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Fighting Tax Competition in the Presence of Unemployment: Complete versus Partial Tax Coordination

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Abstract

In this paper, we analyze the welfare consequences of tax coordination agreements which cover taxes on mobile capital and immobile labor, respectively. In doing so, we take into account two important institutional details. First, we incorporate decentralized wage bargaining, giving rise to involuntary unemployment. Second, we distinguish between complete tax coordination, which effectively covers both tax instruments, and the more plausible case of partial tax coordination, where one tax is marginally increased by all countries, while the other tax rate can still be freely chosen by all countries. It is shown that complete tax coordination remains to be welfare enhancing in the presence of unemployment. In contrast, for partial tax coordination, the welfare effects become ambiguous and are different to the case of competitive labor markets.

JEL Classification: H21, H87, J51

Keywords: factor taxation, (partial) tax coordination, wage bargaining, unemployment

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1 Introduction

Fiscal competition among countries has received increasing attention as jurisdictions are connected by mobile capital. This has created an extensive literature on the (un)desirability of international tax competition.[1] As one basic result, it has been pointed out that benevolent governments ignore the external effect their tax policy has on the tax base of other countries via capital mobility (Wildasin 1989). Thus, each policy instrument that is able to increase the attractiveness of domestic capital employment, e.g., tax cuts, will be excessively used by all countries. Consequently, the resulting equilibrium is inefficient from a worldwide perspective as the public good provision is too low compared with the Samuelson rule (Samuelson 1954). Theoretically, all countries would be better off by jointly increasing their level of taxation in order to capture resources from capital owners since the latter cannot escape a worldwide tax increase.

However, this standard tax competition result of undertaxation in the uncoordinated Nash equilibrium has been challenged by incorporating various existing institutional characteristics pointing out that a joint tax increase may even be welfare worsening. The level of taxation may even be to high in the uncoordinated equilibrium if, e.g., non-benevolent governments are taken into account (Edwards and Keen 1996), federal structures are considered which give rise to vertical fiscal externalities (Keen and Kotsogiannis 2002, 2003) or public input goods are incorporated (Noiset 1995).

In this paper, we take a different view by analyzing whether a coordinated tax increase may be welfare worsening even if the Nash equilibrium is characterized by undertaxation. In doing so, we allow for two institutional details to be found in many countries and analyze the way they interact if tax coordination is carried out. First, we incorporate that labor markets are frequently characterized by wage bargaining, giving rise to involuntary unemployment. Second, and in contrast to parts of the previous literature, we take into account that an international coordination agreement is unlikely to cover all policy instruments available to local governments. In fact, it is more plausible that tax coordination is carried out with regard to *one* tax rate only, whereas all governments are nevertheless free to choose their remaining tax instrument(s) afterwards. This approach can also be motivated by the existence of federal structures, where one tax rate is (jointly) determined on a federal level while local states can nevertheless choose another tax rate non-cooperatively.

So far, the literature that combines optimal taxation with unemployment mostly concentrated on characterizing the structure of optimal taxation in a small open economy by incorporating wage bargaining (see, e.g., Richter and Schneider 2001 or Koskela

[1] This branch of literature was initiated by the seminal contributions of Wilson (1986) and Zodrow and Mieszkowski (1986). For a survey, see Wilson (1999).

and Schöb 2002) or efficiency wages (Eggert and Goerke 2004). One exception is the contribution by Fuest and Huber (1999b), where tax coordination is addressed explicitly. Their analysis is motivated by the presumption that, as tax competition puts a downward pressure on tax rates, this may be desirable if involuntary unemployment calls for a reduced level of taxation. Fuest and Huber put forward that in the presence of involuntary unemployment, due to decentralized wage negotiations, tax competition might be welfare enhancing. In particular, they argue that, for a labor demand elasticity which is smaller than one, a coordinated increase in the capital tax and the wage tax, respectively, reduces welfare. However, they discuss complete coordination only, i.e. they consider a coordinated increase in one tax rate while keeping the respective other tax rate constant.

On the other hand, the existing literature on partial policy coordination has not yet taken into account imperfections on the labor market. Starting with the seminal contribution by Copeland (1990) with respect to trade policy, several authors have analyzed how countries might react to tax coordination if other policy instruments are available which have *not* been subject to the coordination agreement. In response to a joint tax increase, governments may adjust their provision of a public input good (Fuest 1995), other tax rates or depreciation allowances (Fuest and Huber 1999a), tax auditing activities (Cremer and Gahvari 2000) or a tax on a complementary factor (Marchand et al. 2003). Intuitively, in all cases, countries try to compete back to their initial Nash equilibrium. However, as shown by Wehke (2006) for the case of a fully competitive labor market, the total welfare effect of partial tax coordination not only depends on the extent to which all countries are able to compete back to the initial Nash equilibrium. In addition, there may also be positive or negative welfare effects if the distortion of the pre-existing tax system is altered.

The aim of the present paper is to contribute to the literature of tax coordination by taking into account labor market imperfections due to decentralized wage bargaining as well as incomplete, i.e. partial, tax coordination agreements. In doing so, a similar model setup is used as in Wehke (2006), where partial tax coordination is analyzed in the presence of a fully competitive labor market. In detail, we allow for less than 100 percent profit taxation and, in contrast to many other models of wage negotiations (see, e.g., Koskela and Schöb 2002), we assume the marginal disutility of supplying labor to be non-constant (see, e.g., Keen and Marchand 1997 or Fuest and Huber 1999b). It is first shown that, in the presence of unemployment due to wage bargaining, the usage of distortionary taxation deviates from the case of fully competitive labor markets. However, unemployment does not justify different policy conclusions with respect to complete tax coordination. The welfare effect is always positive and qualitatively similar to the scenario of perfect labor markets. In contrast, for partial tax coordination, the welfare effects are shown to become ambiguous and are different to the case of a flexible labor market.

The paper is organized as follows. The basic model of a small unionized country is set up in section 2. Section 3 presents each country's optimal behavior in the uncoordinated equilibrium. Complete tax coordination is considered in section 4, where one tax rate is jointly increased and the respective other tax rate is kept constant. This assumption is then relaxed in section 5, where we study the welfare consequences of partial tax coordination. Finally, the last section summarizes and concludes.

2 The model

We consider an economy that consists of many small and symmetric countries. Each country is inhabited by a large number of (homogenous) households, the number of which we normalize to one. The (representative) household is endowed with a fixed amount of capital $\overline{K}$ and earns a net profit $(1 - t_\pi)\pi$ from national firm ownership. Capital is assumed to be perfectly mobile and can be invested in the home country or in the rest of the world to earn a constant net return r per unit. The profit income accruing to private households is interpreted as the average net profit in the country. In addition to capital income $r\overline{K}$ and net profit income, households obtain income by supplying labor, where we treat labor as perfectly immobile between countries and the household's total time endowment is normalized to one.[2] As we will assume that the net wage rate w is determined by decentralized wage bargaining, each household will be underemployed in the sense that her choice of labor supply is rationed by labor demand. Defining $e(L)$ to be the total disutility from supplying labor this implies that the net wage rate w exceeds the marginal disutility $e'(L)$, where we assume $e(0) = 0$, $e'(L) > 0$ as well as $e''(L) > 0$. Alternatively, we can think of the households to be heterogeneous and divided into L employed households and $(1 - L)$ unemployed households. In this case, we may interpret $e(L)$ to be the aggregate disutility of supplying labor for the whole country and $w > e'(L)$ indicates involuntary unemployment of the $(1 - L)$ households.[3]

Total private utility V is assumed to be additive and consists of two parts. The first one is assumed to be linear in income and represents the net benefit from supplying labor plus capital and net profit income. The second part is utility derived from public good consumption $u(G)$, where $u' > 0$ and $u'' < 0$. Hence,

$$V = wL - e(L) + r\overline{K} + (1 - t_\pi)\pi + u(G). \tag{1}$$

In the following, we will assume that the disutility from labor supply is quadratic, i.e.

[2] The results would not change if we define two separate groups of households, called capitalists and workers.

[3] For a fully flexible labor market, as considered in Wehke (2006), we would have $w = e'(L)$.

$e'''(L) = 0$, for algebraic convenience.[4]

Each country's government provides the public good G and raises revenue R with a non-distortionary profit tax t_π levied on the rent of a third (non-specified) factor,[5] a source-based capital tax t_r on net capital income from domestic capital input, and a wage tax t_w on net labor income. We will assume that the profit tax is restricted to a maximum level $\bar{t}_\pi$, where $0 \leq \bar{t}_\pi \leq 1$, and its revenue does not suffice to ensure a first-best solution, i.e. to provide the public good at the first-best level as well as designing the tax system in order to fully correct for the labor market distortion. The government budget constraint is given by

$$G = t_\pi \pi + t_r r K + t_w w L = R, \tag{2}$$

where the marginal cost of the public good is normalized to one, implying a linear marginal rate of transformation of one between private output and the public good. In what follows, the government will be treated to be a Stackelberg leader towards the private sector behavior, including the wage negotiations between firms and trade unions.

Turning to the production side of the small jurisdiction, a homogenous output good Y is produced by a large number of identical firms, whose number we can normalize to one. The (representative) firm utilizes capital K and labor L as the only variable factor inputs to production. To keep the model manageable, we use a production function with a constant elasticity of substitution between labor and capital as well as decreasing returns to scale in both factors:

$$Y = F(K, L) = \left[\left(K^{\frac{\sigma-1}{\sigma}} + L^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \right]^{1-1/\varepsilon}, \tag{3}$$

where $\varepsilon > 1$ indicates decreasing returns to scale in capital and labor due to the existence of a third (fixed) factor such as land. The parameter $\sigma \geq 0$ denotes the elasticity of substitution between capital and labor. Let the output good be the numeraire.[6]

Taking gross factor prices $\tilde{r} = (1 + t_r)r$ and $\tilde{w} = (1 + t_w)w$ as given, firms maximize profits and thereby choose capital and labor inputs according to $\partial F(K, L)/\partial K = \tilde{r}$

[4] The literature on tax policy in the presence of wage bargaining often treats the marginal disutility of labor as a constant term, i.e. $e''(L) = 0$. See, e.g., Boeters and Schneider (1999) or Koskela and Schöb (2002). Thus, our assumption of a quadratic disutility is even more general than the previous literature. Note that $e''(L) > 0$ implies that the household's preferred labor supply is increasing the net wage rate.

