EUTAX

A MODEL OF TAX POLICY, UNEMPLOYMENT AND CAPITAL FLOWS

Peter Birch Sørensen
Economic Policy Research Unit
Institute of Economics, University of Copenhagen
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I. General features of EUTAX

This technical working paper serves to document an applied general equilibrium model called EUTAX, presented in non-technical form in Sørensen (2001). The model describes the international spillover effects of national tax policies via the world capital market and illuminates the effects of various forms of international tax coordination. It also illustrates the effects of tax policies on the labour market in an integrated world economy with structural unemployment. In the empirical applications, the model is calibrated to describe the economies of the European Union and the interaction between the EU economy and the rest of the OECD. Hence the name EUTAX.

The model is static, describing a stationary long-run equilibrium. Variations in endogenous variables may be interpreted as *level* changes in a time path of exogenous steady-state growth. In each national economy firms combine internationally mobile capital with immobile labour to produce a homogeneous internationally traded good. Each country is inhabited by a large number of identical households endowed with a predetermined stock of human as well as non-human wealth. A consumer may consume his initial non-human wealth immediately, or he may invest it in the capital market at a rising marginal transaction cost. In the latter case he accumulates a capital stock earning an interest which may be consumed along with the principal at the end of the period. The transaction cost may be thought of as the cost of financial intermediation; its role is analogous to the role played by consumer time preference in an explicitly intertemporal model. Weighing the transaction cost against the return to capital, the utility-maximising consumer chooses to increase his supply of capital ('savings') as the after-tax real rate of interest increases. While *endowments* are exogenous, the supply of productive *capital* is thus endogenous.

The product market is competitive, but the labour market is characterized by imperfect competition. Workers are organized in decentralized monopoly trade unions, and each union sets the real wage and the length of the working day for its sector with the purpose of maximising the sum of utilities of its members, subject to the 'right-to-manage' constraint that employers choose the total input of working hours with the purpose of maximising their profits. Union market power leads to some amount of involuntary unemployment as the employed workers' gain from wages above the market-clearing level outweighs the income loss from unemployment. After-tax wages are set as a mark-up over the representative union member's 'outside option' which is the income-equivalent of the expected utility obtainable outside the sector, depending inter alia on after-tax unemployment benefits and on the level of unemployment. Because of rising marginal disutility of work, the working hours set by unions are an increasing function of the after-tax real wage rate.

The world economy is divided into two main regions called the European Union (EU) and the Rest of the World (ROW). Both of the two regions consist of several countries. Capital is imperfectly mobile across nations, and the supply of capital to an individual country is an increasing function of the rate of return offered in that country. The EUTAX model does not explicitly allow for uncertainty, but an incentive for portfolio diversification is generated by assuming that the consumer's total stock of capital is a CES-aggregate of the capital stock invested in the different countries. With a finite substitution elasticity between different national assets, this specification implies that the consumer's aggregate capital stock tends to be more productive - generating a higher net income - if it is spread across countries rather than concentrated in one jurisdiction. The interpretation is that portfolio diversification enables consumers to increase their risk-adjusted (certainty-equivalent) income from capital. By parametrically varying the elasticity of substitution between assets invested in different countries, one can vary the degree of capital mobility. In particular, the model is designed to allow for a higher degree of capital mobility within the EU than between the EU and the rest of the world.

The government of each country levies taxes on labour income, unemployment benefits and capital income (including pure profits), and revenues are spent on unemployment benefits and on an exogenous expenditure component covering all other public expenditures.

The model relies on simple functional forms to secure analytical tractability and to allow easy identification of the key structural parameters determining the quantitative properties of the model.

Part II of the paper describes the household sector, the business sector, the labour market, the capital market, and the government sector. Part III summarizes the parameters, variables and equations of the model.

II. Deriving the equations of EUTAX

In the following, all variables should be understood to refer to a particular country, but country subscripts are left out to avoid notational clutter whenever no misunderstanding is possible.

II.1. The household sector

The preferences of the representative consumer in the representative country are given by the quasi-linear utility function

$$U = \overbrace{C}^{\substack{\text{utility from}\\ \text{consumption}}} - \overbrace{H \cdot \frac{h^{1+\varepsilon}}{1+\varepsilon}}^{\substack{\text{disutility from}\\ \text{work}}}, \qquad \varepsilon > 0 \tag{1}$$

where C is consumption, h is hours of work, and H is an exogenous endowment of human capital. Note that the disutility of work varies in proportion to the consumer's stock of human capital, implying that his productivity in home production and in leisure activities varies pari passu with his productivity in the labour market.

The budget constraint for an employed worker is

$$C = \overbrace{wH(1-t)h}^{\substack{\text{after-tax}\\ \text{labour income}}} + \overbrace{\rho S}^{\substack{\text{after-tax}\\ \text{capital income}}} + \overbrace{(1-\tau)\pi}^{\substack{\text{after-tax}\\ \text{profit income}}}$$

$$+ \overbrace{T}^{\substack{\text{government} \\ \text{transfer}}} + \overbrace{V - c}^{\substack{\text{initial endowment net of} \\ \text{transaction costs}}} \tag{2}$$

where w is the real hourly wage rate per unit of human capital (the reward to an extra year of schooling), t is the effective tax rate on labour income (which may include social security taxes and indirect taxes on consumption), ρ is the average real *after-tax* return to saving, S is the consumer's supply of capital ('saving'), π is the country's average pre-tax profit income per capita, τ is the effective tax rate on capital income and profits, T is a lump sum government transfer paid out in an equal amount to all citizens, V is an exogenous average initial endowment of non-human wealth, and c is a transaction cost. The idea underlying (2) is that the consumer may either consume his initial non-human wealth V right away, or he may invest (part of) it in the capital market to earn interest income which may be consumed along with the principal at the end of the period. If the consumer chooses to channel some of his initial wealth to business firms via the capital market, he incurs a transaction cost which is an increasing function of the fraction of wealth converted into productive business capital, i.e.

$$c = \frac{1}{\varphi + 1} \left(\frac{S}{V} \right)^{\varphi + 1} \cdot V, \qquad \varphi > 0 \tag{3}$$

The transaction cost may be thought of as the cost of financial intermediation. By introducing this variable, we obtain a meaningful trade-off between 'immediate' and 'postponed' consumption without introducing explicit dynamics into the model. Weighing the transaction cost against the positive return to capital, the consumer maximises utility (1) with respect to S, subject to (2) and (3). The solution to this problem yields the 'savings schedule'

$$S = \rho^{\frac{1}{\varphi}} \cdot V \tag{4}$$

showing that the consumer's capital supply S is proportional to his initial wealth and rising with the after-tax interest rate. Thus, while *endowments* of wealth are exogenous, the supply of productive *capital* is endogenous. Notice also that the net interest elasticity of 'saving' is given by $1/\varphi$.

