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## Optimal factor and commodity taxation in a small open economy

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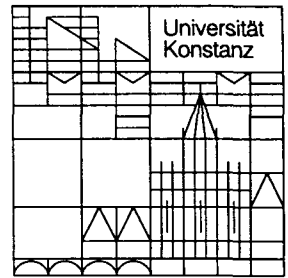
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**Sonderforschungsbereich 178**  
**„Internationalisierung der Wirtschaft“**

Diskussionsbeiträge



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Andreas Haufler

**Optimal Factor and Commodity Taxation  
in a Small Open Economy**

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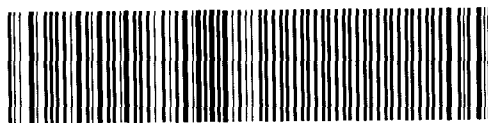
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### **Abstract**

A two-sector trade model with perfect international capital mobility and endogenous supply of specific factors is used to analyze the relation between selective taxes on production (origin-based commodity taxes) and source-based taxes on capital income. A small open economy will set both of these taxes equal to zero when it is able to tax all specific factors optimally. In the absence of a domestic motive for capital taxation a switch towards origin-based commodity taxes leads to a negative source tax on capital (i.e., a subsidy). However, when one of the specific factors is in fixed supply and cannot be taxed by a separate instrument, then the optimal capital tax rate is positive and may be further increased by the introduction of a selective production tax.

# 1 Introduction

The residence principle of capital taxation and the destination principle of commodity taxation have long been the dominant international tax principles, effectively shielding national tax systems from international tax competition. Recent developments have made it difficult, however, to enforce either of these ‘desirable’ principles of taxation. On the one hand the increasing mobility of capital worldwide, together with the existence of tax havens, has put more reliance on source or withholding taxes on capital and has led to capital tax rates being lowered in many countries. As a recent example, Sweden, Norway, Finland and Denmark have switched to a system of dual income taxation where marginal tax rates on capital income are substantially lower than marginal tax rates on wage income (Sørensen, 1994). At the same time, the destination principle has been partially eroded for trade within the European Union (EU) through the abolition of border controls. Since, for most EU countries, the bulk of commodity taxation occurs within the union the origin principle of commodity taxation constitutes an increasingly important element in the international tax system faced by EU countries.

These developments have been reflected in a large body of literature, which can be divided into models of strategic interaction between large countries versus optimal tax rules followed by small open economies. The focus here is on the latter branch of that literature. A central result in the field of international capital taxation is that a country which faces an infinitely elastic supply of capital should not use source-based taxes on capital income if it is able to tax labor optimally and if there are no pure profits (Gordon, 1986; Frenkel, Razin and Sadka, 1991; Bucovetsky and Wilson, 1991). This is an open economy version of Diamond and Mirrlees’ (1971) production efficiency theorem. It has also been shown that if there are constraints on labor or profit taxation, or if foreigners own part of the domestic capital stock, then positive source taxes on capital will be levied even by a small open economy (Bruce, 1992; Slemrod, Hansen and Procter, 1994; Huizinga and Nielsen, 1995). Parallel results are obtained for international commodity taxation. Keen (1993) argues from the production efficiency theorem that countries will endogenously prefer destination- over origin-based commodity taxes. Optimal tax rules have also been derived when pure destination taxes are not feasible due to cross-border shopping and markets are perfectly or imperfectly competitive (Christiansen, 1994).

Little attention has been devoted, however, to the interaction between the simultaneous shifts towards origin taxation of commodities and source taxation of capital. Commodity

tax models do not, in general, allow for international capital mobility whereas models of capital income taxation usually assume a single output good, thus precluding the integration of commodity taxes with distinct economic effects. The only exception I am aware of is Sinn (1990a), who uses a Heckscher-Ohlin model that is augmented by the assumption of internationally mobile capital. He studies the conditions under which commodity taxes and taxes on capital are neutral in their joint effects on trade flows and shows that a number of possible interaction patterns (labelled “additive” vs. “subtractive neutrality”) can emerge. However, Sinn does not endogenize the tax rates set by the national governments and his analysis is thus not comparable to the optimal tax models cited above.

The present paper is an attempt to bridge this gap and provide an integrated treatment of direct and indirect taxes in an optimal taxation framework. The analysis is based on a mobile-capital version of the specific factors model, the second major workhorse of international trade theory. This choice has the advantage over the Heckscher-Ohlin framework that a small open economy produces all goods in a trade equilibrium with perfect capital mobility. The focus will be on the interaction between origin-based commodity taxes and source taxation of capital. From a policy perspective, an important issue is whether a switch to origin taxation in the European Union can be expected to have a systematic influence on the optimal level of capital taxes, and thus whether it is likely to reinforce or counteract the recent downward trend in capital tax rates.

The remainder of the paper is organized as follows. Section 2 presents the optimal tax model and introduces the set of available tax instruments. Section 3 discusses the benchmark case where all tax instruments can be optimized separately. The main results of the paper are in section 4, which analyzes the effects of domestic and international constraints on the optimal level of production and capital taxes. Section 5 concludes and suggests possible extensions.

## 2 The Model

The trade model used in the analysis is an augmented specific factors model with two output goods and three factors. The capital endowment of the economy is given exogenously and capital is perfectly mobile both between the two sectors and internationally. Production in each sector  $i \in [1, 2]$  uses capital and a sector-specific factor  $n_i$ , which is also immobile internationally. These specific factors will receive different interpretations in the course of the analysis but for the purpose of presenting the model they need not

be specified further. Both factors  $n_i$  are assumed to be in elastic supply; fixed factors then follow directly as a special case of the more general model. Equilibrium employment of both specific factors is assumed to be strictly positive, ensuring that the small open economy will produce both goods in a trade equilibrium<sup>1</sup>.

Distributional effects are ignored by assuming that there is a single representative household which owns all factors of production and consumes all goods. The utility function for this individual is strictly quasi-concave and depends positively on the consumption levels  $c_i$  and negatively on the factor supplies  $n_i$ ,

$$u = u(c_1, c_2, n_1, n_2). \quad (1)$$

The small open economy faces fixed world prices for the traded goods and internationally mobile capital<sup>2</sup>. Good 1 is chosen as the numeraire,  $p^*$  gives the world relative price of good 2 and  $r^*$  is the world return to capital. Commodity demands and factor supplies in the small country are affected by world prices and five different tax instruments: a source tax on capital ( $t_k$ ), a selective production tax ( $t_x$ ), a selective consumption tax ( $t_c$ ) and taxes on the specific factors ( $t_{n_i}$ ). By virtue of their algebraic simplicity all taxes are modelled as unit taxes.

The analysis assumes that capital taxation must follow the *source principle*. A residence-based tax on capital (i.e., a savings tax) is lump sum in a single-period framework and is thus excluded. This can be justified by arguing that there is no international cooperation to report foreign earnings to the investor's country of residence. With perfect capital mobility, arbitrage will then ensure that residents of the small country always realize the world return on their capital endowment<sup>3</sup>.

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<sup>1</sup>The same is not true if all factors of production are intersectorally mobile (Heckscher-Ohlin assumption) and capital is also mobile internationally. In the Heckscher-Ohlin framework commodity trade equalizes gross-of-tax factor prices between two countries as long as production in both countries is diversified. In the presence of (differential) capital taxation this is incompatible with investors' arbitrage, which equalizes net-of-tax rates of return to capital. As a consequence, a small open economy which levies non-zero taxes on capital (either directly or indirectly through product taxes) will produce only a single output good in the trade equilibrium (Sinn, 1990a). This "knife-edge property" of the Heckscher-Ohlin trade model in the presence of factor mobility has long been known in the trade literature; see, e.g., Neary (1985) for a detailed discussion.