[5] A tax on profits is indeed non-distortionary in this setting, as we assume firms to be immobile. This is a standard assumption in the existing literature on capital mobility. For models with firm mobility see, e.g., Richter and Wellisch (1996), Janeba (1998) or Aronsson and Sjögren (2004).

[6] Equation (3) can also be interpreted as being a linear-homogenous production function in capital and labor, where the output good faces imperfect competition on the world product market due to monopolistic competition (see Dixit and Stiglitz 1977). In this case, $\varepsilon > 1$ represents the constant price elasticity of output demand.

and $\partial F(K,L)/\partial L = \tilde{w}$. Together with the above production function, this allows us to derive unconditional factor demands $L(\tilde{w},\tilde{r})$ and $K(\tilde{w},\tilde{r})$ with corresponding elasticities that solely depend on the parameters of the productions function, i.e. σ and ε, as well as on the cost share of labor s (see Hamermesh 1993 or, e.g., Koskela and Schöb 2002):

$$\eta_{L,\tilde{w}} = -(1-s)\sigma - s\varepsilon < 0, \tag{4a}$$

$$\eta_{K,\tilde{r}} = -s\sigma - (1-s)\varepsilon < 0, \tag{4b}$$

$$\eta_{L,\tilde{r}} = (1-s)(\sigma - \varepsilon), \tag{4c}$$

$$\eta_{K,\tilde{w}} = s(\sigma - \varepsilon), \tag{4d}$$

where s is given by

$$s = s(\tilde{w},\tilde{r}) = \frac{\tilde{w}^{1-\sigma}}{\tilde{w}^{1-\sigma} + \tilde{r}^{1-\sigma}}.$$

As is common in the literature, we assume capital and labor to be price complements, which is equivalent to suppose $F_{KL} > 0$ as a property of the production function. Consequently, we have $\sigma - \varepsilon < 0$ and the cross-price elasticities (4c) and (4d) are negative in sign as the substitution effect does not outweigh the scale effect.

3 The non-cooperative Nash equilibrium

3.1 Wage bargaining

The small country's net of tax wage rate is supposed to be the outcome of a decentralized union-firm bargain. In particular, we adopt the right-to-manage approach in which the firm can choose employment conditional on the bargained wage rate. For each country, we assume many small and symmetric trade unions that treat government policy, i.e. t_w, t_r and G, as well as the net interest rate r as given. For simplicity, let the total number of trade unions be normalized to one.

Turning to the objective function of the representative trade union, we first assume that all households are trade union members and membership is not subject to changes. The trade union is then interested in maximizing the utility of households as given by equation (1). If the wage negotiation fails, union members receive the outside utility V^o which is, for a small union, given by the member's capital income, average profit income as well as the utility derived from public good consumption, since these numbers are not affected by the outcome of a decentralized wage negotiation:

$$V^o = r\overline{K} + (1-t_\pi)\pi + u(G).$$

Consequently, the trade union's rent from bargaining with the firm is given by

$$\Lambda = V - V^o = wL - e(L).$$

For the representative firm, we assume, as usual, that the outside option is given by zero profits, $\pi^o = 0$.[7] Hence, the rent form bargaining with the trade union is determined by the net of tax profits, $(1 - t_\pi)\pi$.

The Nash maximand of the wage bargaining problem can be written as

$$\Omega = \Lambda^\beta \left[(1 - t_\pi)\pi\right]^{1-\beta},$$

where β denotes the relative bargaining power of the union. The net of tax wage rate w is then implicitly defined by the first-order condition $\Omega_w = 0$ which balances the percentage change in both parties' rents, weighted by their respective bargaining power. This can be rearranged to

$$\widehat{\Omega}_w = \beta \left[w + (w - e')\eta_{L,\tilde{w}}\right] + (1 - \beta)(1 - \varepsilon)s\left(w - \frac{e(L)}{L}\right) = 0. \tag{5}$$

Note that in equation (5) the labor demand elasticity $\eta_{L,\tilde{w}}$, the cost share of labor s as well as the labor demand L, in turn, depend on the gross factor prices $\tilde{w} = w(1+t_w)$ and $\tilde{r} = r(1 + t_r)$. In what follows, we assume that the trade union's bargaining power β is sufficiently large such that $w - e' > 0$ is fulfilled, indicating involuntary unemployment.

Since the government acts as a Stackelberg leader vis-à-vis the private sector, we need to determine how the bargained wage is altered as a reaction to changes in the policy instruments. Our specification of private utility does not allow for an influence of the public good on the wage rate. However, the net wage reactions in response to changes in the tax rates are given by

$$w_i = \frac{\partial w}{\partial i} = -\frac{\widehat{\Omega}_{wi}}{\widehat{\Omega}_{ww}}, \quad i = t_w, t_r,$$

where $\widehat{\Omega}_{ww} < 0$ must hold as a second-order condition of the Nash bargain. Thus, to determine how the wage rate is affected by tax policy, the sign of $\widehat{\Omega}_{wi}$ is important. In detail, we have for the impact of the wage tax rate

$$\widehat{\Omega}_{wt_w} = xs_{t_w} - \frac{\beta\eta_{L,\tilde{w}}\eta_{L,\tilde{w}}e''(L)L}{1 + t_w} - (1 - \beta)(1 - \varepsilon)s\frac{\eta_{L,\tilde{w}}}{1 + t_w}\left(e'(L) - \frac{e(L)}{L}\right), \tag{6}$$

where $x = \beta(w - e')(\sigma - \varepsilon) + (1 - \beta)(1 - \varepsilon)\left(w - e(L)/L\right) < 0$ and $e'(L) > e(L)/L$ due to our assumption that $e(0) = 0$ and $e''(L) > 0$. In equation (6), the first term indicates that an increase in the cost share of labor *ceteris paribus* leads to a reduction in the bargained wage for two reasons. Firstly, the labor demand elasticity increases in absolute terms thereby increasing the union's marginal cost from a wage increase in terms of laid-off workers. Secondly, the reduction in profits following a wage increase

[7] This requires firms to be immobile as supposed above. This assumption is frequently made in the literature (see, e.g., Koskela and Schöb 2002 or Aronsson 2005). With firm mobility, the outside option is given by foreign net of tax profits (see Aronsson and Sjögren 2004).

becomes more pronounced which, in turn, increases the marginal damage to a firm. According to the second term in (6), an increase in the wage tax lowers employment which, in turn, reduces the marginal disutility of labor and renders an increase in employment through a wage cut more interesting for the trade union. Finally, the last term denotes that an increase in wage taxation will lower employment and thus, in turn, the worker's rent from being employed. Furthermore, we have

$$
\begin{aligned}
\widehat{\Omega}_{wt_r} &= xs_{t_r} - \frac{\beta\eta_{L,\tilde{w}}\eta_{L,\tilde{r}}e''(L)L}{1+t_r} - (1-\beta)(1-\varepsilon)s\frac{\eta_{L,\tilde{r}}}{1+t_r}\left(e'(L) - \frac{e(L)}{L}\right), \quad (7)\\
\widehat{\Omega}_{ww} &= xs_w - \frac{\beta\eta_{L,\tilde{w}}\eta_{L,\tilde{w}}e''(L)L}{w} - (1-\beta)(1-\varepsilon)s\frac{\eta_{L,\tilde{w}}}{w}\left(e'(L) - \frac{e(L)}{L}\right)\\
&\quad +\beta(1+\eta_{L,\tilde{w}}) + (1-\beta)(1-\varepsilon)s. \quad (8)
\end{aligned}
$$

The interpretation of equation (7) is analogous to the one with respect to the wage tax rate. The change in the cost share of labor, however, differs among both tax rates and depends on the elasticity of substitution:

$$
\begin{aligned}
s_{t_w} &= \frac{(1-\sigma)(1-s)s}{1+t_w}, \quad (9)\\
s_{t_r} &= -\frac{(1-\sigma)(1-s)s}{1+t_r}. \quad (10)
\end{aligned}
$$

For the change in the gross wage rate $\tilde{w}_{t_w} = w + (1+t_w)w_{t_w}$ we obtain

$$
\tilde{w}_{t_w} = \frac{w\left[\beta(1+\eta_{L,\tilde{w}}) + (1-\beta)(1-\varepsilon)s\right]}{\widehat{\Omega}_{ww}} > 0, \quad (11)
$$

i.e. increasing the wage tax will unambiguously increase the gross wage (and hence reduce employment) since $\widehat{\Omega}_{ww} < 0$ and the numerator of (11) is negative (where the latter follows from the fact that the bargained wage rate must be positive; see Appendix 1).

3.2 Welfare maximization

Assuming a benevolent government, the Lagrangian, to be maximized with respect to G, t_π, t_w and t_r, comprises the total private utility (1), the government budget constraint (2) and a restriction on the maximum level of admissible profit taxation. Hence,

$$
\mathcal{L} = wL - e(L) + r\overline{K} + (1-t_\pi)\pi + u(G) + \lambda\left(t_\pi\pi + t_w wL + t_r rK - G\right) + \mu\left(\bar{t}_\pi - t_\pi\right),
$$

where we keep in mind that $w = w(t_w, t_r, r)$ and $L(\cdot), K(\cdot)$ as well as $\pi(\cdot)$ depend on both gross factor prices $\tilde{r} = r(1+t_r)$ and $\tilde{w} = (1+t_w)w(t_w, t_r, r)$. The parameters λ as well as μ denote Lagrangian multipliers on the government budget constraint and the maximum level of profit taxation, respectively. The first-order conditions with respect to the public good G and the profit tax rate t_π are as follows:

$$u'(G) = \lambda, \tag{12}$$
$$(\lambda - 1)\pi = \mu. \tag{13}$$

According to condition (12), public good provision should be expanded until the marginal utility of public good consumption equals marginal costs of its provision. In our case, the latter is given by the marginal costs of public funds λ since by assumption the marginal rate of transformation between the private and the public good is equal to one. This is referred to as the modified Samuelson rule (see Atkinson and Stern 1974).

Given the complementary slackness condition

$$\mu\,(\bar{t}_\pi - t_\pi) = 0,$$

we can distinguish two cases. Firstly, if the restriction on profit taxation is not binding, $\bar{t}_\pi > t_\pi$, we have $\mu = 0$ and we can infer from (13) that $\lambda = 1$. Tax revenue is then raised non-distortionarily by the profit tax and public good provision is, according to (12), already first-best since $u'(G) = 1$. Secondly, if the restriction is binding, then $t_\pi = \bar{t}_\pi$ and $\mu > 0$ so that $\lambda > 1$ and we are in the more relevant scenario of a second-best world. Public good provision is then inefficiently low, $u'(G) > 1$, because taxation is distortionary (at the margin). In what follows, we restrict our attention to the scenario of second-best taxation, i.e. the case with $\mu > 0$ and $\lambda > 1$.