Having optimised his total capital supply in accordance with (4), the consumer must allocate this capital between assets invested in the EU, S^u, and assets invested in the rest of the world, S^n, with the purpose of maximising his total after-tax income from capital $\rho S = \rho_u S^u + \rho_n S^n$. In the present model which does not explicitly allow for uncertainty, an incentive for portfolio diversification can be generated by assuming that the consumer's total capital stock is a CES-aggregate of the capital stock invested in the two regions:

$$S = \left[\Psi^{-\frac{1}{\sigma}} \left(S^u\right)^{\frac{\sigma+1}{\sigma}} + \left(1-\Psi\right)^{-\frac{1}{\sigma}} \left(S^n\right)^{\frac{\sigma+1}{\sigma}}\right]^{\frac{\sigma}{\sigma+1}}, \qquad 0 < \Psi < 1, \qquad \sigma > 0 \tag{5}$$

With a finite substitution elasticity σ between the two asset types, this specification implies that the total capital stock tends to be more productive - generating a higher after-tax income - if it is spread across the two regions rather than concentrated in one region. Maximising total capital income with respect to S^u and S^n subject to (5), the consumer will choose the portfolio allocation rules

$$S^u = \left(\frac{\rho_u}{\rho}\right)^{\sigma} \Psi S \tag{6}$$

$$S^n = \left(\frac{\rho_n}{\rho}\right)^{\sigma} \left(1-\Psi\right) S \tag{7}$$

where the average net return to saving is given by

$$\rho = \left[\Psi \rho_u^{\sigma+1} + \left(1-\Psi\right) \rho_n^{\sigma+1}\right]^{\frac{1}{\sigma+1}} \tag{8}$$

In a second stage of portfolio optimisation, the consumer must allocate the total capital stocks invested in the two regions across the individual countries within each region. By analogy to (5), the total capital stock invested in the EU is specified as

$$S^u = \left[\phi_1^{-\frac{1}{\omega}} \left(S^{u1}\right)^{\frac{\omega+1}{\omega}} + \ldots\ldots + \phi_{\overline{m}}^{-\frac{1}{\omega}} \left(S^{u\overline{m}}\right)^{\frac{\omega+1}{\omega}}\right]^{\frac{\omega}{\omega+1}} \tag{9}$$

$$\omega > 0, \qquad 0 < \phi_v < 1, \qquad \sum_{v=1}^{\overline{m}} \phi_v = 1$$

where the capital stock invested in EU country v by is denoted by S^{uv}, and where $\overline{m}$ is the number of EU countries. The pre-tax real interest rate in country v is r_v, and the country levies a source-based capital income tax τ_v. In the absence of systematic exchange of information among national tax administrations, the consumer's home country is assumed to be unable to levy a tax on his foreign-source capital income, so the source tax τ_v is also the final tax paid by the consumer on his investment in country v. The consumer maximises his total net income from EU assets $\rho_u S^u = \sum_{v=1}^{\overline{m}} r_v (1 - \tau_v) S^{uv}$ with respect to S^{uv}, subject to (9), implying the investment rule

$$S^{uv} = \left[\frac{r_v (1 - \tau_v)}{\rho_u} \right]^{\omega} \phi_v S^u, \qquad v = 1, ..., \overline{m} \tag{10}$$

and an average net return to EU assets equal to

$$\rho_u = \left[\sum_{v=1}^{\overline{m}} \phi_v \left[r_v (1 - \tau_v) \right]^{\omega+1} \right]^{\frac{1}{\omega+1}} \tag{11}$$

In a similar way, with m denoting the total number of countries in the world and S^{nz} indicating the asset stock invested in ROW country z, the aggregate stock of assets invested in the rest of the world is given by

$$S^n = \left[\upsilon_{\overline{m}+1}^{-\frac{1}{\zeta}} \left(S^{n\overline{m}+1} \right)^{\frac{\zeta+1}{\zeta}} + ... + \upsilon_m^{-\frac{1}{\zeta}} \left(S^{nm} \right)^{\frac{\zeta+1}{\zeta}} \right]^{\frac{\zeta}{\zeta+1}} \tag{12}$$

$$\zeta > 0, \qquad 0 < \upsilon_z < 1, \qquad \sum_{z=\overline{m}+1}^{m} \upsilon_z = 1$$

and an optimal portfolio allocation across the countries of the rest of the world requires that

$$S^{nz} = \left[\frac{r_z\left(1-\tau_z\right)}{\rho_n}\right]^{\zeta} \upsilon_z S^n, \qquad z = \overline{m}+1, ..., m \tag{13}$$

$$\rho_n = \left[\sum_{z=\overline{m}+1}^{m} \upsilon_z \left[r_z\left(1-\tau_z\right)\right]^{\zeta+1}\right]^{\frac{1}{\zeta+1}} \tag{14}$$

An unemployed worker has a budget constraint similar to (2), except that after-tax wage income $whH\left(1-t\right)$ must be replaced by the after-tax rate of unemployment benefit B. The savings and portfolio allocation choices of unemployed individuals are still given by (4), (6), (7), (12) and (13).