<sup>2</sup>Even where the European Union is the relevant market the small country assumption seems applicable for a majority of EU members. In 1993, eleven of the now fifteen EU members had a gross domestic product which was less than five percent of the EU total (OECD, 1994, p. 210).

<sup>3</sup>This includes the possibility that a tax on interest income is nominally in place but raises no revenue



There are no foreign tax credits for source taxes on capital levied by the small country. From investors' arbitrage a source based tax on capital must then raise the gross return to capital by the full amount of the tax in order to attract any capital (either foreign or domestic) to the small country.

$$r = r^* + t_k. \quad (2)$$

Note that  $r^*$  is net of any foreign taxes and thus does not equal the marginal productivity of capital in the world market when large countries impose non-zero production taxes or source taxes on capital.

Commodity taxes can be levied under the *destination principle* or the *origin principle*. In the first case, the tax corresponds to a consumption tax whereas in the second case it corresponds to a production tax that is not rebated for export. Both taxes are allowed to exist simultaneously but I assume that the production tax falls on the numeraire good while the consumption tax is levied on good 2. This allows to combine the two taxes later in the analysis, when some specific features of value-added taxation in the EU internal market are introduced. At this point it suffices to say that none of the results in the benchmark case is affected by the choice to tax the numeraire good<sup>4</sup>.

The production tax in sector 1 must lower the producer price  $p_1$  if domestic goods are to remain competitive in the world market. In the absence of a domestic consumption tax the consumer price in the small country,  $q_1$ , equals the world price, which may include foreign production taxes that are not rebated for export. Thus

$$p_1 = 1 - t_x, \quad q_1 = 1. \quad (3)$$

In sector 2 the producer price equals the world price of this good whereas the con-

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since all capital is invested abroad and no foreign income is reported. Frenkel, Razin and Sadka (1991, pp. 204-206) show that even if a subset of countries (the members of the European Union, for example) agreed to cooperate in order to enforce the residence principle between them, the lack of coordination with the rest of the world will cause EU members to voluntarily forgo residence taxation.

<sup>4</sup>What is excluded throughout the analysis is a uniform commodity tax levied under a general tax principle since these taxes could be duplicated by an appropriate combination of factor taxes. A general destination-based commodity tax is equivalent to an equal-rate tax on the two specific factors plus a residence-based tax on capital (thus containing a lump-sum element). A general origin-based tax is instead equivalent to a tax on the specific factors and a source-based tax on capital. Note also that these general commodity taxes would not be equivalent in the present single-period framework because the general origin-based tax is always of the 'production type'. If the VAT is instead of the 'consumption type', and investment is deductible from the tax base, then general origin and destination based taxes are equivalent even in the presence of capital mobility (cf. Bovenberg, 1994; Genser/Haufler/Sørensen, 1995).

sumption tax raises the consumer price in the small open economy above the world price

$$p_2 = p^*, \quad q_2 = p^* + t_c. \quad (4)$$

Finally, the after-tax return to each specific factor equals the gross return  $w_i$ , less the factor taxes  $t_{n_i}$

$$\omega_i = w_i - t_{n_i} \quad i \in [1, 2]. \quad (5)$$

The relevant prices for the representative consumer in the small open economy are the net returns to specific factors  $\omega_i$  and the consumer price of good 2,  $q_2$ . These determine the private budget constraint

$$c_1 + q_2 c_2 = \omega_1 n_1 + \omega_2 n_2 + r^* \bar{k}, \quad (6)$$

where  $\bar{k}$  is the exogenous capital endowment. Income from this endowment is a lump sum since, from (2), the net return earned is always the world rate, no matter whether capital is invested at home or abroad.

Maximization of (1) subject to (6) yields the individual's indirect utility function  $v(q_2, \omega_1, \omega_2)$ . By Roy's identity, and setting the marginal utility of private income equal to one for notational simplicity, its derivatives are given by

$$\frac{\partial v}{\partial q_2} = -c_2(q_2, \omega_1, \omega_2), \quad \frac{\partial v}{\partial \omega_i} = n_i(q_2, \omega_1, \omega_2) \quad \forall i \in [1, 2]. \quad (7)$$

Gross returns to specific factors are determined endogenously by the production side of the model. Specific factors  $n_i$  and capital inputs  $k_i$  are combined using a constant returns to scale technology. Profit maximization by competitive producers implies that factors are employed to the point where their marginal value product equals gross-of-tax factor prices. Since the production function is homogeneous of degree one in all inputs its derivatives, the marginal productivities, depend only on the ratio of capital to the specific factor

$$\frac{\partial x_i}{\partial k_i} \left( \frac{k_i}{n_i} \right) = \frac{r}{p_i} \quad \forall i \in [1, 2]. \quad (8)$$

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Using (3) and (2) in (8) it is immediately seen that production taxes and source taxes on capital are “additive” in their effects on the required marginal productivity of capital in sector 1. Note that this model implication does *not* depend on the assumption that the production factors  $n_1$  and  $n_2$  are sector-specific. The first-order condition (8) holds in the

present setting, where  $n_1$  and  $n_2$  are determined independently, but also in a Heckscher-Ohlin framework where a fixed amount of labor is perfectly mobile across sectors (in this notation  $n_1 + n_2 = \bar{n}$ )<sup>5</sup>.

Gross returns to the specific factors are derived as a function of producer prices and the costs of capital

$$w_i(r, p_i) = \{p_i x_i[k_i(r, p_i)] - r k_i(r, p_i)\}/n_i \quad \forall \quad i \in [1, 2]. \quad (9)$$

Differentiating (9) with respect to  $r$  and using (8) gives the factor price frontiers

$$\frac{\partial w_i}{\partial r} = -\frac{k_i}{n_i} < 0 \quad \forall \quad i \in [1, 2], \quad (10)$$

Similarly, differentiating (9) with respect to the producer price of good 1 and using (8) gives

$$\frac{\partial w_1}{\partial p_1} = \frac{x_1}{n_1} > 0, \quad \frac{\partial w_2}{\partial p_1} = 0. \quad (11)$$

From (3) a production tax on good 1 lowers the gross return to the specific factor in this sector. This will also reduce the amount of capital used in sector 1. With perfect capital mobility, however, the excess capital will flow abroad rather than into sector 2 so that the return to the specific factor  $n_2$  is unaffected by this change in relative producer prices.