Turning to the first-order conditions with respect to the tax rates, we have $\partial\mathcal{L}/\partial t_w = 0$ which can be written as

$$0 = \frac{w - e'}{\tilde{w}}\eta_{L,\tilde{w}}\tilde{w}_{t_w} + (\lambda - 1)\left[(1 - \bar{t}_\pi)\tilde{w}_{t_w} - w_{t_w}\right] + \lambda\tilde{w}_{t_w}\left(\frac{t_w}{1 + t_w}\eta_{L,\tilde{w}} + \frac{t_r}{1 + t_r}\eta_{L,\tilde{r}}\right)$$

and $\partial\mathcal{L}/\partial t_r = 0$ which yields

$$\begin{aligned} 0 \;=\; & (w - e')\left(\frac{\eta_{L,\tilde{w}}\tilde{w}_{t_r}(1 + t_r)}{\tilde{w}} + \eta_{L,\tilde{r}}\right) \\ & + (\lambda - 1)\left[(1 - \bar{t}_\pi)\left(\tilde{w}_{t_r}(1 + t_r) + \tilde{w}\frac{1 - s}{s}\right) - w_{t_r}(1 + t_r)\right] \\ & + \lambda\left[\frac{t_w}{1 + t_w}\left(\eta_{L,\tilde{w}}\tilde{w}_{t_r}(1 + t_r) + \tilde{w}\eta_{L,\tilde{r}}\right) + \frac{t_r}{1 + t_r}\left(\eta_{L,\tilde{r}}\tilde{w}_{t_r}(1 + t_r) + \tilde{w}\frac{1 - s}{s}\eta_{K,\tilde{r}}\right)\right]. \end{aligned}$$

Each of the two first-order conditions defines the marginal costs of public funds for the respective tax instrument, defined as the utility loss in absolute terms per unit of additional tax revenue. Any level of tax revenue is then raised efficiently by the available tax instruments if the marginal costs of public funds are equalized among the tax rates.

After some manipulation of the above first-order conditions we can derive the following expression for the (effective) capital tax rate (see Appendix 2):

$$\frac{t_r}{1+t_r} = \frac{\lambda-1}{\lambda}\left[\frac{1-\bar{t}_\pi}{\varepsilon} + \frac{\eta_{L,\tilde{w}}}{\sigma\varepsilon}\frac{w_{t_r}}{\tilde{w}_{t_w}}\frac{wL}{rK} - \frac{\eta_{K,\tilde{w}}}{\sigma\varepsilon}\frac{w_{t_w}}{\tilde{w}_{t_w}}\right], \tag{14}$$

where $x < 0$ is as defined above. Thus, there are only two mechanisms at work for the optimal usage of the capital tax rate. The first term on the right hand side of (14) captures how capital taxation is used as a means to indirectly tax pure profits if the maximum level of the admissible profit tax is less than 100 percent (see Huizinga and Nielsen 1997). It is important to note that the parameter $\varepsilon > 1$ determines the extent to which pure profits are available since $1/\varepsilon = \pi/Y$ represents the profit share of domestic production. The two remaining terms on the right hand side of (14) then indicate that capital taxation is used strategically depending on the interaction between taxation and the wage bargaining result. On the one hand, if an increase in the capital tax is associated with a higher net wage, this provides an incentive to *ceteris paribus* use the capital tax as a subsidy in order to lower the wage rate. If, on the other hand, a higher *wage tax* is associated with a higher net wage, the capital tax will be chosen to be positive *ceteris paribus* in order to provide funds that allow for a reduction in the wage tax. Due to our specification of the production function and private utility, we are able to write the combined effect in a more convenient way so that the capital tax rate becomes

$$\frac{t_r}{1+t_r} = \frac{\lambda-1}{\lambda}\left[\frac{1-\bar{t}_\pi}{\varepsilon} - \frac{s}{1-s}\frac{x(1-\sigma)(1-s)s}{\sigma\tilde{w}\left[\beta(1+\eta_{L,\tilde{w}})+(1-\beta)(1-\varepsilon)s\right]}\right]. \tag{15}$$

Consequently, this component of the capital tax is positive (negative) if σ is greater (less) than one. As explained above, the elasticity of substitution between labor and capital crucially determines the change in the cost share of labor which, in turn, influences both the labor demand elasticity and the extent to which a wage increase affects firm profits.

The effective wage tax rate is given by

$$\frac{t_w}{1+t_w} = \frac{\lambda-1}{\lambda}\left[\frac{1-\bar{t}_\pi}{\varepsilon} + \frac{\eta_{K,\tilde{r}}}{\sigma\varepsilon}\frac{w_{t_w}}{\tilde{w}_{t_w}} - \frac{\eta_{L,\tilde{r}}}{\sigma\varepsilon}\frac{w_{t_r}}{\tilde{w}_{t_w}}\frac{wL}{rK}\right] - \frac{w-e'}{\lambda\tilde{w}}. \tag{16}$$

The interpretation of the wage tax differs from the one of the capital tax as additional mechanisms enter the optimal tax formula. The first part of equation (16) shows a similar pattern as the optimal capital tax rate. Wage taxation is also used to indirectly capture pure profits and the wage tax is *ceteris paribus* higher if an increase in the wage tax or reduction in the capital tax is able to reduce the bargained wage rate. The last term entering the optimal wage tax equation (16), represents the ability of the wage tax to directly reduce the distortion on the (monopolized) labor market by subsidizing labor. This effect goes back to Guesnerie and Laffont (1978) who show that, in a first-best scenario, the price maker's output should be subsidized in order to restore Pareto-efficiency. In the second-best setup discussed here, the subsidy, however, must be weighted by $1/\lambda$ to take into account the welfare costs of distortionary taxation. Combining the two terms which comprise the wage responses of tax policy, we can express the optimal wage tax as follows:

$$\begin{aligned} \frac{t_w}{1+t_w} &= \frac{\lambda-1}{\lambda}\frac{1-\bar{t}_\pi}{\varepsilon} + \frac{\lambda-1}{\lambda}\frac{x(1-\sigma)(1-s)s}{\sigma\tilde{w}\left[\beta(1+\eta_{L,\tilde{w}})+(1-\beta)(1-\varepsilon)s\right]} \\ &+ \frac{\lambda-1}{\lambda}\frac{\left[\beta\eta_{L,\tilde{w}}e''(L)L+(1-\beta)(1-\varepsilon)s\left(e'(L)-\frac{e(L)}{L}\right)\right]}{\tilde{w}\left[\beta(1+\eta_{L,\tilde{w}})+(1-\beta)(1-\varepsilon)s\right]} - \frac{w-e'}{\lambda\tilde{w}}. \end{aligned} \tag{17}$$

The combined effect as given in equation (17), reveals that the impact running through a change in the cost share of labor has the opposite sign to the capital tax rate since the overall level of taxation is not used to strategically influence the bargaining outcome. Additionally, however, it turns out that the wage tax is used to tax rents accruing to intramarginal labor suppliers. Even if we fully abstract from trade union wage setting and the corresponding rent accruing to employed workers beyond the competitive wage level $w = e'(L)$, intramarginal labor suppliers obtain rents which give rise to taxation since the marginal disutility of supplying labor is increasing, i.e. $e'(L), e''(L) > 0$.[8] Summing up, the tax structure presented above resembles the results derived by Koskela and Schöb (2002) and extends them to the case of $e''(L) > 0$.

4 Complete tax coordination

Turning to tax coordination, we first analyze *complete* tax coordination in the sense that coordination is effectively carried out with respect to *both* the capital tax as well as the wage tax rate. In doing so, we consider a special case of complete tax coordination, where one tax rate is marginally increased by all countries and the respective other tax rate is agreed to remain constant throughout. This (rather restrictive) procedure is employed by, e.g., Bucovetsky and Wilson (1991) and Wilson (1995) for the case of perfect labor markets as well as Fuest and Huber (1999b) for imperfect labor markets.

4.1 Complete coordination of the capital tax

For a joint increase in the capital tax rate at a constant wage tax, we first have to determine the repercussions on factor prices and allocation. After the marginal coordination

[8] In fact, it is easy to show that the level of distortionary taxation, i.e. $t_r rK + t_w wL$, is solely used to extract rents from the private sector (from private production if $\bar{t}_\pi < 1$ and from labor suppliers as $e''(L) > 0$) and to correct for the labor market imperfection (as $w - e' > 0$).

has been implemented, we must have that the capital employed in each country is still equal to the country's fixed capital endowment due to our assumption of symmetric jurisdictions. Hence,

$$\overline{K} = K(\tilde{w}, \tilde{r}), \tag{18}$$

where the net interest rate r is now subject to changes if capital demand is altered by a joint policy action. Furthermore, both bargaining parties still choose their optimal wage rate in the new equilibrium, so that after coordination we still have

$$\widehat{\Omega}_w = 0. \tag{19}$$

Totally differentiating the equations (18) and (19) with respect to t_r, w and r yields the factor price reactions for a joint increase in the capital tax rate. We have

$$\begin{aligned} \left.\frac{\partial r}{\partial t_r}\right|_{dK=0}^{dt_w=0} &= -\frac{r\left(w\eta_{K,\tilde{r}}/\eta_{K,\tilde{w}} + w_{t_r}(1+t_r)\right)}{(1+t_r)\left(w\eta_{K,\tilde{r}}/\eta_{K,\tilde{w}} + w_r r\right)} \\ &= -\frac{r}{1+t_r} < 0, \end{aligned}$$

since $w_{t_r}(1+t_r) = w_r r$ and[9]

$$\left.\frac{\partial \tilde{r}}{\partial t_r}\right|_{dK=0}^{dt_w=0} = \left.\frac{\partial w}{\partial t_r}\right|_{dK=0}^{dt_w=0} = \left.\frac{\partial \tilde{w}}{\partial t_r}\right|_{dK=0}^{dt_w=0} = 0.$$

As a consequence, the real allocation is unchanged and capital owners have to bear the full burden of the joint increase in the capital tax as their net remuneration is reduced.[10]

Given the above factor price changes in the presence of (complete) capital tax coordination, the corresponding welfare effect is then easily determined. Using the Lagrangian as the welfare measure for any of the countries involved, we have

$$\begin{aligned} \left.\frac{d\mathcal{L}}{dt_r}\right|_{dK=0}^{dt_w=0} &= \overline{K}\left.\frac{\partial r}{\partial t_r}\right|_{dK=0}^{dt_w=0} + \lambda\overline{K}\left(r + t_r\left.\frac{\partial r}{\partial t_r}\right|_{dK=0}^{dt_w=0}\right) \\ &= -(\lambda-1)\overline{K}\left.\frac{\partial r}{\partial t_r}\right|_{dK=0}^{dt_w=0} > 0. \end{aligned} \tag{20}$$

Consequently, a marginal increase in the capital tax, carried out by all countries, is unambiguously welfare enhancing, given that the level of wage taxation remains

[9] Note that we have to assume for stability that

$$w\eta_{K,\tilde{r}}/\eta_{K,\tilde{w}} + w_{t_\rho}(1+t_\rho) \neq 0.$$

In fact, as is shown later, this term must be positive for the sake of stability of the Nash equilibrium.