II.2. The business sector

In each country the representative competitive firm produces output Y by means of effective labour input L, capital K, and a fixed factor. The supply of the fixed factor is assumed to be proportional to total population size N in order to eliminate any inherent cross-country productivity differentials arising from differences in country size. The production function has Cobb-Douglas form, implying

$$Y = AL^{\alpha}K^{\beta} \tag{15}$$

$$A \equiv N^{1-\alpha-\beta}, \qquad 0<\alpha<1, \qquad 0<\beta<1, \qquad 0<\alpha+\beta<1$$

where A measures the output contribution of the fixed factor. The firm's real profit is

$$\Pi = Y - rK - wL \tag{16}$$

which must be maximised with respect to K and L, subject to (15). The first-order conditions for the solution to this problem are

$$\alpha A L^{\alpha-1} K^{\beta} = w \tag{17}$$

$$\beta A L^{\alpha} K^{\beta-1} = r \tag{18}$$

From (16) through (18) we get

$$\Pi = (1 - \alpha - \beta) A L^{\alpha} K^{\beta} \tag{19}$$

while (17) and (18) imply

$$K = \left(\frac{\beta}{\alpha}\right) \left(\frac{w}{r}\right) L \tag{20}$$

Inserting (20) into (17) and remembering that $A = N^{1-\alpha-\beta}$, we obtain

$$L/N = \left(\frac{\alpha}{w}\right)^{\frac{1-\beta}{1-\alpha-\beta}} \left(\frac{\beta}{r}\right)^{\frac{\beta}{1-\alpha-\beta}} \tag{21}$$

which may be substituted into (20) to give

$$k \equiv K/N = \left(\frac{\alpha}{w}\right)^{\frac{\alpha}{1-\alpha-\beta}} \left(\frac{\beta}{r}\right)^{\frac{1-\alpha}{1-\alpha-\beta}} \tag{22}$$

Using (19), (21) and (22) and the fact that $A = N^{1-\alpha-\beta}$, we may express the level of profit per worker as a function of factor prices:

$$\pi \equiv \frac{\Pi}{N} = (1 - \alpha - \beta) \left(\frac{\alpha}{w}\right)^{\frac{\alpha}{1-\alpha-\beta}} \left(\frac{\beta}{r}\right)^{\frac{\beta}{1-\alpha-\beta}} \tag{23}$$

Notice finally that effective labour input is defined by

$$L = hH (1 - u) N \tag{24}$$

where u is the rate of unemployment so that $(1-u)N$ is the total number of employed workers.

II.3. The labour market

Workers are organized in decentralized monopoly trade unions setting the wage level w and the number of working hours h so as to maximise the expected utility of their members, subject to the 'right-to manage' constraint that employers unilaterally choose effective labour input with the purpose of maximising profits. Each union covers a sector which is too small to have a significant impact on macroeconomic variables such as the interest rate r and the level and composition of public transfers. As a metaphor, we may think of the national economy as being divided into a large number of identical 'islands'. Each island is a miniature picture of the national economy: the island's work force has representative preferences, and firms have identical technologies across islands. Union behaviour thus yields the same outcome on all islands.

The analysis in section II.1 implies that the trade union's influence on wage rates and working hours does not enable it to affect the consumer's savings decision. We also assume that the actions of the trade union do not significantly affect the profit income of its members (we may assume that this profit income derives mainly from ownership of firms in other islands). Hence the union may take the property income of its members as given and may concentrate on maximising the membership's expected utility from being associated with the union, given by

$$U^u = (1-u)\left[wHh(1-t) - H \cdot \frac{h^{1+\varepsilon}}{1+\varepsilon}\right] + u\overline{U} \tag{25}$$

The term $\overline{U}$ is the representative union member's 'outside option', i.e., the utility he may expect to obtain if he fails to find work on his own island, $\left[wHh(1-t) - H \cdot \frac{h^{1+\varepsilon}}{1+\varepsilon}\right]$ is an employed member's consumer surplus from work, and the island's employment rate $(1-u)$.is a union member's probability of being employed on the island. Using (21) and (24), we may rewrite (25) as

$$U^u = \left(\frac{\alpha}{w}\right)^{\frac{1-\beta}{1-\alpha-\beta}} \left(\frac{\beta}{r}\right)^{\frac{\beta}{1-\alpha-\beta}} h^{-1}\left[wh(1-t) - \frac{h^{1+\varepsilon}}{1+\varepsilon} - \frac{\overline{U}}{H}\right] + \overline{U} \tag{26}$$

In maximising U^u, the union takes the outside option $\overline{U}$ as given. Maximising (26) with respect to h, one finds that the union's choice of working hours will be dictated by the first-order condition

$$\frac{h^{1+\varepsilon}}{1+\varepsilon} = \frac{\overline{U}}{\varepsilon H} \tag{21}$$

Further, by using (24) it turns out that the first-order condition for the maximisation of U^u with respect to the wage level w can be written as

$$(1-\beta)\left(\frac{h^{1+\varepsilon}}{1+\varepsilon} + \frac{\overline{U}}{H}\right) - \alpha w h\,(1-t) = 0 \tag{22}$$

We assume that a worker who fails to find employment on his island faces a probability $1 - f(\overline{u})$ of obtaining a job on some other island and a probability $f(\overline{u})$ of ending up as unemployed. In the latter case he is entitled to an after-tax unemployment benefit $B = b^n \overline{w}\overline{H}\overline{h}\,(1-t)$, where b^n is the net replacement ratio implied by the system of unemployment compensation, and where the bars indicate the average values of the relevant variables outside the worker's initial island. We may therefore write the outside option as

$$\overline{U} = [1 - f(\overline{u})] \cdot \overline{H}\left[\overline{w}\overline{h}\,(1-t) - \frac{\overline{h}^{1+\varepsilon}}{1+\varepsilon}\right] + f(\overline{u}) \cdot b^n \overline{w}\overline{H}\overline{h}\,(1-t)\,, \qquad f' > 0 \tag{23}$$