To derive optimal tax formulae I also need the signs of the second-order derivatives of the gross wage functions  $w_i(r, p_i)$ . These can easily be inferred from the first-order conditions for the optimal use of capital (8). With a positive elasticity of substitution between the two factors, a tax-induced increase in  $r$  must raise the marginal productivity of capital and thus lower the capital intensity in each sector. Thus

$$\frac{\partial^2 w_i}{\partial r^2} = -\frac{\partial(k_i/n_i)}{\partial r} > 0 \quad \forall \quad i \in [1, 2]. \quad (12)$$

Similarly, a rise in  $p_1$  lowers the marginal physical product of capital from (8) and the capital-labor ratio rises in equilibrium. From the homogeneity of the production function

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<sup>5</sup>This is not in contradiction to Sinn's result that production taxes and source taxes on capital can have 'additive' or 'subtractive' effects on the *aggregate* use of capital. In the Heckscher-Ohlin framework a production tax on good 1 will raise aggregate demand for capital ( $k_1 + k_2$ ) and aggregate production if the taxed sector 1 is labor intensive (Sinn, 1990a, pp. 60-61). In this case a positive source tax on capital is needed to compensate for the effects of the production tax ("subtractive neutrality"). However, the two taxes are still additive in their effects on the marginal productivity of capital in *sector 1*, and this is the relevant issue for optimal tax analysis. Therefore, the core difference to Sinn's analysis lies in the normative question asked here, not in the underlying trade model.

this translates directly into an increased output-labor ratio and

$$\frac{\partial^2 w_1}{\partial p_1^2} = \frac{\partial(x_1/n_1)}{\partial p_1} > 0. \quad (13)$$

Finally, the second-order cross derivatives of  $w_1(r, p_1)$  are again inferred from (8) and are equal by Young's theorem

$$\frac{\partial^2 w_1}{\partial r \partial p_1} = \frac{\partial^2 w_1}{\partial p_1 \partial r} = \frac{-\partial(k_1/n_1)}{\partial p_1} = \frac{\partial(x_1/n_1)}{\partial r} < 0. \quad (14)$$

The government of the small country maximizes the indirect utility of the representative consumer subject to a given revenue requirement  $R_0$ . To allow for fixed factor supplies, which turn the taxes  $t_{n_i}$  into lump-sum instruments, non-negativity conditions are introduced for the *net* returns  $\omega_i$ . In this case it is also assumed that the revenue requirement  $R_0$  exceeds the maximum amount that can be collected from the imposition of lump-sum taxes; otherwise the optimal tax problem would be trivial.

$$\max v(q_2, \omega_1, \omega_2) \quad \text{s.t.} \quad R_0 = t_{n_1} n_1 + t_{n_2} n_2 + t_x x_1 + t_c c_1 + t_k (k_1 + k_2),$$

$$\omega_1 \geq 0, \quad \omega_2 \geq 0.$$

Equations (10) and (11) are used to substitute out for the capital employed in each sector and the production in sector 1. This gives the Lagrangian

$$\begin{aligned} L = & v(q_2, \omega_1, \omega_2) + \lambda \left\{ t_c c_2(q_2, \omega_1, \omega_2) + \left[ t_{n_1} - t_k \frac{\partial w_1}{\partial r}(p_1, r) + t_x \frac{\partial w_1}{\partial p_1}(p_1, r) \right] n_1(q_2, \omega_1, \omega_2) \right. \\ & \left. + \left[ t_{n_2} - t_k \frac{\partial w_2}{\partial r}(r) \right] n_2(q_2, \omega_1, \omega_2) - R_0 \right\} + \mu_1 [w_1(p_1, r) - t_{n_1}] + \mu_2 [w_2(r) - t_{n_2}]. \end{aligned}$$

Using (2)–(5) and Roy's theorem (7) gives the following first-order conditions:

$$\frac{\partial L}{\partial t_c} = -c_2 + \lambda \left[ c_2 + t_c \frac{\partial c_2}{\partial q_2} + \alpha \frac{\partial n_1}{\partial q_2} + \beta \frac{\partial n_2}{\partial q_2} \right] = 0, \quad (15)$$

$$\frac{\partial L}{\partial t_{n_i}} = -n_i + \lambda \left[ n_i - t_c \frac{\partial c_2}{\partial \omega_i} - \alpha \frac{\partial n_1}{\partial \omega_i} - \beta \frac{\partial n_2}{\partial \omega_i} \right] - \mu_i = 0 \quad \forall \quad i \in [1, 2], \quad (16)$$

$$\frac{\partial L}{\partial t_x} = \frac{\partial w_1}{\partial p_1} \frac{\partial L}{\partial t_{n_1}} + \lambda n_1 \left[ t_k \frac{\partial^2 w_1}{\partial r \partial p_1} - t_x \frac{\partial^2 w_1}{\partial p_1^2} \right] = 0, \quad (17)$$

$$\frac{\partial L}{\partial t_k} = -\frac{\partial w_1}{\partial r} \frac{\partial L}{\partial t_{n_1}} - \frac{\partial w_2}{\partial r} \frac{\partial L}{\partial t_{n_2}} + \lambda \left[ t_x n_1 \frac{\partial^2 w_1}{\partial p_1 \partial r} - t_k \left( n_1 \frac{\partial^2 w_1}{\partial r^2} + n_2 \frac{\partial^2 w_2}{\partial r^2} \right) \right] = 0, \quad (18)$$

$$R_0 = t_{n_1} n_1 + t_{n_2} n_2 + t_c c_2 + t_x x_1 + t_k (k_1 + k_2), \quad (19)$$

$$\mu_i \geq 0, \quad w_i - t_{n_i} \geq 0, \quad \mu_i (w_i - t_{n_i}) = 0 \quad \forall \quad i \in [1, 2], \quad (20)$$

and

$$\alpha = t_{n_1} - t_k \frac{\partial w_1}{\partial r} + t_x \frac{\partial w_1}{\partial p_1}, \quad \beta = t_{n_2} - t_k \frac{\partial w_2}{\partial r}$$

can be interpreted as the effective tax rates on the specific factors  $n_i$ .

The first-order conditions (15)–(20) constitute a system of eight simultaneous equations, which determine the five tax rates and the values of three Lagrangian multipliers  $\lambda$  and  $\mu_i$ . The important point to note is that the first-order conditions for  $t_x$  and  $t_k$  fully incorporate (by a multiple) the first-order conditions for the specific factor taxes  $t_{n_i}$ . In addition, the production and capital taxes have interactive effects on each other's tax base, as given in the square brackets of (17) and (18).

The Lagrangian objective function is assumed to be strictly concave in each of its tax instruments, i.e., the second-order conditions for a maximum are fulfilled. Constraints on the set of available taxes can be introduced by specifying additional limits to some of the tax rates, or by combining two taxes to a single instrument. This allows to discuss a variety of institutional settings as special cases of a unified framework.

### 3 The Benchmark: Production Efficiency

I first discuss the benchmark case where all tax instruments introduced in the previous section can be chosen freely. Technically, this means that all first-order conditions (15)–(20) must hold simultaneously. It is then straightforward to show

**Proposition 1:** *If all tax instruments can be optimized separately, then*

$$t_x = 0, \quad t_k = 0,$$

*and production is efficient.*

*Proof:* With optimal taxation of both specific factors equation (17) reduces to

$$\left[ \frac{\partial L}{\partial t_x} \right] t_k \frac{\partial^2 w_1}{\partial r \partial p_1} - t_x \frac{\partial^2 w_1}{\partial p_1^2} = 0, \quad (21)$$

and (18) simplifies to

$$\left[ \frac{\partial L}{\partial t_k} \right] t_k \left( n_1 \frac{\partial^2 w_1}{\partial r^2} + n_2 \frac{\partial^2 w_2}{\partial r^2} \right) - t_x n_1 \frac{\partial^2 w_1}{\partial r \partial p_1} = 0. \quad (22)$$

Solving (21) for  $t_x$  and substituting in (22) gives

$$t_k \left[ n_1 \left( \frac{\partial^2 w_1}{\partial p_1^2} \right)^{-1} J + n_2 \frac{\partial^2 w_2}{\partial r^2} \right] = 0, \quad J = \frac{\partial^2 w_1}{\partial r^2} \frac{\partial^2 w_1}{\partial p_1^2} - \left( \frac{\partial^2 w_1}{\partial r \partial p_1} \right)^2. \quad (23)$$

$J$  equals the Jacobian determinant of the two functions  $\partial w_1/\partial r(p_1, r)$  and  $\partial w_1/\partial p_1(p_1, r)$ . Since these are functionally dependent from (10)–(11) and the linear homogeneity of the production function it follows that  $J = 0$  and the first term in the square bracket cancels in (23). The second term, however, is strictly positive from (12) so that only  $t_k = 0$  satisfies the equation<sup>6</sup>. Substituting this result back into either (21) or (22) shows that  $t_x = 0$  must also be true.  $\square$

Proposition 1 combines two separate implications of Diamond and Mirrlees' (1971) production efficiency theorem for the optimal tax rules followed by a small open economy. The result that a small open economy should not use source taxes on capital is well known from the analyses of Gordon (1986), Frenkel, Razin and Sadka (1991, Ch. 5) and Bucovetsky and Wilson (1991). Since internationally mobile capital escapes any tax burden if the taxing country is small in the world economy, the source-based capital tax is entirely shifted to the specific factors. The tax thus acts like a direct tax on the specific factors but *in addition* causes investors to 'underinvest' in the small country: in equilibrium, the marginal product of capital,  $r$ , exceeds the net world return  $r^*$ , and thus the opportunity costs of capital from the perspective of the small open economy.

