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Capital Income Taxation of Asymmetric Countries

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Capital Income Taxation of Asymmetric Countries

by

Michael J. Koop

April 2001

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Capital Income Taxation of Asymmetric Countries

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Michael J. Koop

Abstract: The paper analyzes the effects of a source-based capital income tax on production and market structures, trade and capital flows as well as national and global welfare. The analysis is carried by means of a general equilibrium model of trade which incorporates international capital flows as well as the existence of multinational enterprises. The focus of the paper is on identifying the influence of different absolute and relative factor endowments on the effects of capital income taxation. Simulations of the model show that a one-size-fits-all tax policy does not exist and that governments need to take their own country's factor endowment into account when making tax policy decisions.

Key Words: Capital Income Taxation, Asymmetric Countries, Capital Mobility, Tax Competition

JEL Classification: D52, H21, H24, H43

Table of Contents:

1. Introduction
 2. A Model of International Trade with Partial Capital Mobility
 3. Unilateral Capital Income Taxation with Symmetric Countries
 4. Unilateral Capital Income Taxation with Asymmetric Countries
 5. Tax Competition
 6. Conclusions
- References / Appendix

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1. Introduction

The taxation of international capital income has been a much debated topic in economic theory and in actual economic policy making. The optimal taxation literature has tried to provide some insights into the question which type of tax arrangements suits a country best (Diamond, Mirrlees 1971, Dixit 1985, Gordon 1992). Discussions closer to policy making focussed more on issues such as the potentially level playing firms for national firms, fiscal considerations such as the maximization of tax revenues or the tax competition issue (Giovannini 1990, Wagener 1996, Cnossen 2000).

This paper focuses on the effects of the introduction of a source based capital income tax on production and market structures, trade and capital flows as well as on national welfare. In doing so, it explicitly does not attempt to analyze an optimal tax. It does, however, take into account the fact that countries differ in size. Since the model is one that includes an oligopolistic market (Guo, Lansing 1998), it can be expected that country size matters in that it affects the location decision of firms. Of the two firm types under consideration, multinational enterprises (MNEs) can undertake foreign direct investment and therefore avoid the source based tax in the home country.

2. A Model of International Trade with Partial Capital Mobility

The model¹ that will be used for analyzing tax policies consists of two countries with fixed stocks of capital and labor and two homogeneous goods, Y and X. Whereas labor cannot migrate capital is internationally partly mobile to the extent that a multinational enterprise can invest some of its domestic capital stock abroad (FDI). In both countries, good X can be produced by exporters and by MNEs. Good X is produced with increasing returns to scale at the firm as well as at the plant level. In addition, an intermediate input (I) is used in the production of X and exporters incur transport costs when exporting good X. Contrary to good X, good Y and the intermediate input I can be transported at no cost.

A multinational enterprise serves both markets by producing the final output in the respective country. It produces firm-specific fixed costs in the home country and incurs plant-specific fixed costs in both countries. By transferring its technologies to a foreign affiliate, the multinational firm engages in international trade in services. Because this transfer is carried out within the firm it

constitutes intrafirm trade. Production of the intermediate input is completely carried out in the foreign country. Part of the intermediate inputs is then shipped back to the home country where it is used for final production. Because there are no independent suppliers of the intermediate input, trade in intermediate inputs is a strictly internal transaction.

A multinational firm fulfills the capital requirements of its foreign affiliate for plant-specific fixed costs as well as for intermediate and final production by deploying part of its domestic capital stock in the foreign country. It is a restricted form of capital mobility as it does not allow domestic firms to draw directly on the foreign capital stock but only indirectly by moving some production activities abroad. Factor markets in both countries are assumed to be fully competitive, i.e. neither exporters nor MNEs can exert monopsonistic powers. The national capital markets clear if the domestic capital supply equals total capital demand of domestic exporters and domestic multinational firms.

It is assumed that consumers in both countries have identical homothetic preferences. Therefore the distribution of income and property rights can be ignored. In other words, it does not matter who owns the multinational firms, an issue with otherwise important implications. Moreover, consumers have no preferences as to whether good X is produced in the home or in the foreign country or whether it is supplied by an exporter or a multinational firm.