For concreteness, the function $f(\overline{u})$ is assumed to have the constant-elasticity form

$$f(\overline{u}) = \overline{u}^{\eta}, \qquad \eta > 0 \tag{24}$$

In a symmetric labour market equilibrium we have $w = \overline{w}$, $h = \overline{h}$, $u = \overline{u}$ and $H = \overline{H}$. It then follows from (21) through (24) that

$$h = \left[\left(\frac{\alpha}{1-\beta}\right) w\,(1-t)\right]^{1/\varepsilon} \tag{25}$$

$$u = \left[\frac{(1+\varepsilon)(1-\alpha-\beta)}{(1+\varepsilon)(1-\beta)(1-b^n)-\alpha} \right]^{1/\eta} \tag{26}$$

From (25) we see that the net wage elasticity of working hours is given by the inverse of the marginal disutility of work, $1/\varepsilon$. Equation (26) implies that the equilibrium unemployment rate is higher the higher the pure profit share $(1-\alpha-\beta)$ and the higher the net replacement ratio b^n. For all plausible parameter values one can also show from (26) that structural unemployment will be higher the higher the elasticity of unemployment risk w.r.t. the unemployment rate, i.e., the higher the value of η. These results are intuitive: more generous unemployment benefits generate higher union wage pressure, and a larger volume of pure profits increases the temptation for unions to cut into these rents via aggressive wage claims. Furthermore, a higher value of η indicates a more 'rigid' labour market since it implies that workers who have been made redundant in their original occupation have a lower chance of finding a job in some other sector.

To complete the description of the labour market, we derive the equilibrium wage rate from the condition that the demand for effective labour input, given by (21), must equal effective labour supply, given by (24). Combining these two equations and solving for the wage rate, we get

$$w = \alpha \left(\frac{\beta}{r} \right)^{\frac{\beta}{1-\beta}} \left(\frac{1}{(1-u)\,hH} \right)^{\frac{1-\alpha-\beta}{1-\beta}} \tag{27}$$

II.4. The capital market

We turn now to the equilibrium conditions for the national capital markets. Since assets invested in different countries are imperfect substitutes, there is a separate capital market for each country, although national markets are linked by capital mobility. To derive the supply of capital to an individual country, notice first that the total population of country j may be written as $N_j \equiv s_j N^w$, where N^w is total world population and s_j is country j's share of world population. From equation (4) it follows that the total supply of savings from the residents of country j will be $\rho_j^{\frac{1}{\varphi_j}} N_j V_j = \rho_j^{\frac{1}{\varphi_j}} s_j N^w V_j$. According to (4), (6), and (10), the supply of capital from country j to EU country v is therefore equal to $\left[\frac{r_v(1-\tau_v)}{\rho_{uj}}\right]^{\omega} \phi_{vj} \left(\frac{\rho_{uj}}{\rho_j}\right)^{\sigma} \Psi_j \rho_j^{\frac{1}{\varphi_j}} s_j N^w V_j$. Summing over the capital supplies from all countries in the world, rearranging slightly, and noting that the demand for capital in country v is equal to $s_v N^w k_v$, with k_v given by (22), we may thus write the equilibrium condition for the capital market of EU country v as

$$\underbrace{s_v k_v}_{\substack{\text{demand}\\ \text{for capital}}} = \overbrace{[r_v(1-\tau_v)]^{\omega}\sum_{j=1}^{m} s_j V_j \phi_{jv} \Psi_j \rho_{uj}^{\sigma-\omega} \rho_j^{\frac{1-\sigma\varphi_j}{\varphi_j}}}^{\text{supply of capital}}, \qquad v = 1, ..., \overline{m} \tag{28}$$

In a similar way, it follows from (4), (7), and (13) that the supply of capital from country j to ROW country z equals $\left[\frac{r_z(1-\tau_z)}{\rho_{nj}}\right]^{\zeta} \upsilon_{zj} \left(\frac{\rho_{nj}}{\rho_j}\right)^{\sigma} (1-\Psi_j)\, \rho_j^{\frac{1}{\varphi_j}} s_j N^w V_j$ so that the capital market equilibrium condition in ROW country z may be written as

$$s_z k_z = [r_z(1-\tau_z)]^{\zeta} \sum_{j=1}^{m} s_j V_j \upsilon_{jz} (1-\Psi_j)\, \rho_{nj}^{\sigma-\zeta} \rho_j^{\frac{1-\sigma\varphi_j}{\varphi_j}}, \qquad z = \overline{m}+1, ..., m \tag{29}$$

This completes the description of the private sector of the model.

II.5. The government sector

As mentioned earlier, the government of each country levies a source-based tax on all capital income generated within its jurisdiction but is unable to monitor and tax the foreign-source capital income of domestic residents. The tax rate on capital income (τ) also applies to pure profit income. Balancing its budget, the government is thus subject to the per-capita budget constraint

$$\begin{aligned} T &= (1-u)\, twHh - uB + \tau(rk+\pi) \\ &= wHh\,[t(1-u) - ub^n(1-t)] + \tau(rk+\pi) \end{aligned} \tag{30}$$

where all variables are measured on a per-capita basis. Recalling that b^n is the *net* replacement ratio, we have the identity

$$b^n = \frac{b(1-\mu t)}{1-t}, \qquad 0 \leq \mu \leq 1 \tag{31}$$

where b is the *gross* replacement ratio, defined as the pre-tax rate of unemployment benefit relative to the average pre-tax wage income of an employed worker, and μ is the effective tax rate on benefit income relative to the effective tax rate on labour income. In policy experiments with the model, we may treat either b^n or b as the exogenous policy variable determining the generosity of the benefit system. If b is taken to be the policy variable, we must include equation (31) in the model, whereas (31) is redundant if we treat b^n as exogenous.