A parallel reasoning applies for the result that the optimal production tax in sector 1 is zero. The tax is shifted backwards to the factors of production and is entirely born by the specific factor  $n_1$  when international capital mobility is perfect. Therefore, a direct tax on  $n_1$  dominates the production tax. Alternatively, this can be interpreted as saying that small countries endogenously prefer the destination principle over the origin principle of commodity taxation. While this result has been suggested in the previous literature (Keen, 1993) I am not aware that it has been formally derived before. Of course, there is also a close link between this analysis and the standard result in trade theory that the optimal tariff (which is equivalent to a production subsidy and a consumption tax) is zero for a small country which cannot improve its terms of trade.

It should be emphasized that allowing for optimal taxes on both specific factors is sufficient to obtain the result that  $t_k = t_x = 0$ . The consumption tax [eq. (15)] is not needed for this result and could be dropped altogether, provided that revenues from the taxation of both specific factors are sufficient to cover the overall revenue requirement. Of

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<sup>6</sup>In contrast, if a *general* production tax were levied equations (21) and (22) would be linearly dependent and the entire square bracket in (23) would be zero, i.e., an infinite number of combinations  $(t_k, t_x)$  satisfies the constraints. This, of course, is an immediate implication of the fact that general commodity taxes can be duplicated by an appropriate combination of factor taxes (cf. footnote 4).

course, it is for the same reason that the absence of a residence-based tax on capital in this model does not affect the production efficiency result in Proposition 1.

Finally, it is also irrelevant whether the non-negativity constraints  $\mu_i$  are binding or not. This is seen from the fact that the Lagrange parameters do not enter into the first-order conditions for  $t_x$  and  $t_k$  other than through the terms  $\partial L/\partial t_{n_i}$ . Therefore, gross returns to specific factors may be partially ( $\mu_i = 0$ ) or fully taxed ( $\mu_i > 0$ ) by the specific tax instruments. Of course, these two alternatives describe the cases of elastic vs. fixed factor supplies. The following analysis concentrates on the case where one specific factor  $n_i$  is supplied elastically whereas  $n_j$  ( $j \neq i$ ) is in fixed supply. The first factor may be interpreted as labor, so that  $-n_i$  gives the demand for leisure. This allows to sign all remaining tax instruments by

**Proposition 2:** *Rents from a fixed factor  $n_j$  are fully taxed in the optimum, i.e.,  $t_{n_j} = w_j$ . Furthermore, if leisure ( $-n_i$ ) and commodity consumption are net complements then, for  $j \neq i$*

$$t_c > 0 \quad \text{and} \quad t_{n_i} > 0.$$

*Proof:* Without loss of generality assume that the fixed factor is  $n_2$  while  $n_1$  is elastically supplied. Uncompensated price effects are decomposed using the Slutsky equations

$$\frac{\partial z}{\partial q_2} = \frac{\partial z^C}{\partial q_2} - c_2 \frac{\partial z}{\partial y}, \quad \frac{\partial z}{\partial \omega_1} = \frac{\partial z^C}{\partial \omega_1} + n_1 \frac{\partial z}{\partial y}, \quad \frac{\partial z}{\partial \omega_2} = n_2 \frac{\partial z}{\partial y} \quad \forall \quad z \in [n_1, c_2], \quad (24)$$

where a superscript  $C$  denotes a compensated derivative,  $y$  is nominal income and the last equation follows from the symmetry of compensated cross-price effects. Using (24) in (16) and noting that  $n_2$  is a constant gives

$$\frac{\partial L}{\partial t_{n_2}} = n_2 \theta - \mu_2 = 0, \quad \theta = \lambda \left( 1 - t_c \frac{\partial c_2}{\partial y} - \alpha \frac{\partial n_1}{\partial y} \right) - 1, \quad (25)$$

and  $\theta > 0$  must hold if the revenue requirement  $R_0$  exceeds the maximal amount that can be collected by the lump-sum tax  $t_{n_2}$  (cf. Atkinson and Stiglitz, 1980, p. 373). From (25) it then immediately follows that  $\mu_2 > 0$ , i.e., the constraint is binding and  $t_{n_2} = w_2$  from (20).

Introducing the Slutsky relationships (24) to (15) and (16) gives

$$\frac{\partial L}{\partial t_c} = c_2 \theta + \lambda \left( t_c \frac{\partial c_2^C}{\partial q_2} + \alpha \frac{\partial n_1^C}{\partial q_2} \right) = 0, \quad \frac{\partial L}{\partial t_{n_1}} = n_1 \theta - \lambda \left( t_c \frac{\partial c_2^C}{\partial \omega_1} + \alpha \frac{\partial n_1^C}{\partial \omega_1} \right) = 0,$$

where  $\theta$  is given in (25) and  $\alpha$  has been reduced to  $t_{n_1}$  from  $t_x = t_k = 0$ . Combining the two equations gives

$$-t_c \left( \frac{1}{c_2} \frac{\partial c_2^C}{\partial q_2} + \frac{1}{n_1} \frac{\partial c_2^C}{\partial \omega_1} \right) = t_{n_1} \left( \frac{1}{c_2} \frac{\partial n_1^C}{\partial q_2} + \frac{1}{n_1} \frac{\partial n_1^C}{\partial \omega_1} \right).$$

Using the assumption that leisure  $(-n_1)$  and  $c_2$  are net complements

$$\frac{\partial c_2^C}{\partial \omega_1} = \frac{-\partial n_1^C}{\partial q_2} < 0,$$

shows that both tax rates must have the same sign. From the government budget constraint it then follows that  $t_c$  and  $t_{n_1}$  must both be positive.  $\square$

The interpretation of Proposition 2 is familiar from standard optimal tax problems. Taxes on a fixed factor represent lump-sum taxes that will always be used to the fullest possible extent. The sufficient conditions for labor and consumption taxes to be both positive differ from those in the standard Ramsey problem of taxing a set of commodities in the presence of an untaxable numeraire (leisure). Given a positive factor tax in sector  $i$  a positive consumption tax on good 2 will reduce the factor market distortion if and only if it reduces the demand for leisure, i.e., consumption of good 2 and leisure are net complements. Whether this is a realistic assumption is, of course, an empirical matter but it should be stressed that the conditions on cross-price effects stated in Proposition 2 are sufficient, not necessary for the results. If own-price effects are sufficiently large then both tax rates  $t_c$  and  $t_{n_i}$  will be positive, irrespective of the sign of cross-price effects.