[10] The allocation may change, however, if we drop the assumption of a linear private utility. See Aronsson and Wehke (2006).

constant. The intuition is analogous to the case of a fully flexible labor market. As capital is immobile from a worldwide perspective and the allocation of (immobile) labor is unchanged in the course of the coordination, the burden of a joint capital tax increase is fully born by worldwide capital owners and the additional tax revenue is captured lump-sum. Thus, the welfare effect consists of the additional lump-sum tax revenue weighted by the net welfare gain if one unit of tax revenue is spent on public good consumption in a second-best environment. The qualitative welfare effect does not depend on whether the labor market is governed by equalization of labor supply and labor demand or is organized by Nash wage bargaining. The principle insights from the tax competition literature with perfect labor markets thus also hold for countries with distorted labor markets.

4.2 Complete coordination of the wage tax

In this subsection, we now consider the case in which all countries agree to marginally increase their wage tax rate while keeping the capital tax fixed at the level determined in the Nash equilibrium. Theoretically, the possibility of capturing lump-sum resources by means of wage tax coordination is addressed by Bucovetsky and Wilson (1991) and Fuest and Huber (1999b). Depending on the respective labor market organization, however, they derive at different results.

In the present setting, complete wage tax coordination triggers factor price reactions that again have to fulfill equations (18) and (19). In detail, and defining $A \equiv w_r r + w\eta_{K,\tilde{r}}/\eta_{K,\tilde{w}} > 0$,[11] the factor price changes can be written as

$$\left.\frac{\partial r}{\partial t_w}\right|_{dK=0}^{dt_r=0} = -\frac{r}{1+t_w}\frac{\tilde{w}_{t_w}}{A} < 0, \tag{21a}$$

$$\left.\frac{\partial w}{\partial t_w}\right|_{dK=0}^{dt_r=0} = \frac{w}{1+t_w}\frac{-w_r r + w_{t_w}(1+t_w)\eta_{K,\tilde{r}}/\eta_{K,\tilde{w}}}{A}, \tag{21b}$$

$$\left.\frac{\partial \tilde{w}}{\partial t_w}\right|_{dK=0}^{dt_r=0} = \frac{w}{A}\frac{\eta_{K,\tilde{r}}}{\eta_{K,\tilde{w}}}\tilde{w}_{t_w} > 0, \tag{21c}$$

$$\left.\frac{\partial \tilde{r}}{\partial t_w}\right|_{dK=0}^{dt_r=0} = -\frac{\tilde{r}}{1+t_w}\frac{\tilde{w}_{t_w}}{A} < 0. \tag{21d}$$

A marginal increase in the wage tax which is carried out by all countries has an ambiguous effect on the bargained net of tax wage rate. The gross wage rate, however, is unambiguously increased due to the higher tax wedge. Since labor demand falls in the gross wage, the marginal product of capital is reduced in each country which, in turn, calls for a worldwide reduction in the interest rate in order to fully employ capital

[11] Assuming $A > 0$ is equivalent to suppose $dK/dr < 0$. This must hold as a stability condition of the Nash equilibrium. See the Appendix for details.

again. In contrast to marginal capital tax coordination, the joint change in the wage tax will alter the worldwide allocation. In particular, each country's labor employment is, in general, reduced:

$$\left.\frac{\partial L}{\partial t_w}\right|_{dK=0}^{dt_r=0} = L_{\tilde{w}} \left.\frac{\partial \tilde{w}}{\partial t_w}\right|_{dK=0}^{dt_r=0} + L_{\tilde{r}} \left.\frac{\partial \tilde{r}}{\partial t_w}\right|_{dK=0}^{dt_r=0} = \frac{L\tilde{w}_{t_w}}{(1+t_w)A\eta_{K,\tilde{w}}}\varepsilon\sigma \leq 0. \tag{22}$$

Consequently, only for the special case of capital and labor being perfect complements in production, i.e. $\sigma = 0$, a joint change in the wage tax rate does not affect employment. Intuitively, if capital and labor are employed in a constant ratio and the capital employment must remain unchanged, the reduction in the interest rate will exactly suffice to compensate for the initial reduction in labor demand due to the increase in the wage rate.

Given the factor price reactions in (21) and keeping the capital tax constant, the welfare effect of (complete) wage tax coordination is then given by

$$\begin{aligned}\left.\frac{d\mathcal{L}}{dt_w}\right|_{dK=0}^{dt_r=0} &= -(\lambda-1)\overline{K}\left.\frac{\partial r}{\partial t_w}\right|_{dK=0}^{dt_r=0} - (\lambda-1)L\left.\frac{\partial w}{\partial t_w}\right|_{dK=0}^{dt_r=0} + (w - e' + \lambda t_w w)\left.\frac{\partial L}{\partial t_w}\right|_{dK=0}^{dt_r=0} \\ &\quad -(\lambda-1)(1-\bar{t}_\pi)\left.\frac{\partial \pi}{\partial t_w}\right|_{dK=0}^{dt_r=0}. \end{aligned} \tag{23}$$

As is shown in Appendix 3 all terms except of the first one cancel out since the first-order conditions of the initial Nash equilibrium serve as a starting point of coordination. Thus, the welfare effect reduces to

$$\left.\frac{d\mathcal{L}}{dt_w}\right|_{dK=0}^{dt_r=0} = -(\lambda-1)\overline{K}\left.\frac{\partial r}{\partial t_w}\right|_{dK=0}^{dt_r=0} > 0. \tag{24}$$

Similar to the case of the joint increase in the capital tax rate, the only effect that is relevant with respect to welfare is the ability to reduce the net of tax interest rate. Again, the intuition runs in an analogous way as in the case of a fully competitive labor market. Although a marginal increase in the wage tax alters the allocation by changing the wage rate and thus, in turn, employment and profits [see equation (23)], the same is true for the uncoordinated case. As coordination starts from the uncoordinated Nash equilibrium, the corresponding welfare effects are already 'optimized out'. Consequently, the only effect relevant for welfare stems from the reduction in the capital remuneration r, a factor price change that was not part of a small country's uncoordinated decision problem.

Both, the result with respect to complete capital tax coordination as well as the above result of a joint increase in the wage tax are in contrast to the one derived by Fuest and Huber (1999b), who conclude that in the presence of involuntary unemployment a coordinated increase in the capital tax or the labor tax will be welfare worsening if the labor demand elasticity is smaller than one in absolute terms. However, by applying the envelope theorem, complete tax coordination must be welfare enhancing, irrespective of the underlying labor market organization since it nevertheless captures additional lump-sum revenues from the owners of the mobile factor.

Summing up, even if we allow for a labor market distortion that gives rise to involuntary unemployment, (complete) tax coordination is nevertheless desirable. So far, the only difference is that countries use their tax policy to take the labor market imperfection into account. However, the level of taxation is still too low in the Nash equilibrium since each country ignores the externality of its tax policy on other countries.

5 Partial tax coordination

As indicated earlier, the coordination agreement discussed in the previous section is highly restrictive. In fact, it requires that both policy instruments are jointly chosen. A more realistic approach would be to allow for a coordination of only *one* tax rate because coordination agreements are likely to be incomplete in this sense or tax rates are assigned to lower levels of government with the right to set them freely.

Analogous to the procedure in Wehke (2006), we therefore analyze how the results of the preceding section change if one tax rate is jointly increased but the respective other tax rate can still be freely chosen by all countries in order to maximize their own welfare. To keep the calculations manageable and reduce the complexity of the analysis in this section we restrict our attention to the extreme case of a monopoly trade union, i.e. we use $\beta = 1$ in what follows.

5.1 Partial coordination of the capital tax

After all countries have agreed to marginally increase their capital tax rate, we now assume that they can still make use of the wage tax in order to optimally respond to the coordination agreement. Since we know that, in the uncoordinated Nash equilibrium, the wage tax is determined by the first-order condition $\partial \mathcal{L}/\partial t_w = 0$ we have to find out to which extent *all* countries will adjust their wage tax if they face a coordinated increase in the capital tax in order to ensure that this condition still holds. Each country's first-order condition with respect to the wage tax rate yields its marginal costs of public funds for the wage tax instrument:

$$\lambda^{t_w} = \frac{\left(-\frac{w-e'}{\tilde{w}}\eta_{L,\tilde{w}} + (1-\bar{t}_\pi)\right)\tilde{w}_{t_w} - w_{t_w}}{\left(\frac{t_w}{1+t_w}\eta_{L,\tilde{w}} + \frac{t_r}{1+t_r}\eta_{L,\tilde{r}} + (1-\bar{t}_\pi)\right)\tilde{w}_{t_w} - w_{t_w}}. \tag{25}$$

By totally differentiating the right hand side of this expression with respect to both tax rates and taking into account the corresponding factor price reactions for joint changes in tax rates we have:

$$\left.\frac{dt_w}{dt_r}\right|_{dK=0} = -\frac{\partial\lambda^{t_w}/\partial t_r\big|_{dK=0}}{\partial\lambda^{t_w}/\partial t_w\big|_{dK=0}}. \tag{26}$$

Equation (26) gives us the magnitude by which *all* countries have eventually adjusted their wage tax in the new Nash equilibrium if the capital tax has been marginally increased by all countries so that each country's capital employment remains constant in both cases. The sign of (26) can easily be determined, even without discussing its explicit expression. First, note that stability of the Nash equilibrium requires that the marginal cost of public funds of a tax rate must be increasing in this tax rate, if the tax is changed jointly by all countries, i.e. $\partial\lambda^{t_w}/\partial t_w\big|_{dK=0} > 0$.[12] Second, a worldwide increase in the capital tax rate reduces the marginal tax revenue of the wage tax instrument, thereby increasing the marginal costs of public funds of the wage tax, so that $\partial\lambda^{t_w}/\partial t_r\big|_{dK=0} > 0$. This can easily be seen by inspecting (25) and recalling that a joint increase in t_r does not affect the real allocation and thus, in turn, the values of w_{t_w}, $\tilde{w}_{t_w}$ as well as the factor demand elasticities. Since the denominator of (25) is negatively affected by a coordinated increase in the capital tax rate, each country perceives its wage tax to be more distortionary at the margin and is therefore willing to reduce its level of wage taxation. Consequently, in the new Nash equilibrium, we observe that *all* countries have lowered their wage tax as a response to the coordinated increase in the capital tax so that we can sign equation (26) as $dt_w/dt_r|_{dK=0} < 0$.