There is free entry and exit in the oligopolistic market. Exporters and MNEs maximize their profits subject to the constraints that production quantities and profits be nonnegative. Their behavior is strictly noncooperative. In order to maximize profits firms set marginal revenues to be not higher than marginal costs and they charge markups in order to recover their fixed costs. Given that there are no barriers to free entry and exit in the oligopolistic sector, companies must make zero profits, i.e. total markup revenues must be equal to total fixed costs. Since the number of firms present in equilibrium is endogenous it might turn out that in some situations the zero profit condition cannot be fulfilled by one or more firm types. In this case, the number of firms (e_i for exporters or m_i for MNEs) is equal to zero, meaning that good X is not produced by the respective firm type. In other words, the set of possible solutions is not by assumption restricted to interior solutions but may very well contain corner solutions.

Although marginal costs are constant which normally allows to solve one-period oligopoly problems for each market separately (Brander 1981), the equations need to be solved simultaneously because the markets are interrelated. This is due to the endogeneity of the number and type of firms which determine supply conditions in the two markets simultaneously. In order to analyze the effects of different factor endowments simulation techniques were applied. In the simulations², good X is the capital-intensive good whereas Y is the labor-intensive one. However, firms can split up the production of X into three different stages: the production of fixed costs (R&D, T), the intermediate input (I) and final assembly (F). Each step requires capital and labor to be used, albeit in different proportions. In the benchmark scenario, relative factor endowments and capital intensities with respect to the various production stages are as follows:

$$(K^{R\&D}_i / L^{R\&D}_i) = (K^T_i / L^T_i) > (K^F_i / L^F_i) > (K_i / L_i) > (K^Y_i / L^Y_i) > (K^I_i / L^I_i)$$

In the benchmark equilibrium, total capital intensity of good X is approximately twice that of good Y. The expenditure shares in the Cobb-Douglas utility functions are 0.5 for both products.

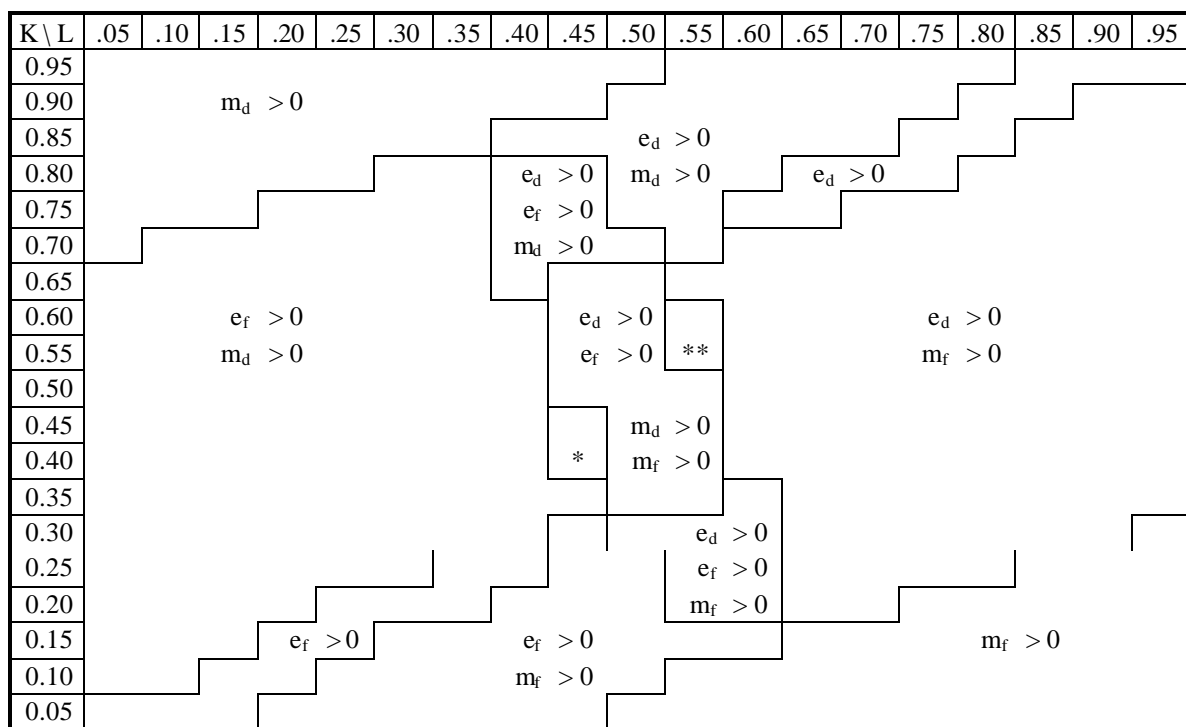
The question of the market structure prevailing for some distribution of production factors can be answered by looking at the cost structures of the two firm types. First, the concentration-proximity trade-off is of interest. Although the production technologies of both firms are essentially the same some cost-relevant differences exist. Exporters incur plant-specific fixed costs only once so their fixed capital cost are comparatively low. On the other hand, producing far away from the market lead to additional transport costs which are variable labor costs. Secondly, exporters must always employ the resource of their home country. MNEs can exploit relative factor price differences by investing abroad.