## 4 Constraints on Tax Instruments

### 4.1 Domestic Constraints

Since optimal taxation of both specific factors is a rather strong requirement it seems worthwhile to study the implications of relaxing this assumption. This applies in particular to the case where one specific factor is in fixed supply so that the optimal tax rule prescribes that its return must be fully taxed away. Confiscatory taxes are rarely observed in practice, presumably because they violate constitutional property rights (e.g. Richter and Wellisch, 1993). In the presence of such a constraint on the taxation of rents (or profits) other taxes that are able to reduce the *gross* return to the fixed factor obtain a lump-sum element.

To see this analytically consider the following constraints

$$t_{n_i} \leq \overline{t_{n_i}} \leq w_i \quad \forall \quad i \in [1, 2], \quad (26)$$

which are associated with Lagrange parameters  $\pi_i$ . For the first-order conditions of the specific taxes  $t_{n_i}$  [eq. (16)] the only change is that  $\pi_i$  replaces the Lagrange parameters  $\mu_i$  of the benchmark case (which are no longer binding and thus redundant). However, the



new Lagrange parameters will now enter into the first-order conditions for the production and the capital tax<sup>7</sup>.

Given the constraints, specific factor taxes are chosen optimally so that  $\partial L / \partial t_{n_i} = 0$ . The first-order conditions for  $t_x$  and  $t_k$  will then change to

$$\frac{\partial L}{\partial t_x} = \frac{\partial w_1}{\partial p_1} \pi_1 + \lambda n_1 \left[ t_k \frac{\partial^2 w_1}{\partial r \partial p_1} - t_x \frac{\partial^2 w_1}{\partial p_1^2} \right] = 0. \quad (27)$$

$$\frac{\partial L}{\partial t_k} = -\frac{\partial w_1}{\partial r} \pi_1 - \frac{\partial w_2}{\partial r} \pi_2 + \lambda \left[ t_x n_1 \frac{\partial^2 w_1}{\partial p_1 \partial r} - t_k \left( n_1 \frac{\partial^2 w_1}{\partial r^2} + n_2 \frac{\partial^2 w_2}{\partial r^2} \right) \right] = 0. \quad (28)$$

From the previous discussion, a sufficient condition for one of the constraints (26) to be binding is that the corresponding specific factor is in fixed supply. In this case the optimal choices of both  $t_k$  and  $t_x$  must differ from those in the benchmark case. Note, however, that  $\pi_i$  is also compatible with an endogenous supply of factor  $n_i$ , provided that the constraint on the level of specific taxation is sufficiently strong. The optimal tax rules that emerge under this restriction are summarized in

**Proposition 3:** *If the specific factor tax on  $n_2$  ( $n_1$ ) is constrained from above so that  $\pi_2 > 0$  ( $\pi_1 > 0$ ), then the optimal tax rate on capital is positive (negative) and the optimal production tax is negative (positive).*

*Proof:* See the appendix.

Proposition 3 parallels a result that Slemrod, Hansen and Procter (1994) have - in a setting with simultaneous taxes on imports and exports of capital - labelled the *seesaw principle* in international tax policy. In the present context it states that if, due to constraints on the taxation of specific factors, one of the taxes  $t_k$  and  $t_x$  is *higher* than in the unconstrained case (i.e., positive rather than zero) then the other of the two taxes will be *below* its unconstrained level (i.e., negative rather than zero). Underlying this inverse relationship are, of course, the cumulative effects that capital and production taxes have on the production inefficiencies generated in sector 1.

To interpret these results in somewhat more detail consider first the case where  $\overline{t_{n_2}}$  is binding. Since there is no production tax in sector 2 the only way to indirectly increase the tax on  $n_2$  is to levy a positive capital tax  $t_k > 0$ . While this distorts production in both sectors the production distortion in sector 1 can be counteracted by an appropriate

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<sup>7</sup>This is so because, in contrast to the benchmark constraints  $\mu_i$ , the new constraints are not affected by production and capital taxes. The production tax, for example, then has (by a multiple) all the effects of a specific tax on  $n_1$ , *except* for the negative effect on the Lagrange multiplier  $\pi_1$ .

production subsidy. As a side effect of the subsidy the effective taxation of  $n_1$  is reduced below its optimal level, but this can always be corrected by an appropriate increase in the specific tax on this factor, which is free to adjust. In the second case, where  $t_{n_1}$  is 'too low' relative to its optimal level, both the production and the capital tax can be employed to increase the effective taxation of  $n_1$ . However, it is clear from the principle of targeting in the optimal tax literature that the production tax in sector 1 is the relatively more efficient instrument since it does not simultaneously distort sector 2 production. The capital tax is then used to reduce the distortion in the production of sector 1 at the price of introducing a new production distortion in sector 2.

Proposition 3 can be related to several recent contributions which have motivated positive source taxes on capital by the inability to fully tax pure profits (Bruce, 1992; Huizinga and Nielsen, 1995). In the present framework, pure profits can be interpreted as the return to a fixed factor that supplies entrepreneurial services. On the one hand, this analysis shows that the argument for capital (or production) taxes can be extended to the case where these services are not in perfectly inelastic supply. On the other hand, if profits are concentrated in certain sectors of the economy then an output tax specific to these sectors may be preferable to a source tax on all capital used in the economy.

A stronger argument for the taxation of capital at source emerges if one assumes that it is not possible in practice to distinguish between the return to capital ( $r$ ) and the return to entrepreneurial services ( $w_i$ ). Existing corporate taxes generally do not allow to deduct the opportunity costs of capital financed out of own resources from the tax base. Therefore, the corporation tax can be seen as a hybrid between a tax on pure rents or profits and a tax on the capital employed by the firm. Analytically this constraint can be captured by replacing the independent tax instruments  $t_k$  and  $t_{n_i}$  by a single tax instrument denoted by  $t_{\hat{k}}$ . To distinguish this new tax from the pure source tax on capital I will generally refer to it as a 'corporation tax' in the following. Its optimal level is determined by the first-order condition

$$\frac{\partial L}{\partial t_{\hat{k}}} = \frac{\partial L}{\partial t_k} + \frac{\partial L}{\partial t_{n_i}} = 0, \quad (29)$$

where  $t_{\hat{k}} = t_k = t_{n_i}$  in (16) and (18). While this new tax instrument will, of course, always be positive when  $t_{n_2}$  is constrained it is no longer dominated by an output tax on sector 1 when  $n_1$  cannot be taxed optimally. Instead, either  $t_x$  or  $t_{\hat{k}}$  or both can be positive in this case.

## 4.2 International Constraints

In this subsection I reverse the assumptions made so far and impose constraints on the international commodity tax regime while allowing optimal domestic taxes on specific factors. The background for this analysis is the abolition of internal borders in the European Union, which effectively eliminates export tax rebates for all goods that are purchased by final consumers. If consumption goods are exclusively purchased by private consumers who face no transaction costs, then a selective value-added tax turns from a consumption into a production tax. (Sinn, 1990a, 1990b).

It is clear from the above analysis that if all commodity taxes have to be levied on an origin basis then the small country will choose not to tax commodity trade at all if the revenue requirement can be met by exclusively relying on the taxation of specific factors. However, under both the transitional system in place until (at least) 1997 and the international tax credit method envisaged for the period thereafter all purchases by VAT-registered traders are still taxed under the destination principle in the internal market. Therefore, many observers argue that commodity taxation in post-1992 Europe follows a ‘mixed’ international tax scheme with elements of both destination and origin taxation (e.g. Keen, 1993).