II.6. National income and social welfare

By definition, national income must equal the disposable income for the private sector plus the net revenue collected by government. Calculating this sum, one finds that national income per capita (X) is

$$X = (1-u)\, wHh + V\rho^{\frac{1+\varphi}{\varphi}} + \tau rk + \pi \tag{32}$$

It is also of interest to calculate utilitarian social welfare, i.e., the average level of welfare attained in a given country. This magnitude may be found by inserting the private and public budget constraints into the consumer's utility function (1), summing over all consumers (employed as well as unemployed), and dividing by the exogenous population size N. One then finds that utilitarian social welfare (W) is given by

$$W = (1-u)\, H\left[wh - \frac{h^{1+\varepsilon}}{1+\varepsilon}\right] + \left[1 + \left(\frac{\varphi}{\varphi+1}\right)\rho^{\frac{\varphi+1}{\varphi}}\right]V + \pi + \tau rk \tag{33}$$

Essentially, this expression for social welfare is just national income adjusted for the disutility of work, and accounting for the consumption of initial non-human wealth net of transaction costs.

II.7. Residence-based taxation within the EU

The version of the EUTAX model derived above assumes that capital income taxation is purely source-based. In this section I describe how the model may be modified to analyze the effect of the reform of capital income taxation within the EU proposed by Sørensen (2001, section 1.13). According to this proposal all EU countries levy a harmonised source-based capital income tax at the common rate of $\overline{\tau}$. In addition EU countries exchange information with each other to enable each member state to enforce residence-based taxation of capital income from all EU sources. The harmonised source-based tax thus serves only as a preliminary withholding tax for which full credit is given when the residence-based capital income tax is imposed. Under such a system the effective tax rate on all EU source capital income earned by EU citizens is given by the tax rate of the residence country whereas capital income from non-EU sources only carries source-country tax, since there is no exchange of information with third countries.

To model this mixed tax regime, it is useful to introduce a new variable r_j^u denoting the average *pre-tax* return to EU assets earned by a resident in country j:

$$r_j^u = \left[\sum_{v=1}^{\overline{m}} \phi_{jv} r_v{}^{\omega+1} \right]^{\frac{1}{\omega+1}}, \qquad j = 1, ..., m \tag{34}$$

For EU residents who are all subject to residence-based taxation of their capital income from the EU area the after-tax return to EU assets may then be written as

$$\rho_{uj} = (1 - \tau_j)\, r_j^u, \qquad j = 1, ..., \overline{m} \tag{35}$$

whereas for ROW residents who are only subject to the harmonised EU source tax $\overline{\tau}$ the net return to EU assets will be given by

$$\rho_{uj} = (1 - \overline{\tau})\, r_j^u, \qquad j = \overline{m} + 1, ..., m \tag{36}$$

Because of the different tax regimes for EU and ROW residents, the specification of the total capital supply to an EU country must now distinguish between capital supplied from the EU region and capital supplied from ROW. Hence the capital market equilibrium condition for EU country v previously given by (28) must now be respecified as

$$\overbrace{s_v k_v}^{\substack{\text{demand} \\ \text{for capital}}} = \overbrace{r_v^{\omega} \sum_{j=1}^{\overline{m}} (1 - \tau_j)^{\omega} s_j V_j \phi_{jv} \Psi_j \rho_{uj}^{\sigma - \omega} \rho_j^{\frac{1 - \sigma\varphi_j}{\varphi_j}}}^{\text{supply of capital from EU}}$$

$$+ \overbrace{\left[r_v (1 - \overline{\tau}) \right]^{\omega} \sum_{j=\overline{m}+1}^{m} s_j V_j \phi_{jv} \Psi_j \rho_{uj}^{\sigma - \omega} \rho_j^{\frac{1 - \sigma\varphi_j}{\varphi_j}}}^{\text{supply of capital from ROW}}, \qquad v = 1, ..., \overline{m} \tag{37}$$

Finally, the government budget constraint for an EU country must be modified to read

$$T_j = w_j H_j h_j \left[t_j \left(1 - u_j\right) - u_j b_j \left(1 - \mu_j t_j\right)\right] + \overline{\tau} r_j k_j + \tau_j \pi_j$$

$$+ \left(\tau_j - \overline{\tau}\right) r_j^u \left(\frac{\rho_{uj}}{\rho_j}\right)^{\sigma} \Psi_j \rho_j^{\frac{1}{\varphi_j}} V_j, \qquad j = 1, ..., \overline{m} \tag{38}$$

where the last term on the right-hand side of (38) is the revenue from the residence-based tax on EU source capital income net of the tax credit for the withholding tax $\overline{\tau}$ which has already been paid.

For countries outside the EU the capital market equilibrium condition (29) and the government budget constraint (30) continue to apply.

III. Summarizing the EUTAX model

Taking stock of all the equations derived above, we are now ready to summarize the EUTAXC model. In doing so, we introduce a few self-explanatory auxiliary variables to simplify exposition. Moreover, in specifying the portfolio preference parameters ϕ_j and υ_j, we assume that consumers may have a 'home bias' in favour of assets invested in their own country and that their preference for assets invested in a particular foreign country is proportional to the population size of that country. Finally, our specification of the portfolio preference parameter Ψ_j assumes that the EU and the ROW have symmetric degrees of home bias.

Parameters

Structural parameters which are not country-specific:

$m =$ total number of countries in the world

$\overline{m} =$ number of EU countries

$\sigma =$ elasticity of substitution between EU and ROW assets

$\omega =$ elasticity of substitution between national assets within EU

$\zeta =$ elasticity of substitution between national assets within ROW

$\Psi =$ degree of home bias between EU and ROW

$\phi =$ degree of home bias within EU

$\upsilon =$ degree of home bias within ROW

Structural parameters which may vary across countries:

$\alpha =$ elasticity of output w.r.t. labour input (wage share of GDP)

$\beta =$ elasticity of output w.r.t. capital input

$\varepsilon =$ elasticity of marginal disutility of work
($1/\varepsilon =$ net wage elasticity of notional labour supply)

$\varphi =$ elasticity of marginal transaction cost
($1/\varphi =$ net interest elasticity of saving)