Figure 1 presents an overview of market structures for 361 different factor distributions. There is no tax on capital income yet. In the equilibrium with identical countries (both countries own 50 percent of the world capital stock and 50 percent of the world's labor pool), exporters from both countries and therefore intraindustry trade in identical products exists. They profitably engage in „reciprocal dumping“, i.e. they undercut the price in the other country as they only have to cover their marginal costs which are below prices due to fixed costs (Brander, Krugman 1983).

Therefore a product sold at a lower price in the foreign market cannot profitably be re-imported to the country of origin. In addition to exporters, MNEs from both countries exist because (with equalized relative factor prices) the concentration-proximity tradeoff just balances.

Changing the factor distribution and making one country capital-abundant and/or big has a significant impact on the market structure as well as on trade and investment flows. Mixed equilibria and single firm type equilibria exist depending on the relative strength of the concentration-proximity tradeoff and relative factor price differences.

Figure 1: Active Types of Firms with Partly Mobile Capital



* $e_d > 0, e_f > 0, m_d > 0$; ** $e_d > 0, e_f > 0, m_f > 0$.

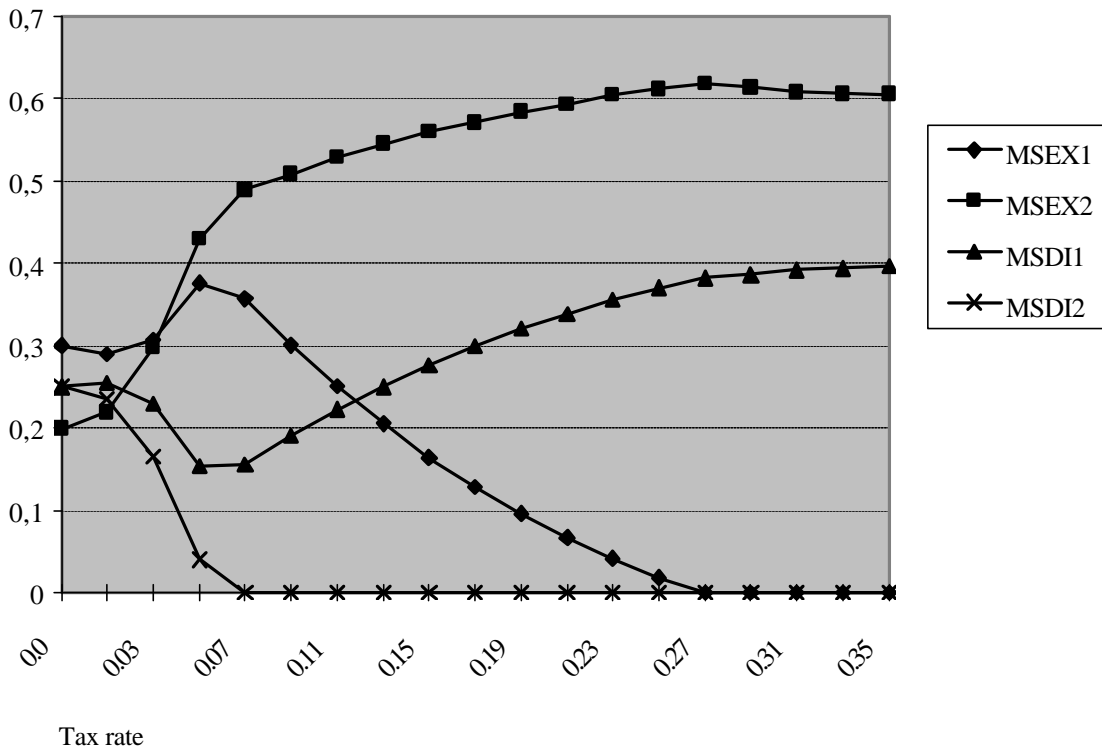
3. Unilateral Capital Income Taxation with Symmetric Countries