A simple way to capture these conditions is to model the value-added tax as a general tax, which combines a production tax on good 1 with an equal-rate consumption tax on good 2. Good 1 can be thought of as a category of goods that are easily purchased abroad by final consumers so that international arbitrage is based on gross-of-tax prices. In contrast, transaction costs are assumed to be too high to make cross-border shopping worthwhile for good 2 and arbitrage by traders will equalize producer prices for this good (cf. Haufler, 1993, pp. 59-63). This corresponds to the determination of producer and consumer prices in (3)–(4). Denoting the new tax instrument by  $t_{\hat{x}}$  the constraint is given by

$$\frac{\partial L}{\partial t_{\hat{x}}} = \frac{\partial L}{\partial t_x} + \frac{\partial L}{\partial t_c} = 0, \quad (30)$$

where  $t_{\hat{x}} = t_x = t_c$ . Thus the set of available tax instruments no longer dichotomizes into pure consumption and production taxes. The optimal tax policy for the small country is now described by

**Proposition 4:** *If leisure is a net complement to commodity consumption and taxes on both specific factors can be optimized then the introduction of a mixed production-*

consumption tax leads to

$$t_{\hat{x}} > 0 \quad \text{and} \quad t_k < 0.$$

*Proof:* Under the assumptions made it follows from Proposition 2 that an isolated consumption tax on good 2 would be positive whereas an isolated production tax on good 1 and a tax on capital would both be zero. From the concavity of the objective function with respect to each tax instrument

$$\frac{\partial L}{\partial t_x} + \frac{\partial L}{\partial t_c} = \frac{\partial L}{\partial t_{\hat{x}}} \Big|_{t_{\hat{x}}=t_k=0} > 0, \quad \frac{\partial L}{\partial t_k} \Big|_{t_{\hat{x}}=t_k=0} = 0.$$

Thus  $t_{\hat{x}}$  must be positive to meet the first-order condition. Since tax rates on both specific factors can be optimized this in turn implies  $t_k < 0$  from (22).  $\square$

Proposition 4 gives another example of the inverse ‘seesaw’ relationship between the optimal tax rates on capital and production. Within the set of available tax instruments  $t_{\hat{x}}$  is the only possible substitute for the missing consumption tax on good 2 and forces the marginal productivity of capital in sector 1 above the return to capital in the world market. Therefore, starting from an optimal level of zero in the case without origin-based commodity taxes the small open economy will *subsidize* the capital employed in its jurisdiction in order to reduce the production distortion in sector 1. This production effect is isolated here through the assumption that both specific factors can be taxed optimally. A more realistic analysis of changing the commodity tax regime in the European Union must, however, take account of existing positive corporate tax rates before the switch occurs. This case is taken up in the following.

### 4.3 Combining Domestic and International Constraints

Positive corporate taxes are motivated by the *domestic* constraint that profits and capital must be taxed at the same rate [eq. (29)]. In addition, output taxes are unable to effectively tax these profits, i.e., the fixed factor is taken to be  $n_2$ . An independent argument for positive production taxes is given by the *international* constraint that only mixed commodity tax regimes are feasible under conditions of economic integration [eq. (30)]. It is then straightforward to show that at least one of the taxes  $t_{\hat{k}}$  and  $t_{\hat{x}}$  must be positive. Moreover, the corporate tax and the mixed commodity tax will both be positive when the elasticity of factor substitution in sector 1 – which underlies the negative relationship between the two instruments – is not too large. This assumption is made in the following.

The issue is then whether an inverse relationship between production and capital taxes can still be expected in general, in the sense that a switch to partial origin taxation *lowers* the optimal corporate tax rate. The change in the commodity tax principle is represented in the simplest possible way by introducing exogenously a small production tax  $t_x$  while holding  $t_c$  constant. The analysis determines the effects of this change on the optimal level of the corporate tax  $t_k$ , taking account of the simultaneous change in the specific tax  $t_{n_1}$  (interpreted as a wage tax). To keep matters simple the utility function is constrained to be quasilinear and all income effects accrue to the numeraire good 1. Furthermore, the third derivatives of the gross return functions  $w_i(r, p_i)$  are neglected.

The first-order condition for  $t_{n_1}$  is simplified from (16) since  $n_2$  is a constant. For the optimal choice of  $t_k$  I use (18) and (25) in (29) [assuming that  $\mu_2$  is not binding] and the assumption that income effects are zero for the non-numeraire goods so that  $\theta = \lambda - 1$ . This yields

$$\frac{\partial L}{\partial t_{n_1}} = -n_1 + \lambda \gamma = 0; \quad \gamma = n_1 - t_c \frac{\partial c_2}{\partial \omega_1} - \left( t_{n_1} - t_k \frac{\partial w_1}{\partial r} + t_x \frac{\partial w_1}{\partial p_1} \right) \frac{\partial n_1}{\partial \omega_1}, \quad (31)$$

$$\frac{\partial L}{\partial t_k} = \left( 1 - \frac{\partial w_2}{\partial r} \right) n_2 (\lambda - 1) - \frac{\partial w_1}{\partial r} \frac{\partial L}{\partial t_{n_1}} + \lambda \left[ n_1 t_x \frac{\partial^2 w_1}{\partial r \partial p_1} - t_k \left( n_1 \frac{\partial^2 w_1}{\partial r^2} + n_2 \frac{\partial^2 w_2}{\partial r^2} \right) \right] = 0. \quad (32)$$

The standard procedure to solve this system is to eliminate the Lagrangian multipliers from the two first-order conditions and add the government budget constraint. Changes in the tax rates  $t_k$  and  $t_{n_1}$  then simultaneously reflect substitution effects between the two taxes and an adjustment of tax levels to compensate for changes in the tax base<sup>8</sup>. Instead, I focus here directly on the *structure* of direct taxation and ignore all repercussions through the government budget constraint. This procedure takes advantage of the fact that the first-order condition for the wage tax (31) is fully included in the optimality condition for the corporate tax (32). The Lagrange multipliers are treated as a variable that is affected by the introduction of a small production tax. It will be seen below that this effect can be readily signed and interpreted.

Focusing on the change in  $t_k$  gives the following equation, which is derived in the

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<sup>8</sup>Recall that, in the present model, any reduction (increase) in  $n_1$  leads to a capital outflow from (inflow to) sector 1 so that a production tax will always change the tax bases of the wage tax and the corporate tax in the same direction.

appendix:

$$\frac{dt_{\hat{k}}}{dt_x} = \frac{1}{\Delta} \left\{ \frac{-\partial^2 L}{\partial t_{n_1}^2} \left[ \underbrace{\lambda n_1 \frac{\partial^2 w_1}{\partial r \partial p_1}}_{(1) (-)} + \underbrace{\left(1 - \frac{\partial w_2}{\partial r}\right) \frac{n_2}{\lambda} \frac{\partial \lambda}{\partial t_x}}_{(2) (+)} \right] + \underbrace{\lambda t_{\hat{k}} \frac{\partial^2 w_1}{\partial r^2} \frac{\partial n_1}{\partial \omega_1} \left( \frac{n_1}{\lambda} \frac{\partial \lambda}{\partial t_{x_1}} - \lambda t_{\hat{k}} \frac{\partial^2 w_1}{\partial r \partial p_1} \frac{\partial n_1}{\partial \omega_1} \right)}_{(3) (+)} \right\}. \quad (33)$$

It is shown in the appendix that the determinant  $\Delta$  must be positive from the second-order conditions for a maximum. Furthermore  $(-\partial^2 L / \partial t_{n_1}^2) > 0$  from the concavity of the objective function,  $t_{\hat{k}} > 0$  in the initial equilibrium and  $(\partial n_1 / \partial \omega_1) > 0$  in the absence of income effects. Together with (10)–(14) this signs all terms in (33).