$H =$ average skill level of labour force

$V =$ initial per-capita endowment of non-human wealth

$s =$ share of world population

Exogenous country-specific policy variables:

$t =$ effective tax rate on labour income

$\tau =$ effective tax rate on capital income

$b =$ gross replacement ratio: (pre-tax benefits)/(pre-tax average wage rate)

$\mu =$ (effective tax rate on benefits)/(effective tax rate on wages)

Endogenous variables

$b^n =$ net replacement ratio

$u =$ rate of unemployment

$k =$ capital stock per worker

$r =$ real interest rate before tax

$w =$ real hourly wage rate per skill unit

$F =$ wage/rental ratio

$h =$ individual working hours

$\pi =$ real profits per capita

$\rho =$ average after-tax return to saving

$\rho_u =$ average after-tax return to EU assets

$\rho_n =$ average after-tax return to ROW assets

$\Psi_j =$ intensity of preference for EU assets

$\phi_j =$ intensity of preference for national EU assets

$\upsilon_j =$ intensity of preference for national ROW assets

$y =$ real GDP per capita

$X =$ real national income per capita

$R =$ ratio of national income to national product

$T =$ real public transfer per capita (excluding unemployment benefits)

$W =$ utilitarian social welfare per capita

III.1. Summary of the EUTAX model with source-based taxation in all countries

Equations of lowest order in recursive structure:

Intensity of preference for EU assets:

$$\Psi_j = \Psi, \qquad j = 1, 2, ..., \overline{m} \tag{A.1}$$

$$\Psi_j = 1 - \Psi, \qquad j = \overline{m} + 1,\ \overline{m} + 2, ..., m \tag{A.2}$$

Intensity of preference for national EU assets:

$$\phi_{jj} = \phi, \qquad j = 1, ..., \overline{m} \tag{A.3}$$

$$\phi_{jv} = \frac{(1 - \phi)\, s_v}{\sum_{v=1,\ v \neq j}^{\overline{m}} s_v}, \qquad j = 1, ..., \overline{m}; \quad j \neq v \tag{A.4}$$

$$\phi_{jv} = \frac{s_v}{\sum_{v=1}^{\overline{m}} s_v}, \qquad j = \overline{m} + 1, ..., m \tag{A.5}$$

Intensity of preference for national ROW assets:

$$\upsilon_{jz} = \frac{s_z}{\sum_{z=\overline{m}+1}^{m} s_z}, \qquad j = 1, ..., \overline{m} \tag{A.6}$$

$$\upsilon_{jj} = \upsilon, \qquad j = \overline{m} + 1, ..., m \tag{A.7}$$

$$v_{jz} = \frac{(1-v)\, s_z}{\sum_{z=\overline{m}+1,\ z\neq j}^{m} s_z}, \qquad j = \overline{m}+1, ..., m; \quad j \neq z \tag{A.8}$$

Net replacement ratio:

$$b_j^n = \frac{b_j \left(1 - \mu_j t_j\right)}{1 - t_j}, \qquad j = 1, ..., m \tag{A.8}$$

Unemployment rate:

$$u_j = \left[\frac{(1+\varepsilon_j)\left(1 - \alpha_j - \beta_j\right)}{(1+\varepsilon_j)\left(1-\beta_j\right)\left(1 - b_j^n\right) - \alpha_j} \right]^{1/\eta_j}, \qquad j = 1, ..., m \tag{A.9}$$

Simultaneous structure

Individual working hours:

$$h_j = \left[\left(\frac{\alpha_j}{1 - \beta_j} \right) w_j \left(1 - t_j\right) \right]^{\frac{1}{\varepsilon_j}}, \qquad j = 1, ..., m \tag{A.10}$$

Wage level::

$$w_j = \alpha_j \left(\frac{\beta_j}{r_j} \right)^{\frac{\beta_j}{1-\beta_j}} \left(\frac{1}{h_j H_j \left(1 - u_j\right)} \right)^{\frac{1-\alpha_j-\beta_j}{1-\beta_j}}, \qquad j = 1, ..., m \tag{A.11}$$

Capital per worker invested in country j:

$$k_j = \left(\frac{\alpha_j}{w_j} \right)^{\frac{\alpha_j}{1-\alpha_j-\beta_j}} \left(\frac{\beta_j}{r_j} \right)^{\frac{1-\alpha_j}{1-\alpha_j-\beta_j}}, \qquad j = 1, ..., m \tag{A.12}$$

Capital market equilibrium in EU country v:

$$s_v k_v = [r_v (1-\tau_v)]^{\omega} \sum_{j=1}^{m} s_j V_j \phi_{jv} \Psi_j \rho_{uj}^{\sigma-\omega} \rho_j^{\frac{1-\sigma\varphi_j}{\varphi_j}}, \qquad v = 1, ..., \overline{m} \tag{A.13}$$

Capital market equilibrium in ROW country z:

$$s_z k_z = [r_z (1-\tau_z)]^{\zeta} \sum_{j=1}^{m} s_j V_j \upsilon_{jz} (1-\Psi_j) \rho_{nj}^{\sigma-\zeta} \rho_j^{\frac{1-\sigma\varphi_j}{\varphi_j}}, \qquad z = \overline{m}+1, ..., m \tag{A.14}$$

Average net return to saving:

$$\rho_j = \left[\Psi_j \rho_{uj}^{\sigma+1} + (1-\Psi_j) \rho_{nj}^{\sigma+1}\right]^{\frac{1}{\sigma+1}}, \qquad j = 1, ..., m \tag{A.15}$$

Average net return to EU assets:

$$\rho_{uj} = \left[\sum_{v=1}^{\overline{m}} \phi_{jv} [r_v (1-\tau_v)]^{\omega+1}\right]^{\frac{1}{\omega+1}}, \qquad j = 1, ..., m \tag{A.16}$$

Average net return to ROW assets:

$$\rho_{nj} = \left[\sum_{z=\overline{m}+1}^{m} \upsilon_{jz} [r_z (1-\tau_z)]^{\zeta+1}\right]^{\frac{1}{\zeta+1}}, \qquad j = 1, ..., m \tag{A.17}$$