The overall welfare effect of such partial capital tax coordination is then given by the sum of two effects. First, welfare is increased since the capital tax rate is jointly raised at a constant wage tax and additional lump-sum tax revenue is captured from capital owners; see section 4.1. Second, welfare is reduced as all countries will react by lowering their wage tax at a given capital tax and tax revenues are shifted back to capital owners in a lump-sum manner; to see this, recall (the counterpart of) the discussion in section 4.2 that a joint reduction in the wage tax, at a constant capital tax, unambiguously reduces welfare even in the presence of unemployment. Thus, the net welfare effect crucially depends on the magnitude of the worldwide reaction in the wage tax:

$$\left.\frac{d\mathcal{L}}{dt_r}\right|_{dK=0}^{part.} = \left.\frac{d\mathcal{L}}{dt_r}\right|_{dK=0}^{dt_w=0} + \left.\frac{dt_w}{dt_r}\right|_{dK=0} \left.\frac{d\mathcal{L}}{dt_w}\right|_{dK=0}^{dt_r=0}, \tag{27}$$

where both welfare effects on the right hand side of (27) have already been determined in sections 4.1 and 4.2, respectively.

Before we turn to an expression of the welfare effect in algebraic terms let us first set out an intuition about the mechanisms at work. To begin with, recall that the

[12] To see this, suppose that in all countries the wage tax is slightly higher (lower) than the one in uncoordinated Nash equilibrium. As *all* countries have an incentive to lower (increase) their wage tax, this joint reduction (increase) must lower (increase) the marginal costs of public funds of this tax instrument in order to reach a stable Nash equilibrium.

starting point is a joint increase in the capital tax which does not change the worldwide allocation. However, this coordination agreement disturbs the initial (uncoordinated) Nash equilibrium as it fixes the capital tax rate on a higher level than preferred by each country individually. As a consequence, all countries now engage in tax competition by solely using the wage tax instrument. Each jurisdiction tries to attract mobile capital from the rest of the world by lowering the wage tax but will fail in the new equilibrium as all (symmetric) countries face the same incentive. This may be characterized as an attempt to compete back to the initial Nash equilibrium which has been described in section 3 to be the most preferred allocation from a single country's point of view. The better all countries are able to compete back, the smaller *ceteris paribus* the remaining welfare gain of the marginal coordination of the capital tax. Intuitively, we should expect that the joint wage tax adjustment is not perfectly able to undo the initial coordination gain of the capital tax. To see this point, bear in mind that the initial joint increase in the capital tax does not change the real allocation. The joint wage tax adjustment, however, does alter the allocation on the labor market. Consequently, this joint adjustment is, in general, 'more costly' than the initial capital tax coordination. From a worldwide perspective, the wage tax is still distortionary, while the capital tax then reduces to a lump-sum instrument.

In other words, when trying to compete back to the initial Nash equilibrium, each country will realize that the employment level, in fact, deviates from the one that has been most preferred before. This costly adjustment will induce countries not to perfectly go back to their starting Nash equilibrium. To be even more detailed, recall that a joint adjustment of the wage tax will alter each country's total labor employment according to equation (22). Thus, only for the extreme case of capital and labor being perfect complements in production, i.e. $\sigma = 0$, total employment turns out to remain constant when countries jointly change their level of wage taxation. In this case the joint wage tax adjustment amounts to a lump-sum instrument that shifts resources from the government back to the private sector. The wage tax adjustment is then equally harmless to allocation as is the joint increase in the capital tax (see Appendix 4). As a consequence, the wage tax can be used to perfectly mimic the capital tax so that the initial welfare gain of coordination can be wiped out completely, *ceteris paribus*.

On the other hand, overall welfare might also be affected through a second channel since the pre-existing distortion of the tax system may be altered. To see this intuitively, recall that the starting point of coordination is the Nash equilibrium as has been presented in section 3. In this uncoordinated equilibrium, each government chooses its tax instruments by balancing the trade-off between the corresponding distortions in the private sector with the gain of spending the public revenue. In doing so, each benevolent government is willing to accept a certain distortion (at the margin) in return for the additional benefit from public good consumption. If this pre-existing tax distortion is changed after the coordination agreement has been implemented, we have a second mechanism through which welfare might be affected. In the present case, the initial joint increase in the capital tax does not affect employment as well as gross factor prices. Consequently, we cannot expect to observe a change in the pre-existing distortion due to the initial coordination agreement. Once the capital tax has been fixed on a higher level than preferred by each country individually, however, it is the joint reduction in the wage tax that triggers a change in gross factor prices and employment. In particular, this will have repercussions on the cost share of labor and thus, in turn, on the distortion of the tax system.

Returning to the detailed welfare effect of equation (27) and inserting equations (20), (24) and (26), we obtain after some cumbersome manipulations:[13]

$$\left.\frac{d\mathcal{L}}{dt_r}\right|_{dK=0}^{part.} = -\left.\frac{dt_w}{dt_r}\right|_{dK=0} \frac{(\lambda-1)\tilde{r}\overline{K}}{\eta_{L,\tilde{r}}\tilde{w}(1+\eta_{L,\tilde{w}})}\Upsilon.$$

Since $\eta_{L,\tilde{r}} < 0$ and $(1+\eta_{L,\tilde{w}}) < 0$,[14] the sign of the term Υ also determines the direction of the total welfare effect. This term becomes

$$\frac{\lambda-1}{\lambda}\frac{1-s}{s}\sigma\tilde{w}(1+\eta_{L,\tilde{w}})\frac{\partial}{\partial t_w}\left[\frac{s}{1-s}\frac{(w-e')(\sigma-\varepsilon)(1-s)(1-\sigma)s}{\tilde{w}(1+\eta_{L,\tilde{w}})\sigma}\right]\Bigg|_{dK=0} \tag{28a}$$

$$-\quad \frac{\lambda-1}{\lambda}(\sigma-\varepsilon)\left.\frac{\partial s}{\partial t_w}\right|_{dK=0}^{dt_r=0}\left[(w-e')\left[1-\frac{s(\sigma-\varepsilon)}{\varepsilon}\right]+\frac{e''(L)L\eta_{L,\tilde{w}}}{(1+\eta_{L,\tilde{w}})}\right] \tag{28b}$$

$$+\quad \left.\frac{\partial L}{\partial t_w}\right|_{dK=0}^{dt_r=0}\frac{\eta_{L,\tilde{w}}}{\lambda L}\left[e''(L)L\left[\lambda(1-2\eta_{L,\tilde{w}})+\eta_{L,\tilde{w}}-2\right]+(\lambda-1)\,e'+\frac{\left[e'(L)\right]^2}{w}\right], \tag{28c}$$

where $\tilde{w}_{t_w} > 0$, $A > 0$ and $\eta_{K,\tilde{w}} < 0$.

The last line in (28) is non-negative in sign which *ceteris paribus* indicates that a non-negative overall welfare effect remains even after the wage tax adjustment has taken place. Only for the special case where $\partial L/\partial t_w|_{dK=0}^{dt_w=0} = 0$ this expression reduces to zero. Referring back to equation (22), this is the benchmark case of capital and labor being perfect complements in production ($\sigma = 0$). The joint adjustment of the wage tax then does not alter each country's labor employment since capital and labor are employed in constant proportions and each country's capital employment will remain unchanged in a symmetric equilibrium. It is important to note that each individual country perceives its wage tax to be an instrument that unambiguously changes domestic employment. As all country follow the same incentive, however, the resulting change in the interest rate will finally restore the initial employment level for $\sigma = 0$. Since all countries will find their employment level unchanged, the wage tax

[13] The calculations are available upon request.

[14] Note that for $\beta = 1$ the condition $\widehat{\Omega}_w = 0$ reads $w(1+\eta_{L,\tilde{w}}) = e'\eta_{L,\tilde{w}}$ which implies that the monopoly trade union will choose a wage rate where labor demand is elastic.

can, in fact, be used as an instrument that is equally non-distortionary as has been the case with the initial capital tax coordination. Consequently, for this benchmark case, the wage tax can *ceteris paribus* be used as a perfect mimicry to the capital tax as a means to compete for mobile capital. If the elasticity of substitution is strictly positive, the joint wage tax adjustment is 'costly', since it does change the employment level compared with each country's welfare maximizing choice. For this reason, countries are not willing to use the wage tax to perfectly undo the gain of the capital tax coordination and a positive welfare effect remains. Thus, in general, the last term in (28) may be interpreted as the extent to which all countries are able to compete back to the initial Nash equilibrium.

As indicated earlier, welfare is also affected through another channel. Since the uncoordinated Nash equilibrium is characterized by distortions due to wage negotiations, we might see welfare effects if the pre-existing distortions are altered due to the joint adjustment of the wage tax. In particular, the cost share of labor and the change of the cost share of labor, respectively, determine this distortion. In this context, another benchmark case is worth mentioning.

If the elasticity of substitution between capital and labor is unity, i.e. the production technology is Cobb-Douglas, the cost share remains constant and the welfare effects in the first two lines of (28) vanish.

The second line in (28) turns out to be positive (negative) if $\sigma < (>)1$. From section 3 it is already known that unilateral tax changes have repercussions on the factor demand elasticities through the cost shares of capital and labor, respectively. For joint tax changes, however, it is only the wage tax that is able to affect the factor's cost shares. More precisely, we obtain

$$\left.\frac{\partial s}{\partial t_w}\right|_{dK=0}^{dt_r=0} = -\frac{\tilde{w}_{t_w}\varepsilon(1-s)s(1-\sigma)}{A(1+t_w)\eta_{K,\tilde{w}}}, \tag{29}$$

i.e. a joint reduction in the wage tax increases (reduces) the cost share of labor if the elasticity of substitution is greater (less) than one which, in turn, is associated with a negative (positive) welfare impact. The influence of the factor cost shares runs through its impact on the factor demand elasticities [see the equations in (4)]. In particular, a reduction in the cost share of labor renders the labor demand elasticity $\eta_{L,\tilde{w}}$ less elastic.