There are three effects in (33) which can be interpreted as changes in the ‘marginal costs’ and the ‘marginal benefits’ of the corporate tax instrument, relative to a tax on labor (i.e.,  $n_1$ ).

(1) The first effect is the direct *effect on production efficiency* from the previous discussion. It is unambiguously negative from (14), indicating an increase in the marginal costs of using the capital tax instrument after a small production tax has been introduced. This once again reflects the additive effects of origin-based commodity taxes and source-based capital taxes on the production distortion caused in the taxed sector.

(2) In the case where the source tax on capital is combined with a tax on rents there is, however, a positive second effect which may be labelled an *excess burden effect*. It arises from the fact that a switch to partial origin taxation will generally change the marginal excess burden of taxation, as reflected in the shadow price of the government budget constraint<sup>9</sup>. This effect is captured here even by a ‘small’ production tax because a zero initial level of  $t_x$  is not optimal. Rather, it follows from Proposition 3 and the concavity of the objective function that

$$\left. \frac{\partial L}{\partial t_x} \right|_{t_x=0} < 0,$$

and this welfare change must be inversely related to the change in the excess burden of taxation. Therefore, it must be true that  $\partial \lambda / \partial t_x > 0$  and the increase in the excess

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<sup>9</sup>This corresponds to the result in the tax competition literature (e.g. Mintz and Tulkens, 1986) that public goods are undersupplied in a Nash equilibrium when origin-based taxes must be used. From the optimality condition of the government this increase in the marginal valuation of the public good is caused by a rise in the shadow price of government revenues.

burden of taxation tends to increase the optimal corporate tax rate. The intuition for this is straightforward: the higher the excess burden of taxation the larger are the marginal benefits of being able to tax rents or pure profits through the corporation tax.

(3) Finally, there is a third *factor supply effect*, which arises when  $t_k \neq 0$  initially. It is positive under the assumptions made here, but need not be so for more general tax reforms (that include, for example, a reduction in consumption tax rates). The effect describes the change in the weight  $n_1$  of the production inefficiency that a given capital tax causes in sector 1, and thus a further change in the marginal costs of using the corporate tax instrument.

Ruling out the case where the supply of  $n_1$  is so elastic as to overcompensate the first effect in (33) these findings can be summarized as follows:

**Proposition 5:** *A small production tax simultaneously increases the production inefficiencies caused by a corporate tax, and the benefits of being able to levy a tax with lump sum elements. Depending on which effect dominates a switch to partial origin taxation may thus raise or lower the corporate tax rate, relative to a tax on the specific factor  $n_1$  (labor).*

Proposition 5 should be quite intuitive given the hybrid nature of the corporation tax in the present context, which combines the aspects of a pure source tax on capital with those of a lump-sum tax. In this setting an inverse relationship between (changes in) production taxes and source-based corporate taxes is thus no longer a necessary result. Moreover, many observers believe that only a relatively small subset of goods will be subject to origin taxation in the European Union's internal market whereas the destination principle continues to apply for most commodity purchases. Therefore, the production efficiency argument, which tends to support an inverse relationship between production taxes and source taxes on capital, may not be very strong in the EU context. If the marginal welfare costs of taxation nevertheless rise measurably as a result of the constraints on international commodity taxation, then the role of a corporate tax that falls partly on rents or profits may actually be strengthened.

## 5 Concluding Remarks

This paper has focused on the interdependencies between optimal taxes on production (origin-based commodity taxes) and source-based taxes on capital income. A small open

economy will set both of these taxes equal to zero when it is able to tax domestic factors of production optimally and it can choose freely between alternative schemes of international commodity taxation. In the presence of a single constraint on the set of available tax instruments, an inverse “seesaw” relationship emerges between optimal taxes on capital and production, where one of the tax rates is positive and the other is negative in equilibrium. This result is driven by the cumulative effects that the two instruments have on the production inefficiencies caused in the taxed sector.

The implication then seems to be that a switch to partial origin taxation of commodities should lower the level of capital taxation at source. This intuition is generally correct, however, only for a ‘pure’ source tax on capital. Instead, existing corporate taxes are hybrid instruments that include a lump-sum element due to domestic constraints on the taxation of pure rents or profits. An international constraint that raises the excess burden of taxation will then cause a second, positive effect on the corporate tax by increasing the value to the government of its lump-sum component. Therefore, there is a distinct possibility – counterintuitive at first sight – that taxes on internationally mobile capital are raised as a result of the commodity tax reform, relative to a tax on factors that are immobile across borders (labor).

It is quite obvious that an attempt to integrate direct and indirect taxes in a small-scale analytical model is subject to a number of inherent limitations. First, the modelling of factor taxes has been rather crude in the present paper. Residence-based taxes on capital income were excluded altogether in the single-period framework chosen, and an intertemporal model would be needed to include this tax instrument in a meaningful way. Another restriction of the specific factors model used here is that there is no room for a general wage tax. This would require an additional factor of production that is intersectorally but not internationally mobile, while maintaining two specific factors to avoid specialization in production. The extension to a four factor model raises no conceptual difficulties but will make the model quite complex.

Second, the analysis has been confined to the effects of a change in the scheme of commodity taxation on the optimal combination of factor taxes. More generally, one would also expect the mix between indirect and direct taxes, treated as aggregates, to change following a rise in the costs of commodity taxation. Relatedly, the fixed-revenue assumption is not strictly appropriate in a setting where the marginal costs of taxation change, and should be replaced by an endogenously supplied public good. Once again, the binding restriction is analytical tractability and it is likely that simulation methods must be



employed to isolate the different effects.

A final point concerns the rationalization of existing tax rates on capital income. In line with other contributions (e.g. Bruce, 1992; Huizinga and Nielsen 1995) this analysis has motivated positive source taxes on capital by a conventional second-best argument, i.e., the inability to tax profits or rents by means of other tax instruments. In a recent paper, Gordon and MacKie-Mason (1994) have taken a different route, explaining corporate income taxes by the need to prevent the conversion of labor income into otherwise untaxed corporate income. These differences in the basic view of the corporation tax may well affect the optimal adjustment of this tax in response to exogenous shocks. Therefore, an important task for empirical analysis is to discriminate between the two competing – or complementary? – explanations of existing corporate income taxes.

## Appendix:

**Proof of Proposition 3:** I turn first to the case where  $t_{n_2}$  is constrained. Since  $\pi_1 = 0$  equation (27) reduces to (21) as before. Solving for  $t_x$  and substituting in (28) gives

$$t_k = -\frac{1}{n_2} \left( \frac{\partial^2 w_2}{\partial r^2} \right)^{-1} \frac{\partial w_2}{\partial r} \pi_2 > 0, \quad (\text{A.1})$$

where (10) and  $J = 0$  from (23) have been used to sign  $t_k$ . Using (13) and (14) it then immediately follows from (27) that  $\text{sign}(t_x) = -\text{sign}(t_k) = -1$ .