The introduction of a source-based capital income tax in one country has profound effects on the economies of both countries even if these countries are identical. Figure 2 indicates the changes in market structure, i.e. the changes in competitiveness of the four firm types. The direct effect of the source-based income tax is that it drives a wedge between gross and net returns thereby making the domestic country a less profitable location for investment. It can be expected that market shares shift from those firm types which have to deploy part or all of their capital stock in the domestic country to those which can invest abroad. The first firm type to exit the market are foreign MNEs. In the benchmark scenario, the foreign exporters and foreign MNEs are both competitive because the transport cost savings of MNEs are just offset by additional plant-specific fixed costs. Even relatively low tax rates tip the balance towards the foreign exporters and foreign MNEs exit the market at a tax rate of 7 percent (Figure 2). An increase in the tax rate beyond that point starts to impede the competitiveness of domestic exporters which are fully exposed to the domestic tax and have (unlike domestic MNEs) no alternative at hand. Therefore equilibria for tax rates higher than 27 percent consist of domestic MNEs and foreign exporters only.

Not surprisingly, the introduction of a domestic capital income tax immediately turns the domestic country into a net capital exporter. However, for low tax rates domestic gross capital exports decrease, albeit less than gross capital imports. As soon as the tax rates reaches a level that forces foreign MNEs out of the market and thus capital imports cease to exist, domestic capital exports increase with higher tax rates.

4. Unilateral Capital Income Taxation with Asymmetric Countries

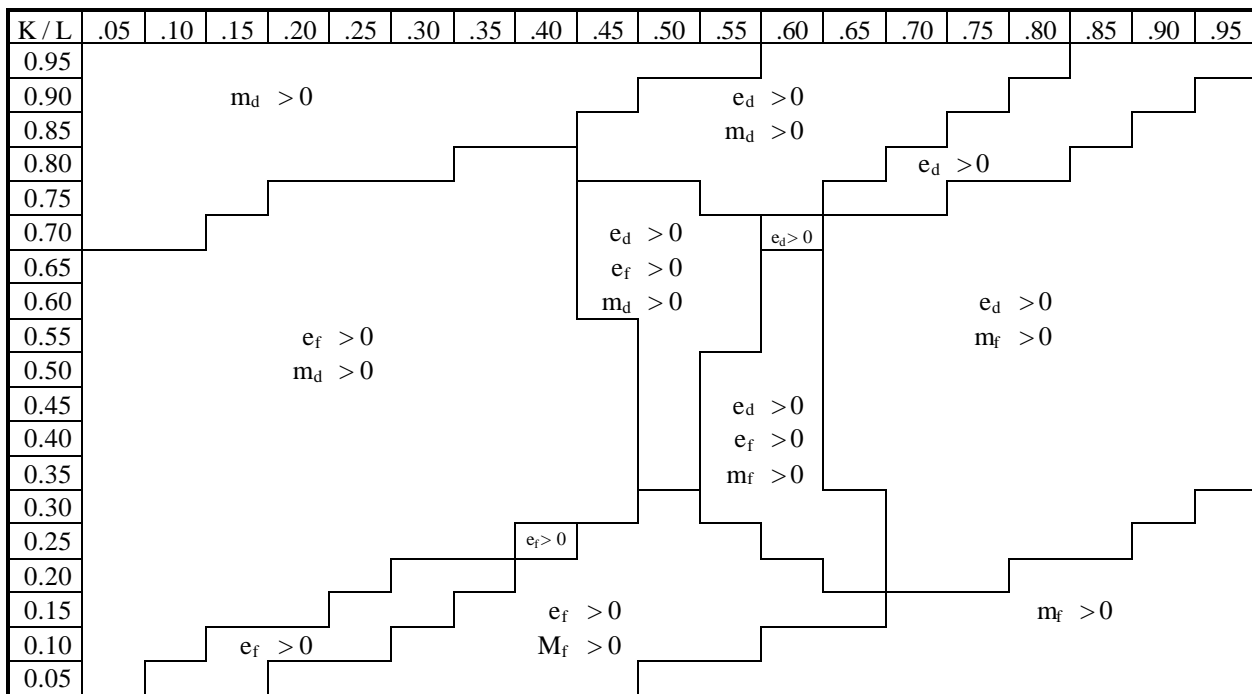
When the world's resources are not distributed equally, the introduction of a source-based tax on international capital income changes market structures, trade and capital flows as well as national welfare levels. The new market structures are shown in Figure 3 and the darker factor distributions in Figure 4 are those for which one or more firm types had to exit the market due to a tax-related loss of competitiveness.