According to the first line of equation (28), overall welfare is affected depending on how the term $\frac{s}{1-s}(w-e')(\sigma-\varepsilon)(1-s)(1-\sigma)s/\left[\tilde{w}(1+\eta_{L,\tilde{w}})\sigma\right]$ is altered due to a joint change in the wage tax. In fact, this term corresponds to the second term on the right hand side of the optimal capital tax formula for $\beta = 1$ [see equation (15)]. It captures the extent to which each country uses the capital tax unilaterally to influence the outcome of the wage bargain. Consider the case in which the expression $\frac{s}{1-s}(w-e')(\sigma-\varepsilon)(1-s)(1-\sigma)s/\left[\tilde{w}(1+\eta_{L,\tilde{w}})\sigma\right]$ becomes larger when all countries jointly *reduce* their wage tax rate, indicating that this is associated with a positive overall welfare effect. Referring back to equation (15), the right hand side of the optimal capital tax formula then becomes smaller, whereas the corresponding capital tax adjustment is excluded due to the international coordination agreement. In this case, the capital tax rate is again higher than the level that is individually preferred by each country which, in turn, contributes to higher welfare. Appendix 6 shows that $\frac{\partial}{\partial t_w}\left[\frac{s}{1-s}\frac{(w-e')(\sigma-\varepsilon)(1-s)(1-\sigma)s}{\tilde{w}(1+\eta_{L,\tilde{w}})\sigma}\right]\Big|_{dK=0}$ is negative in sign if the elasticity of substitution between capital and labor falls short of unity implying a positive welfare effect. In contrast, for $\sigma > 1$ this term cannot be signed. Again, for the special case of a Cobb-Douglas production function, this component of the welfare effect does not appear since the tax system is not used to strategically influence the bargaining outcome by altering the labor demand elasticity.

Summing up, if the elasticity of substitution between capital and labor is smaller than or equal to one, then it is sufficiently ensured that partial capital tax coordination is welfare enhancing in the presence of unemployment. In contrast, if the elasticity of substitution is larger than one, there are two opposing effects. On the one hand, welfare increases since the labor tax adjustment is costly and will not be used to completely undo the welfare gain of the capital tax coordination. On the other hand, the pre-existing distortion is augmented which is welfare worsening.

5.2 Partial coordination of the wage tax

Finally, let us turn to the question in which way a joint increase in the wage tax affects welfare if the capital tax is still free to be adjusted by each country. In fact, coordination agreements with respect to the wage tax rate are not a current issue in the political debate of tax competition. As mentioned above, it has rather been the theoretical literature on tax coordination that pointed out the link between the net remuneration of capital and the factor costs of a complementary factor. However, the analysis in this section may nevertheless be interesting since one often observes countries with federal structures, where the wage tax is determined on a federal level, which may be interpreted as tax setting on a coordinated level. On the other hand, local taxes, e.g., a business tax, can then be freely chosen by lower-level governments.

In the case of a fully competitive labor market, the labor supply elasticity plays a crucial role in determining the direction of the welfare effect when partial wage tax coordination is carried out. To see this, note that a joint change in the capital tax does not alter the allocation and all countries are therefore perfectly able to compete back to the allocation of the initial Nash equilibrium if the labor supply elasticity remains constant in the course of a joint wage tax increase. The total welfare effect of partial wage tax coordination is zero in this case. However, since the distortion of the tax system in the Nash equilibrium crucially depends on the absolute value of the labor supply elasticity, we observe welfare changes for a non-constant labor supply elasticity. If a coordinated increase in the wage tax increases (decreases) the labor supply elasticity, the pre-existing distortion of the tax system increases (decreases) and overall welfare effect is then negative (positive).

Returning to the case of a non-competitive labor market, we analyze whether a similar property carries over to a situation in which wages are determined by small monopoly trade unions ($\beta = 1$). If all countries agree only to marginally increase their wage tax and national autonomy is retained in the choice of the capital tax, we now have to determine to which extent all countries finally adjust their capital tax such that they still perceive this tax rate to be the best response from its small country perspective. The optimal choice regarding the capital tax rate is given by the first-order condition $\partial\mathcal{L}/\partial t_r = 0$, which defines the marginal costs of public funds for this tax instrument:

$$\lambda^{t_r} = \frac{\left(-\frac{w-e'}{\tilde{w}}\eta_{K,\tilde{w}} + (1-\bar{t}_\pi)\right)\left(\tilde{w}_{t_r}(1+t_r) + \frac{1-s}{s}\tilde{w}\right) - w_{t_r}(1+t_r)\left(1 - \frac{w-e'}{w}\sigma\right)}{\left(\frac{t_w\eta_{K,\tilde{w}}}{1+t_w} + \frac{t_r\eta_{K,\tilde{r}}}{1+t_r} + (1-\bar{t}_\pi)\right)\left(\tilde{w}_{t_r}(1+t_r) + \frac{1-s}{s}\tilde{w}\right) - w_{t_r}(1+t_r)\left(1 + \frac{(t_w-t_r)\sigma}{1+t_r}\right)}.$$

Totally differentiating this expression at a constant capital employment yields the worldwide reaction of the capital tax rate following a coordinated marginal increase in the wage tax:

$$\left.\frac{dt_r}{dt_w}\right|_{dK=0} = -\frac{\partial\lambda^{t_r}/\partial t_w\big|_{dK=0}}{\partial\lambda^{t_r}/\partial t_r\big|_{dK=0}}, \tag{30}$$

where, for stability of the Nash equilibrium, we need to have $\partial\lambda^{t_r}/\partial t_r\big|_{dK=0} > 0$.[15] The overall welfare effect of the partial coordination in the wage tax rate is then again given by the sum of two effects, the initial welfare enhancing effect due to the joint increase in the wage tax at a constant capital tax (see section 4.2) and the subsequent welfare effect due to the worldwide adjustment of the capital tax at a given wage tax:

$$\left.\frac{d\mathcal{L}}{dt_w}\right|_{dK=0}^{part.} = \left.\frac{d\mathcal{L}}{dt_w}\right|_{dK=0}^{dt_r=0} + \left.\frac{dt_r}{dt_w}\right|_{dK=0}\left.\frac{d\mathcal{L}}{dt_r}\right|_{dK=0}^{dt_w=0}. \tag{31}$$

Following the procedure of the previous subsection, we first describe the mechanisms that are able to affect welfare in this case before we turn to the detailed expression of the overall welfare effect.

For an intuitive explanation of the total welfare effect it proves convenient to again decompose the total effect into, first, a coordinated increase in the wage tax at a constant capital tax and, second, a joint change in the capital tax at a constant wage taxation. From our previous discussion we know that, starting from the Nash equilibrium, a joint increase in the wage tax changes the worldwide allocation, which has

[15] Note that $sign\{\partial\lambda^{t_r}/\partial t_r\big|_{dK=0}\} = sign\{A\}$ as is shown in Appendix 5. Thus, as indicated earlier, $A > 0$ must hold in the Nash equilibrium for the sake of stability.

no first-order effect on welfare. The welfare impact solely stems from the availability to reduce the net interest rate which captures lump-sum tax revenue. On the other hand, any joint reaction in the capital tax does not affect employment and gross factor prices, but only the net remuneration of capital owners. Therefore, it should *ceteris paribus* be possible for all countries to exactly compete back to their individually preferred allocation which is given by the initial uncoordinated Nash equilibrium. This mechanism alone would enable all countries to exactly wash away the initial welfare gain of the coordination in the wage tax.

Similar to the preceding subsection, however, there is a second channel through which welfare is affected. The initial marginal increase in the wage tax rate, carried out by all countries, will change the pre-existing distortion of the tax system. If this initial coordination step augments (alleviates) the pre-existing distortion, the overall welfare effect is negative (positive).

Inserting equations (20), (24) and (30) into the overall welfare effect (31), we derive at

$$\left.\frac{d\mathcal{L}}{dt_w}\right|_{dK=0}^{part.} = (\lambda-1)r\overline{K}\frac{1+t_r}{1+t_w}\frac{\tilde{w}_{t_w}}{A}\Phi.$$

Consequently, the sign of the total welfare effect is determined by the sign of the term Φ, which is equivalent to

$$\frac{1+\frac{e''(L)L}{e'(L)}\varepsilon}{(1-s)(\sigma-\varepsilon)}\left[\frac{\lambda-1}{\lambda}\frac{\partial}{\partial t_w}\left(\frac{(w-e')(\sigma-\varepsilon)(1-\sigma)(1-s)s}{w(1+\eta_{L,\tilde{w}})}\right)\bigg|_{dK=0} - \frac{\sigma}{\lambda}\frac{\partial}{\partial t_w}\left(\frac{w-e'}{w}\right)\bigg|_{dK=0}\right]$$
$$+\frac{\lambda-1}{\lambda}\left(1-\frac{(w-e')\,(\sigma-\varepsilon)(1-\sigma)(1-s)s}{w(1+\eta_{L,\tilde{w}})(1-s)(\sigma-\varepsilon)}\varepsilon\right)\frac{\partial}{\partial t_w}\left(\frac{e''(L)L}{e'(L)}\right)\bigg|_{dK=0}. \tag{32}$$

Turning to the interpretation of the above welfare effect, it is instructive to recall the expression for the optimal wage tax in the Nash equilibrium. For $\beta=1$ and full profit taxation we have

$$t_w = \frac{\lambda-1}{\lambda}\frac{(w-e')(\sigma-\varepsilon)(1-\sigma)(1-s)s}{\sigma w(1+\eta_{L,\tilde{w}})} + \frac{\lambda-1}{\lambda}\frac{e''(L)L}{e'(L)} - \frac{w-e'}{\lambda w}. \tag{33}$$

Intuitively, the optimal usage of the wage tax depends on the availability of rents among labor suppliers (see the second term) as well as the existence of unemployment (see the first and third term, respectively). Welfare effects arise if the right hand side of this equation is changed by the marginal tax coordination, but the corresponding wage tax adjustment is excluded due to the international coordination agreement.