The case where  $t_{n_1}$  is constrained requires a few more steps. Substituting (27) in (28) and setting  $\pi_2 = 0$  gives

$$t_k n_2 \frac{\partial^2 w_2}{\partial r^2} = \pi_1 \varepsilon, \quad \varepsilon = \frac{\partial^2 w_1 / \partial p_1 \partial r}{\partial^2 w_1 / \partial p_1^2} \frac{\partial w_1}{\partial p_1} - \frac{\partial w_1}{\partial r}. \quad (\text{A.2})$$

Using the zero-profit condition in sector 1

$$p_1 \frac{\partial w_1}{\partial p_1} - w_1 + r \frac{\partial w_1}{\partial r} = 0$$

and expanding by  $r$  gives

$$\varepsilon = \frac{1}{r} \left[ \frac{\partial w_1 / \partial p_1}{\partial^2 w_1 / \partial p_1^2} \left( r \frac{\partial^2 w_1}{\partial r \partial p_1} + p_1 \frac{\partial^2 w_1}{\partial p_1^2} \right) - w_1 \right] = -\frac{w_1}{r} < 0, \quad (\text{A.3})$$

since  $\partial w_1 / \partial p_1$  is homogeneous of degree zero in  $r$  and  $p_1$ . From (A.2) and (12) follows

$$\text{sign}(t_k) = -\text{sign}(\pi_1) = -1.$$

Substituting (A.2) into (28) using (A.3) gives

$$t_x = t_k \left( \frac{\partial^2 w_1}{\partial p_1^2} \right)^{-1} \left[ \frac{\partial^2 w_1}{\partial r \partial p_1} - \frac{n_2}{n_1} \frac{r}{w_1} \frac{\partial w_1}{\partial p_1} \frac{\partial^2 w_2}{\partial r^2} \right]$$

which can be signed from (11)–(14)

$$\text{sign}(t_x) = -\text{sign}(t_k) = 1. \quad \square$$

**Derivation of Equation (33):** The equation system (31)–(32) is rewritten in compact form

$$\begin{aligned} \partial L / \partial t_{\hat{k}} &\equiv F_{\hat{k}}(t_{n_1}, t_{\hat{k}}; t_x) = 0, \\ \partial L / \partial t_{n_1} &\equiv F_{n_1}(t_{n_1}, t_{\hat{k}}; t_x) = 0, \end{aligned}$$

where the production tax  $t_x$  is treated as an exogenous shift variable. The changes  $dt_{\hat{k}}/dt_x$  and  $dt_{n_1}/dt_x$  are obtained using the implicit function theorem. Totally differentiating and solving the resulting matrix equation through inversion gives

$$\begin{bmatrix} dt_{\hat{k}} \\ dt_{n_1} \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} -\frac{\partial F_{n_1}}{\partial t_{n_1}} & \frac{\partial F_{\hat{k}}}{\partial t_{n_1}} \\ \frac{\partial F_{n_1}}{\partial t_{\hat{k}}} & -\frac{\partial F_{\hat{k}}}{\partial t_{\hat{k}}} \end{bmatrix} \begin{bmatrix} \frac{\partial F_{\hat{k}}}{\partial t_x} & dt_x \\ \frac{\partial F_{n_1}}{\partial t_x} & dt_x \end{bmatrix}, \quad (\text{A.4})$$

where

$$\Delta = \frac{\partial F_{n_1}}{\partial t_{n_1}} \frac{\partial F_{\hat{k}}}{\partial t_{\hat{k}}} - \frac{\partial F_{n_1}}{\partial t_{\hat{k}}} \frac{\partial F_{\hat{k}}}{\partial t_{n_1}} > 0$$

from the second-order condition for a maximum of the optimal tax problem. In a first step only the partial derivatives  $\partial F_{\hat{k}}/\partial t_x$  and  $\partial F_{\hat{k}}/\partial t_{n_1}$  need to be calculated. To differentiate (32) with respect to  $t_x$  I use the fact that  $F_{n_1}$  is zero initially since the labor tax rate is optimized. Furthermore,  $t_x$  is zero initially and second-order derivatives of  $w_i(p_i, r)$  are constants by assumption. Thus

$$\frac{\partial F_{\hat{k}}}{\partial t_x} = -\frac{\partial w_1}{\partial r} \frac{\partial F_{n_1}}{\partial t_x} + \left(1 - \frac{\partial w_2}{\partial r}\right) \frac{n_2}{\lambda} \frac{\partial \lambda}{\partial t_x} + \lambda n_1 \frac{\partial^2 w_1}{\partial r \partial p_1} + \lambda t_{\hat{k}} \frac{\partial^2 w_1}{\partial r^2} \frac{\partial w_1}{\partial p_1} \frac{\partial n_1}{\partial \omega_1}, \quad (\text{A.5})$$

where the second term on the RHS of this equation is derived as the sum of two effects

$$\left(1 - \frac{\partial w_2}{\partial r}\right) \frac{n_2}{\lambda} \frac{\partial \lambda}{\partial t_x} = \left[ \left(1 - \frac{\partial w_2}{\partial r}\right) n_2 - t_{\hat{k}} \left( n_1 \frac{\partial^2 w_1}{\partial r^2} + n_2 \frac{\partial^2 w_2}{\partial r^2} \right) \right] \frac{\partial \lambda}{\partial t_x},$$

and the optimal value of the corporate tax in the initial equilibrium is substituted from (32), recalling that  $t_{n_1}$  is optimized and  $t_x = 0$  initially

$$t_{\hat{k}} = \frac{\lambda - 1}{\lambda} \left(1 - \frac{\partial w_2}{\partial r}\right) n_2 \left( n_1 \frac{\partial^2 w_1}{\partial r^2} + n_2 \frac{\partial^2 w_2}{\partial r^2} \right)^{-1}.$$

Differentiating (32) with respect to  $t_{n_1}$  yields

$$\frac{\partial F_{\hat{k}}}{\partial t_{n_1}} = -\frac{\partial w_1}{\partial r} \frac{\partial F_{n_1}}{\partial t_{n_1}} + \lambda t_{\hat{k}} \frac{\partial^2 w_1}{\partial r^2} \frac{\partial n_1}{\partial \omega_1}, \quad (\text{A.6})$$

where a small change in  $t_{n_1}$  does not affect  $\lambda$  because  $t_{n_1}$  is optimized initially.

Substituting (A.5)–(A.6) in (A.4) and cancelling terms gives as an intermediate result

$$\begin{aligned} \frac{dt_{\hat{k}}}{dt_x} = \frac{1}{\Delta} \left\{ \frac{-\partial F_{n_1}}{\partial t_{n_1}} \left[ \lambda n_1 \frac{\partial^2 w_1}{\partial r \partial p_1} + \left( 1 - \frac{\partial w_2}{\partial r} \right) \frac{n_2}{\lambda} \frac{\partial \lambda}{\partial t_x} \right] \right. \\ \left. + \lambda t_{\hat{k}} \frac{\partial^2 w_1}{\partial r^2} \frac{\partial n_1}{\partial \omega_1} \left( \frac{\partial F_{n_1}}{\partial t_x} - \frac{\partial w_1}{\partial p_1} \frac{\partial F_{n_1}}{\partial t_{n_1}} \right) \right\}. \end{aligned} \quad (\text{A.7})$$

In a second step the last effect in (A.7) is further reduced by differentiating (31) with respect to  $t_x$ . In the familiar way this derivative can be expressed with reference to the effects of a direct tax on  $n_1$  so that

$$\frac{\partial F_{n_1}}{\partial t_x} = \frac{\partial w_1}{\partial p_1} \frac{\partial F_{n_1}}{\partial t_{n_1}} + \frac{n_1}{\lambda} \frac{\partial \lambda}{\partial t_x} - \lambda t_{\hat{k}} \frac{\partial^2 w_1}{\partial r \partial p_1} \frac{\partial n_1}{\partial \omega_1}, \quad (\text{A.8})$$

where  $n_1/\lambda = \gamma$  has been used from the optimal choice of  $t_{n_1}$  in (31). Substituting (A.8) in the second line of (A.7) gives equation (33) in the main text.

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