European Economic Review*, 42, 155-183

Rebelo, S. (1991), Long-run Policy Analysis and Long-run Growth, *Journal of Political Economy*, 99, 500-21

Stokey, N.L. and S. Rebelo (1995), Growth Effects of Flat-tax Rates, *Journal of Political Economy*, 103, 519-50

Van der Ploeg, F. (1987), Trade Unions, Employment and Investment: a Non-cooperative Approach, *European Economic Review,* 31, 1465-92

Westermark, A. (1999), *A Model of Union Formation*, WP 1999:8, Department of Economics, Uppsala University