Equations of higher order

Wage/rental ratio:

$$F_j = \frac{w_j}{r_j}, \qquad j = 1, ..., m \tag{A.18}$$

GDP per capita:

$$y_j = \left[H_j h_j \left(1 - u_j\right)\right]^{\alpha_j} k_j^{\beta_j}, \qquad j = 1, ..., m \tag{A.19}$$

Pure profit per capita:

$$\pi_j = \left(1 - \alpha_j - \beta_j\right) y_j, \qquad j = 1, ..., m \tag{A.20}$$

National income per capita:

$$X_j = \left(1 - u_j\right) H_j w_j h_j + V_j \rho^{\frac{\varphi_j + 1}{\varphi_j}} + \tau_j r_j k_j + \pi_j, \qquad j = 1, ..., m \tag{A.21}$$

Ratio of national income to national product:

$$R_j = \frac{X_j}{y_j}, \qquad j = 1, ..., m \tag{A.22}$$

Public transfer per capita (net of unemployment benefits):

$$T_j = w_j H_j h_j \left[t_j \left(1 - u_j\right) - u_j b_j \left(1 - \mu_j t_j\right)\right] + \tau_j \left(r_j k_j + \pi_j\right), \tag{A.23}$$

$$j = 1, ..., m$$

Utilitarian social welfare:

$$W_j = H_j \left(1 - u_j\right) \left[w_j h_j - \frac{h^{1+\varepsilon_j}}{1 + \varepsilon_j}\right] + V_j \left[1 + \left(\frac{\varphi_j}{\varphi_j + 1}\right) \rho^{\frac{\varphi_j + 1}{\varphi_j}}\right] + \pi_j + \tau_j r_j k_j, \tag{A.24}$$

$$j = 1, ..., m$$

III.2. Summary of EUTAX model with residence-based taxation in the EU

This section summarizes all equations in the version of the EUTAX model incorporating the tax regime described in section II.7 which combines residence-based taxation within the EU with source-based taxation of the return to capital flows between the EU and ROW.

The parameters and exogenous variables in the present modified version of the model are the same as in the version with purely source-based taxation, except that we now introduce the following new exogenous policy variable:

$\overline{\tau}$ = harmonised source-based withholding tax on capital income earned in the EU

All equations which are unchanged relative to the model version with purely source-based taxation carry the same number as in section III.1 and are all marked with an 'A'. Equations which are new are marked by a 'B'.

Equations of lowest order in recursive structure:

Intensity of preference for EU assets:

$$\Psi_j = \Psi, \qquad j = 1, 2, ..., \overline{m} \tag{A.1}$$

$$\Psi_j = 1 - \Psi, \qquad j = \overline{m} + 1,\ \overline{m} + 2, ..., m \tag{A.2}$$

Intensity of preference for national EU assets:

$$\phi_{jj} = \phi, \qquad j = 1, ..., \overline{m} \tag{A.3}$$

$$\phi_{jv} = \frac{(1 - \phi)\, s_v}{\sum_{v=1,\ v \neq j}^{\overline{m}} s_v}, \qquad j = 1, ..., \overline{m}; \quad j \neq v \tag{A.4}$$

$$\phi_{jv} = \frac{s_v}{\sum_{v=1}^{\overline{m}} s_v}, \qquad j = \overline{m}+1, ..., m \tag{A.5}$$

Intensity of preference for national ROW assets:

$$\upsilon_{jz} = \frac{s_z}{\sum_{z=\overline{m}+1}^{m} s_z}, \qquad j = 1, ..., \overline{m} \tag{A.6}$$

$$\upsilon_{jj} = \upsilon, \qquad j = \overline{m}+1, ..., m \tag{A.7}$$

$$\upsilon_{jz} = \frac{(1-\upsilon)\, s_z}{\sum_{z=\overline{m}+1,\; z\neq j}^{m} s_z}, \qquad j = \overline{m}+1, ..., m; \quad j \neq z \tag{A.8}$$

Net replacement ratio:

$$b_j^n = \frac{b_j\left(1-\mu_j t_j\right)}{1-t_j}, \qquad j = 1, ..., m \tag{A.8}$$

Unemployment rate:

$$u_j = \left[\frac{(1+\varepsilon_j)\left(1-\alpha_j-\beta_j\right)}{(1+\varepsilon_j)\left(1-\beta_j\right)\left(1-b_j^n\right)-\alpha_j}\right]^{1/\eta_j}, \qquad j = 1, ..., m \tag{A.9}$$

Simultaneous structure

Individual working hours:

$$h_j = \left[\left(\frac{\alpha_j}{1-\beta_j}\right) w_j\left(1-t_j\right)\right]^{\frac{1}{\varepsilon_j}}, \qquad j = 1, ..., m \tag{A.10}$$

Wage level::

$$w_j = \alpha_j \left(\frac{\beta_j}{r_j}\right)^{\frac{\beta_j}{1-\beta_j}} \left(\frac{1}{h_j H_j (1-u_j)}\right)^{\frac{1-\alpha_j-\beta_j}{1-\beta_j}}, \qquad j = 1, ..., m \tag{A.11}$$

Capital per worker invested in country j:

$$k_j = \left(\frac{\alpha_j}{w_j}\right)^{\frac{\alpha_j}{1-\alpha_j-\beta_j}} \left(\frac{\beta_j}{r_j}\right)^{\frac{1-\alpha_j}{1-\alpha_j-\beta_j}}, \qquad j = 1, ..., m \tag{A.12}$$

Capital market equilibrium in EU country v:

$$s_v k_v = r_v^{\omega} \sum_{j=1}^{\overline{m}} (1-\tau_j)^{\omega} s_j V_j \phi_{jv} \Psi_j \rho_{uj}^{\sigma-\omega} \rho_j^{\frac{1-\sigma\varphi_j}{\varphi_j}}$$

$$+ \left[r_v (1-\overline{\tau})\right]^{\omega} \sum_{j=\overline{m}+1}^{m} s_j V_j \phi_{jv} \Psi_j \rho_{uj}^{\sigma-\omega} \rho_j^{\frac{1-\sigma\varphi_j}{\varphi_j}}, \qquad v = 1, ..., \overline{m} \tag{B.1}$$