Figure 2: Market Shares of Different Firm Types

The impact of a capital income tax is that it strengthens those firm types which can avoid the tax, in particular foreign exporters and domestic multinationals. Even when countries are very dissimilar this holds true. Take, for instance, the introduction of a capital income tax in a big and very capital-abundant country (upper central area in Figure 3) where 95 percent of capital and 55 percent of labor define the factor endowment of the domestic economy. Here, the introduction of a capital income tax fosters the competitiveness of domestic MNEs further, forcing domestic exporters to exit the market. While in this particular case, Figure 1 shows that without taxation both domestic exporters and domestic MNEs are active in equilibrium, Figure 3 identifies domestic multinationals as the sole suppliers of good X. The reason for this shift in competitiveness is that domestic MNEs can and do invest heavily in the foreign country whereas domestic exporters are exposed to the tax to its full extent. The foreign investment undertaken by domestic MNEs influences the international division of labor, leading to changes in national factor demands and

consequently to changing relative factor prices. FDI increases the demand for labor in the foreign country because (a) all final assembly of good X to be sold in the foreign country is now carried out in the foreign country and (b) production of the intermediate input which is the most labor-intensive production stage is completely relocated to the foreign country. Because the labor-abundant country specializes in the production of the most labor-intensive production the tax imposing country moves in the direction of the homogeneous good Y whose labor-intensity is between the final assembly of X and the intermediate input. Thus, the change in capital flows is accompanied by a change in the volume and composition of trade flows. Whereas the final product X is not traded anymore, the volume of intermediate inputs exported to the tax-imposing country and the exports of good Y from the tax-imposing country increase. Obviously, the single period nature of the model requires that the trade deficit of the tax-imposing country is accompanied by a surplus in its service account (consisting of returns and capital and markups as remuneration for the provision of the firm-specific and plant-specific fixed costs).

Figure 3: Active Types of Firms



From a policy perspective it is interesting to see how the imposition of a source-based capital income tax affects national welfare. Welfare in this model can be measured in terms of the Hicksian equivalent. For the benchmark equilibrium (equal division of factor endowments), utility levels for both countries are normalized to equal one. Of course, interpreting changes in national utility levels due to the redistribution of factors of production is not meaningful. Instead, the national welfare levels must be compared for the same distribution of factors before and after the introduction of the tax.

The overall change in welfare is brought about by a number of factors. First, the volume of intra-industry trade in the final good X determines how much labor is needed to provide transport services. Elimination of intra-industry trade in X as well as any reduction in total volume of trade in X would free labor which could be used to produce the final goods. Secondly, the size of firms plays a role insofar as fewer and bigger firms spend less on firm-specific and plant-specific fixed costs. In particular, the composition of supply is important because exporters only produce at one plant and incur plant-specific fixed costs only once. Moving from an equilibrium with MNEs to one in which exporters dominate should in and by itself be welfare improving (however, the counteracting effect of higher transport costs needs to be taken in consideration). Thirdly, the introduction of the tax is bound to change the terms of trade. Changes in factor prices and in markups charged to recover fixed costs are the main sources for changes in the terms of trade. Finally, the tax redistributes rents. If the capital importing country imposes a tax it reduces the rents earned by the MNEs of the other country. Taken together, these four factors determine what the net effect for an individual country and for the world is and it comes as no surprise that the introduction of a capital income tax does not produce a generally applicable result with respect to welfare changes. Instead, the welfare effects depend on a country's absolute and relative factor endowment.