To begin with, note first that the change of the elasticity $e''(L)L/e'(L)$ is of crucial importance. In fact, for the special case of a Cobb-Douglas production function ($\sigma=1$) it becomes the only component of the total welfare effect which can be seen by referring back to equation (32). Since in the Cobb-Douglas case the costs shares of labor and capital are constant in the uncoordinated setting the wage tax is not used in the Nash equilibrium to strategically influence the net of tax wage rate by changing the labor demand elasticity. Moreover, for the special case of monopoly unions, as considered in this section, we known from (5) that $(w - e')/w = -1/\eta_{L,\tilde{w}}$ which remains unchanged for $\sigma = 1$. The direction of the overall welfare effect is then solely determined by the sign of $\partial[e''(L)L/e'(L)]/\partial t_w|_{dK=0}$. To shed some light on the intuition behind the result, bear in mind that a unilateral change in the wage tax always alters domestic employment. Thus, each government will make use of the wage tax in the uncoordinated Nash equilibrium depending on (the change of) the marginal disutility of labor. In particular, the absolute value of the elasticity $e''(L)L/e'(L)$ crucially determines the marginal welfare costs of wage taxation in the Nash equilibrium. To see this, note that for a rather inelastic value of $e''(L)L/e'(L)$ the labor supply curve is relatively flat. In turn, this implies rather high welfare costs of wage taxation (at the margin) since it becomes more difficult to capture intramarginal rents from labor suppliers by marginally increasing the wage tax rate. In contrast, the corresponding increase in the gross wage rate is rather high implying a large reduction in employment and thus a higher welfare loss due to additional involuntary unemployment. The more elastic the marginal disutility the smaller is the reduction in employment that is necessary to capture rents from labor suppliers. Therefore, if a joint increase in the wage tax increases this elasticity, i.e. $\partial\left[e''(L)L/e'(L)\right]/\partial t_w|_{dK=0} > 0$, the pre-existing tax system becomes less distortionary at the margin which gives rise to a positive welfare effect. The opposite applies when a coordinated increase in the wage tax reduces the elasticity of the marginal disutility of labor.

For the more general setting in which the elasticity of substitution differs from unity, welfare is also affected through additional channels. On the one hand, the above effect running the change in the disutility of labor is modified. As can be seen from the lower line of (32), it is augmented (attenuated) if $\sigma < (>)1$.

On the other hand, for $\sigma \neq 1$, the upper line of equation (32) enters the total welfare effect. A partial coordination agreement regarding the wage tax then contributes to higher welfare if the initial joint increase in the wage tax reduces $(w - e')(\sigma - \varepsilon)(1 - \sigma)(1 - s)s/w(1 + \eta_{L,\tilde{w}})$ and increases $(w - e')/w$, respectively. The former is sufficiently ensured if $s \geq 0.5$; the latter holds for $\sigma > 1$ (see Appendix 7). Both terms are also components of the optimal wage tax expression (33) above. The interpretation is analogous to that of the previous subsection. If the joint increase in the wage tax lowers the right hand side of the optimal wage tax formula, this contributes to higher welfare since the wage tax has been cooperatively chosen which, in turn, precludes a corresponding tax adjustment. As argued before, the whole economy is characterized by undertaxation so that all countries gain in terms of welfare if the wage tax is higher than individually preferred by each country.

6 Concluding remarks

Tax coordination is aimed at mitigating a worldwide tax distortion which emerges when countries ignore the fiscal externalities of unilateral changes in their policy instruments. The more policy instruments are included in a worldwide coordination agreement the more effective it is. This paper analyzes this issue by employing taxes on immobile labor and mobile capital, taking into account that wage bargaining gives rise to involuntary unemployment. In particular, two (extreme) scenarios of tax coordination are discussed.

First, concerning complete tax coordination, imperfections on the labor market are not able to justify different policy conclusions with regard to coordination compared with the case of fully competitive labor markets as has been suggested by Fuest and Huber (1999b). We find that, starting from the uncoordinated Nash equilibrium, a joint increase in the capital tax is always welfare enhancing, if the wage tax is held constant. The same holds true for a coordinated increase in the wage tax at a constant capital tax, provided that capital and labor are complements in production. In both cases, marginal tax coordination is able to reduce the net remuneration of capital ownership, thereby shifting resources to the public sector in a lump-sum manner, a policy option not available to individual countries. Whether or not the underlying tax structure is designed for flexible labor markets or imperfect labor markets is not important for the welfare impact of coordination. Thus, even for Nash equilibria which are qualitatively different the desirability of (complete) tax coordination is the same.

With regard to partial tax coordination, however, the organization of the labor market does matter. In the presence of unemployment due to decentralized wage bargaining, the welfare results are more complex and become ambiguous. In general, there are two mechanisms at work. On the one hand, the tax instrument that is still free to be adjusted by each country after the tax coordination is used to mimic the tax rate that has been coordinated so that countries try to compete back to the initial Nash equilibrium. Taxes on labor and capital are different in that respect. While an uncoordinated but symmetric adjustment of the capital tax is non-distortionary and can be used to perfectly undo any gains of coordination, such an adjustment in the wage tax is, in general, distortionary from a global perspective. On the other hand, the pre-existing distortion of the tax system may be altered due to the coordination or the subsequent joint tax adjustment. Since the optimal usage of the available tax rates in the presence of unemployment differs from the case of competitive labor markets, we have a mechanism that introduces different welfare effects when comparing flexible and rigid labor markets.

Even under the rather restrictive assumptions made, the present paper illustrates that if tax coordination fails to include all policy instruments the overall welfare effects become quite complex and are ambiguous *a priori.* An important benchmark case, that reduces this ambiguity, is the one of a Cobb-Douglas production technology. For this situation, a marginal coordination of the capital tax is welfare enhancing even if all countries can freely decide upon their wage tax rate. In contrast, a marginal coordination of the wage tax is then associated with a welfare gain if the elasticity of the marginal disutility of labor is augmented, provided that each country retains national autonomy in the choice of the capital tax.

Appendix

1. Nash wage bargaining and the sign of equation (11)
Solving the first-order condition of the Nash maximand, i.e.

$$\beta\left(w+(w-e')\eta_{L,\tilde{w}}\right)+(1-\beta)(1-\varepsilon)s\left(w-\frac{e(L)}{L}\right)=0,$$

for the net wage rate yields

$$w=\frac{\beta e'(L)\eta_{L,\tilde{w}}+(1-\beta)(1-\varepsilon)se(L)/L}{\beta\left(1+\eta_{L,\tilde{w}}\right)+(1-\beta)(1-\varepsilon)s}.$$

As the numerator is strictly negative due to $\eta_{L,\tilde{w}}<0$ and $\varepsilon>1$, we must have

$$\beta\left(1+\eta_{L,\tilde{w}}\right)+(1-\beta)(1-\varepsilon)s<0$$

to ensure a positive net wage rate.

2. Derivation of the optimal tax rates in the Nash equilibrium
First, multiplying first-order condition $\partial\mathcal{L}/\partial t_w=0$ with $(1+t_r)\tilde{w}_{t_r}$ and $\partial\mathcal{L}/\partial t_r=0$ with $\tilde{w}_{t_w}$ and combining both expressions yields

$$0=\frac{\lambda-1}{\lambda}\left((1-\bar{t}_\pi)\frac{1-s}{s}-\frac{w_{t_r}}{\tilde{w}_{t_w}}\frac{1+t_r}{1+t_w}\right)+\left(\frac{w-e'}{\lambda\tilde{w}}+\frac{t_w}{1+t_w}\right)\eta_{L,\tilde{r}}+\frac{t_r}{1+t_r}\frac{1-s}{s}\eta_{K,\tilde{r}}.$$

Second, rearranging $\partial\mathcal{L}/\partial t_w=0$ gives

$$0=\frac{\lambda-1}{\lambda}\left(-(1-\bar{t}_\pi)+\frac{w_{t_w}}{\tilde{w}_{t_w}}\right)=\left(\frac{t_w}{1+t_w}+\frac{w-e'}{\lambda\tilde{w}}\right)\eta_{L,\tilde{w}}+\frac{t_r}{1+t_r}\eta_{L,\tilde{r}}.$$

Combing these two equations by adding them up yields

$$\begin{aligned}&\frac{\lambda-1}{\lambda}\frac{1-\bar{t}_\pi}{\varepsilon}-\frac{\lambda-1}{\lambda}\frac{s}{\varepsilon\tilde{w}_{t_w}}\left(w_{t_r}\frac{1+t_r}{1+t_w}+w_{t_w}\right)-s\frac{w-e'}{\lambda\tilde{w}}\\=\;&s\frac{t_w}{1+t_w}+(1-s)\frac{t_r}{1+t_r}.\end{aligned}$$

Inserting this expression into the first-order conditions $\partial\mathcal{L}/\partial t_w=0$ and $\partial\mathcal{L}/\partial t_r=0$, respectively, gives us the optimal tax rates:

$$\begin{aligned}\frac{t_r}{1+t_r}&=\frac{\lambda-1}{\lambda}\frac{1-\bar{t}_\pi}{\varepsilon}+\frac{\lambda-1}{\lambda}\frac{\eta_{L,\tilde{w}}}{\sigma\varepsilon}\frac{w_{t_r}}{\tilde{w}_{t_w}}\frac{s}{1-s}\frac{1+t_r}{1+t_w}-\frac{\lambda-1}{\lambda}\frac{\eta_{K,\tilde{w}}}{\sigma\varepsilon}\frac{w_{t_w}}{\tilde{w}_{t_w}},\\ \frac{t_w}{1+t_w}&=\frac{\lambda-1}{\lambda}\frac{1-\bar{t}_\pi}{\varepsilon}-\frac{\lambda-1}{\lambda}\frac{\eta_{K,\tilde{w}}}{\sigma\varepsilon}\frac{w_{t_r}}{\tilde{w}_{t_w}}\frac{1+t_r}{1+t_w}+\frac{\lambda-1}{\lambda}\frac{\eta_{K,\tilde{r}}}{\sigma\varepsilon}\frac{w_{t_w}}{\tilde{w}_{t_w}}-\frac{w-e'}{\lambda\tilde{w}}.\end{aligned}$$

3. The welfare effect of a joint increase in the wage tax ($dt_r = 0$)
Using equation (22) for the employment effect and applying Hotelling's lemma, i.e. $\pi_{\tilde{w}} = -L$ and $\pi_{\tilde{r}} = -K$, the effect on total welfare is given by

$$\begin{aligned}\left.\frac{d\mathcal{L}}{dt_w}\right|_{dK=0}^{dt_r=0} &= -(\lambda-1)\overline{K}\left.\frac{\partial r}{\partial t_w}\right|_{dK=0}^{dt_r=0} - (\lambda-1)L\left.\frac{\partial w}{\partial t_w}\right|_{dK=0}^{dt_r=0}\\ &\quad +(w-e'+\lambda t_w w)\left(L_{\tilde{w}}\left.\frac{\partial \tilde{w}}{dt_w}\right|_{dK=0}^{dt_r=0} + L_{\tilde{r}}\left.\frac{\partial \tilde{r}}{dt_w}\right|_{dK=0}^{dt_r=0}\right)\\ &\quad -(\lambda-1)(1-\bar{t}_\pi)\left(-L\left.\frac{\partial \tilde{w}}{dt_w}\right|_{dK=0}^{dt_r=0} - K\left.\frac{\partial \tilde{r}}{dt_w}\right|_{dK=0}^{dt_r=0}\right).\end{aligned}$$