Capital market equilibrium in ROW country z:

$$s_z k_z = \left[r_z (1-\tau_z)\right]^{\zeta} \sum_{j=1}^{m} s_j V_j \upsilon_{jz} (1-\Psi_j) \rho_{nj}^{\sigma-\zeta} \rho_j^{\frac{1-\sigma\varphi_j}{\varphi_j}}, \qquad z = \overline{m}+1, ..., m \tag{A.14}$$

Average net return to saving:

$$\rho_j = \left[\Psi_j \rho_{uj}^{\sigma+1} + (1-\Psi_j) \rho_{nj}^{\sigma+1}\right]^{\frac{1}{\sigma+1}}, \qquad j = 1, ..., m \tag{A.15}$$

Average pre-tax return to EU assets:

$$r_j^u = \left[\sum_{v=1}^{\overline{m}} \phi_{jv} {r_v}^{\omega+1}\right]^{\frac{1}{\omega+1}}, \qquad j = 1, ..., m \tag{B.2}$$

Average net return to EU assets earned by EU residents:

$$\rho_{uj} = (1 - \tau_j)\, r_j^u, \qquad j = 1, ..., \overline{m} \tag{B.3}$$

Average net return to EU assets earned by ROW residents:

$$\rho_{uj} = (1 - \overline{\tau})\, r_j^u, \qquad j = \overline{m} + 1, ..., m \tag{B.4}$$

Average net return to ROW assets:

$$\rho_{nj} = \left[\sum_{z=\overline{m}+1}^{m} \upsilon_{jz} \left[r_z \left(1 - \tau_z\right)\right]^{\zeta+1} \right]^{\frac{1}{\zeta+1}}, \qquad j = 1, ..., m \tag{A.17}$$

Equations of higher order

Wage/rental ratio:

$$F_j = \frac{w_j}{r_j}, \qquad j = 1, ..., m \tag{A.18}$$

GDP per capita:

$$y_j = \left[H_j h_j \left(1 - u_j\right)\right]^{\alpha_j} k_j^{\beta_j}, \qquad j = 1, ..., m \tag{A.19}$$

Pure profit per capita:

$$\pi_j = \left(1 - \alpha_j - \beta_j\right) y_j, \qquad j = 1, ..., m \tag{A.20}$$

National income per capita for an EU country:

$$X_j = (1-u_j)\, w_j H_j h_j + V_j \rho_j^{\frac{1+\varphi_j}{\varphi_j}} + \pi_j + \overline{\tau} r_j k_j$$

$$+ (\tau_j - \overline{\tau})\, r_j^u \left(\frac{\rho_{uj}}{\rho_j}\right)^{\sigma} \Psi_j \rho_j^{\frac{1}{\varphi_j}} V_j, \qquad j = 1, ..., \overline{m} \tag{B.5}$$

National income per capita for an ROW country:

$$X_j = (1-u_j)\, H_j w_j h_j + V_j \rho^{\frac{\varphi_j+1}{\varphi_j}} + \tau_j r_j k_j + \pi_j, \qquad j = \overline{m}+1, ..., m \tag{A.21}$$

Ratio of national income to national product:

$$R_j = \frac{X_j}{y_j}, \qquad j = 1, ..., m \tag{A.22}$$

Public transfer per capita (net of unemployment benefits) in an EU country:

$$T_j = w_j H_j h_j \left[t_j (1-u_j) - u_j b_j \left(1 - \mu_j t_j\right)\right] + \overline{\tau} r_j k_j + \tau_j \pi_j$$

$$+ (\tau_j - \overline{\tau})\, r_j^u \left(\frac{\rho_{uj}}{\rho_j}\right)^{\sigma} \Psi_j \rho_j^{\frac{1}{\varphi_j}} V_j, \qquad j = 1, ..., \overline{m} \tag{B.6}$$

Public transfer per capita (net of unemployment benefits) in an ROW country:

$$T_j = w_j H_j h_j \left[t_j (1-u_j) - u_j b_j \left(1 - \mu_j t_j\right)\right] + \tau_j \left(r_j k_j + \pi_j\right), \tag{A.23}$$

$$j = \overline{m}+1, ..., m$$

Utilitarian social welfare in an EU country:

$$W_j = H_j\left(1-u_j\right)\left[w_j h_j - \frac{h^{1+\varepsilon_j}}{1+\varepsilon_j}\right] + V_j\left[1+\left(\frac{\varphi_j}{\varphi_j+1}\right)\rho^{\frac{\varphi_j+1}{\varphi_j}}\right] + \pi_j + \overline{\tau} r_j k_j,$$

$$+\left(\tau_j - \overline{\tau}\right) r_j^u \left(\frac{\rho_{uj}}{\rho_j}\right)^{\sigma} \Psi_j \rho_j^{\frac{1}{\varphi_j}} V_j, \qquad j = 1, ..., \overline{m} \tag{B.7}$$

Utilitarian social welfare in an ROW country:

$$W_j = H_j\left(1-u_j\right)\left[w_j h_j - \frac{h^{1+\varepsilon_j}}{1+\varepsilon_j}\right] + V_j\left[1+\left(\frac{\varphi_j}{\varphi_j+1}\right)\rho^{\frac{\varphi_j+1}{\varphi_j}}\right] + \pi_j + \tau_j r_j k_j, \tag{A.24}$$

$$j = \overline{m}+1, ..., m$$

Reference

Sørensen, Peter Birch (2001). ”Tax Co-ordination in the European Union: What Are the Issues?” Invited paper for the conference on *Macroeconomic Policy Co-ordination in the EU: How Far Should It Go?*, organized by the Economic Council of Sweden, Stockholm, 28 May 2001.