Rearranging the last three terms by inserting the joint factor price changes from (21) yields

$$\frac{1}{A}\left[(\lambda-1)wL\left(w_r r - w_{t_w}(1+t_w)\frac{\eta_{K,\tilde{r}}}{\eta_{K,\tilde{w}}}\right) + \frac{\tilde{w}L\tilde{w}_{t_w}\varepsilon\sigma}{\eta_{K,\tilde{w}}}\left(\frac{w-e'}{\tilde{w}} + \frac{\lambda t_w}{1+t_w} - \frac{(\lambda-1)(1-\bar{t}_\pi)}{\varepsilon}\right)\right].$$

After plugging in the optimal wage tax as given by equation (16), we have

$$\begin{aligned}&(\lambda-1)\frac{wL}{A}\left[\left(w_r r - w_{t_w}(1+t_w)\frac{\eta_{K,\tilde{r}}}{\eta_{K,\tilde{w}}}\right) + \left(-w_{t_r}(1+t_r) + w_{t_w}(1+t_w)\frac{\eta_{K,\tilde{r}}}{\eta_{K,\tilde{w}}}\right)\right]\\ &= 0.\end{aligned}$$

4. The distortion of a joint change in the wage tax rate

To determine the extent to which a coordinated increase in the wage tax is distortionary, we have to compare the corresponding effects on private utility and total tax revenue. Using Hotelling's lemma, the additional tax revenue amounts to

$$\begin{aligned}\left.\frac{dR}{dt_w}\right|_{dK=0}^{dt_r=0} &= t_\pi\left(-L\left.\frac{\partial \tilde{w}}{\partial t_w}\right|_{dK=0}^{dt_r=0} - K\left.\frac{\partial \tilde{r}}{\partial t_w}\right|_{dK=0}^{dt_r=0}\right)\\ &\quad +t_r K\left.\frac{\partial r}{\partial t_w}\right|_{dK=0}^{dt_r=0} + wL + t_w L\left.\frac{\partial w}{\partial t_w}\right|_{dK=0}^{dt_r=0} + t_w w\left.\frac{\partial L}{\partial t_w}\right|_{dK=0}^{dt_r=0}.\end{aligned}\qquad\text{(A.1)}$$

Private utility will be negatively affected by a joint increase in the wage tax. Thus, the change in private utility in absolute terms is given by

$$\begin{aligned}-\left.\frac{dV}{dt_w}\right|_{dK=0}^{dt_r=0} &= -(w-e')\left.\frac{\partial L}{\partial t_w}\right|_{dK=0}^{dt_r=0} - L\left.\frac{\partial w}{\partial t_w}\right|_{dK=0}^{dt_r=0} - K\left.\frac{\partial r}{\partial t_w}\right|_{dK=0}^{dt_r=0}\\ &\quad -(1-t_\pi)\left(-L\left.\frac{\partial \tilde{w}}{\partial t_w}\right|_{dK=0}^{dt_r=0} - K\left.\frac{\partial \tilde{r}}{\partial t_w}\right|_{dK=0}^{dt_r=0}\right).\end{aligned}\qquad\text{(A.2)}$$

Since $\tilde{w} = (1+t_w)w$ and $\tilde{r} = (1+t_r)r$, we have $\partial\tilde{w}/\partial t_w|_{dK=0}^{dt_r=0} = (1+t_w)\,\partial w/\partial t_w|_{dK=0}^{dt_r=0} + w$ and $\partial\tilde{r}/\partial t_w|_{dK=0}^{dt_r=0} = (1+t_r)\,\partial r/\partial t_w|_{dK=0}^{dt_r=0}$ which, in turn, simplifies the last term in (A.2) such that the change in private utility becomes

$$
\begin{aligned}
-\left.\frac{dV}{dt_w}\right|_{dK=0}^{dt_r=0} &= -(w-e')\left.\frac{\partial L}{\partial t_w}\right|_{dK=0}^{dt_r=0} + wL + t_w L\left.\frac{\partial w}{\partial t_w}\right|_{dK=0}^{dt_r=0} + t_r K\left.\frac{\partial r}{\partial t_w}\right|_{dK=0}^{dt_r=0} \\
&+t_\pi\left(-L\left.\frac{\partial \tilde{w}}{\partial t_w}\right|_{dK=0}^{dt_r=0} - K\left.\frac{\partial \tilde{r}}{\partial t_w}\right|_{dK=0}^{dt_r=0}\right). \qquad \text{(A.3)}
\end{aligned}
$$

Comparing expressions (A.1) and (A.3) reveals that they coincide only if $\partial L/\partial t_w|_{dK=0}^{dt_r=0} = 0$. Note that this holds irrespective of whether or not we start from the uncoordinated equilibrium.

5. Joint factor price changes and the sign of A

Note first that the marginal costs of public funds for the capital tax are given by

$$
\lambda^{t_r} = \frac{\left(-\frac{w-e'}{\tilde{w}}\eta_{K,\tilde{w}} + (1-\bar{t}_\pi)\right)\left(\tilde{w}_{t_r}(1+t_r) + \frac{1-s}{s}\tilde{w}\right) - w_{t_r}(1+t_r)\left(1-\frac{w-e'}{w}\sigma\right)}{\left(\frac{t_w\eta_{K,\tilde{w}}}{1+t_w} + \frac{t_r\eta_{K,\tilde{r}}}{1+t_r} + (1-\bar{t}_\pi)\right)\left(\tilde{w}_{t_r}(1+t_r) + \frac{1-s}{s}\tilde{w}\right) - w_{t_r}(1+t_r)\left(1+\frac{(t_w-t_r)\sigma}{1+t_r}\right)},
$$

as given in the text (see section 5.2). For a joint increase in the capital tax, we have

$$
\begin{aligned}
\left.\frac{\partial \lambda^{t_r}}{\partial t_r}\right|_{dK=0}^{dt_w=0} &= -\frac{\lambda^{t_r}}{\Delta(1+t_r)^2}\left[\eta_{K,\tilde{r}}\left(\tilde{w}_{t_r}(1+t_r) + \frac{1-s}{s}\tilde{w}\right) + \tilde{w}_{t_r}(1+t_r)\sigma\right] \\
&= -\frac{\lambda^{t_r}(1+t_w)}{\Delta(1+t_r)^2}\eta_{K,\tilde{w}}\frac{1-s}{s}\left(w_{t_r}(1+t_r) + \frac{\eta_{K,\tilde{r}}}{\eta_{K,\tilde{w}}}w\right),
\end{aligned}
$$

where Δ is the denominator of λ^{t_r} and the term in bracket is equivalent to A. Thus,

$$
sign\left\{\left.\frac{\partial \lambda^{t_r}}{\partial t_r}\right|_{dK=0}^{dt_w=0}\right\} = sign\{A\}.
$$

As already mentioned in the text, to reach a stable Nash equilibrium requires that the welfare cost of a tax instrument increase if this tax is increased by all countries jointly. Hence, $A > 0$ ensures this stability.

6. Partial coordination of the capital tax

For a constant capital employment, the repercussion of a change in the wage tax on the right hand side of the optimal capital tax equation is given by

$$
\begin{aligned}
&\left.\frac{\partial}{\partial t_w}\left(\frac{s}{1-s}\frac{(w-e')(\sigma-\varepsilon)(1-\sigma)(1-s)s}{\tilde{w}(1+\eta_{L,\tilde{w}})}\right)\right|_{dK=0} = \\
&\frac{\tilde{w}_{t_w}}{(1+t_w)A\eta_{K,\tilde{w}}}\frac{s}{1-s}\frac{(\sigma-\varepsilon)(1-\sigma)(1-s)s}{\tilde{w}(1+\eta_{L,\tilde{w}})}\left\{-\frac{e''(L)\varepsilon\sigma}{1+\eta_{L,\tilde{w}}}\right. \\
&\left.+(w-e')\left[2(1-\sigma)(1-s)\varepsilon\left(\frac{s(\sigma-\varepsilon)}{1+\eta_{L,\tilde{w}}}-1\right) - \eta_{K,\tilde{r}}\right]\right\},
\end{aligned}
$$

where $s(\sigma-\varepsilon)/(1+\eta_{L,\tilde{w}})-1=[\sigma-1]/(1+\eta_{L,\tilde{w}})$. Thus the whole expression becomes negative for $\sigma<1$ and ambiguous for $\sigma>1$.

7. Partial coordination of the wage tax

First, we have

$$\frac{\partial}{\partial t_w}\left(\frac{(w-e')(\sigma-\varepsilon)(1-\sigma)(1-s)s}{w(1+\eta_{L,\tilde{w}})}\right)\Bigg|_{dK=0}=$$
$$\frac{\tilde{w}_{t_w}\varepsilon}{(1+t_w)A\eta_{K,\tilde{w}}}\frac{(w-e')(\sigma-\varepsilon)(1-\sigma)^2(1-s)s}{w(1+\eta_{L,\tilde{w}})}\left[(\sigma-\varepsilon)(1-s)s\frac{1+2\eta_{L,\tilde{w}}}{(1+\eta_{L,\tilde{w}})\eta_{L,\tilde{w}}}-(1-2s)\right],$$

which is unambiguously smaller than zero for $s\geq 1/2$. For $s<1/2$ it cannot be signed.

Secondly, we have

$$\frac{\partial}{\partial t_w}\left(\frac{w-e'}{w}\right)\Bigg|_{dK=0}=\frac{\tilde{w}_{t_w}}{(1+t_w)A\eta_{K,\tilde{w}}}\frac{(w-e')(\sigma-\varepsilon)(1-\sigma)(1-s)s}{w(1+\eta_{L,\tilde{w}})}\frac{e'(L)}{w}\varepsilon,$$

so that

$$sign\left\{\frac{\partial}{\partial t_w}\left(\frac{w-e'}{w}\right)\Bigg|_{dK=0}\right\}=sign\left\{\sigma-1\right\}.$$

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