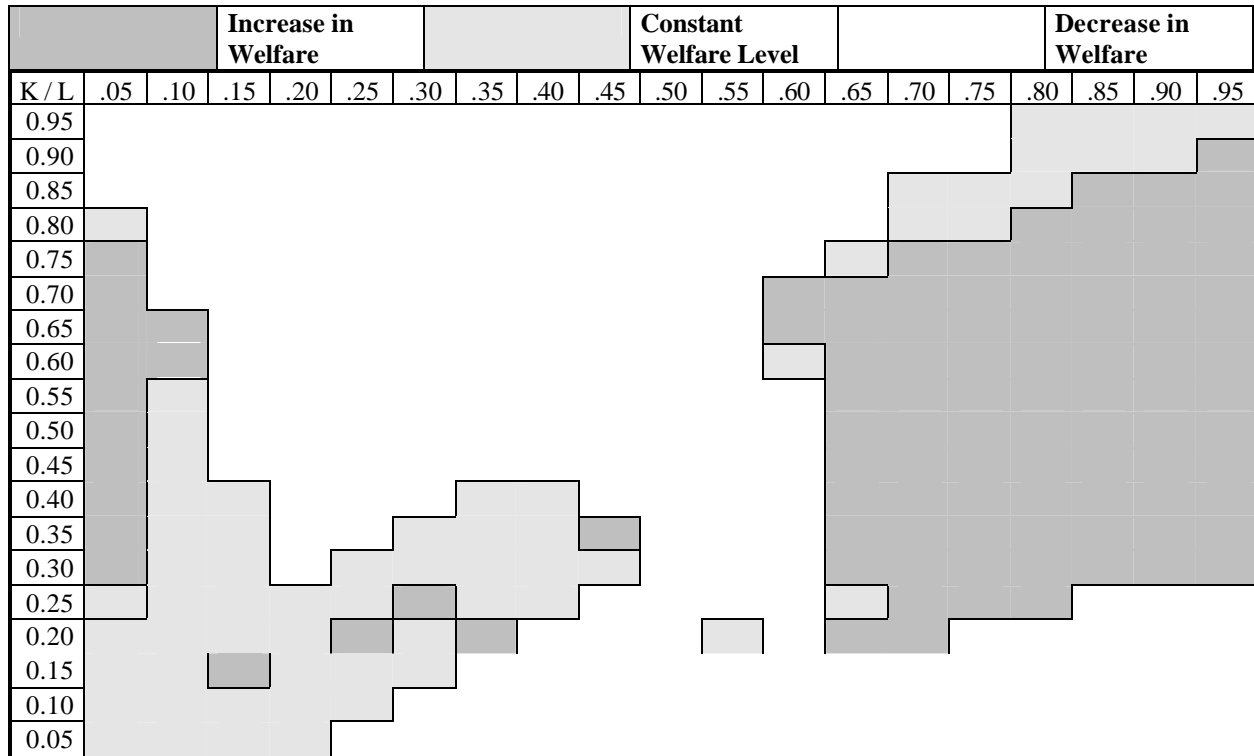
Figure 5: Changes in Domestic Welfare due to Domestic Source Tax on Capital Income

Figure 5 (6) presents the welfare effects from the point of view of the tax-imposing domestic (foreign) country while Figure 7 presents the changes in world welfare. For many factor distributions, imposing a capital income tax reduces domestic welfare. In most capital-abundant country cases, this is due to the fact that the tax simply forces the domestic MNEs to invest abroad instead of at home. This reduces the marginal productivity of labor at home and therefore domestic wages as well as returns on capital earned in the foreign country. One consistent exception is when a country is big and labor-abundant. In this case, the country is sufficiently big and sufficiently labor-abundant to attract foreign FDI. The main determinant for the change in welfare is the redistribution of rents from the foreign to the domestic country. This is supported by the findings that (a) the foreign country's and (b) the world welfare level are reduced.

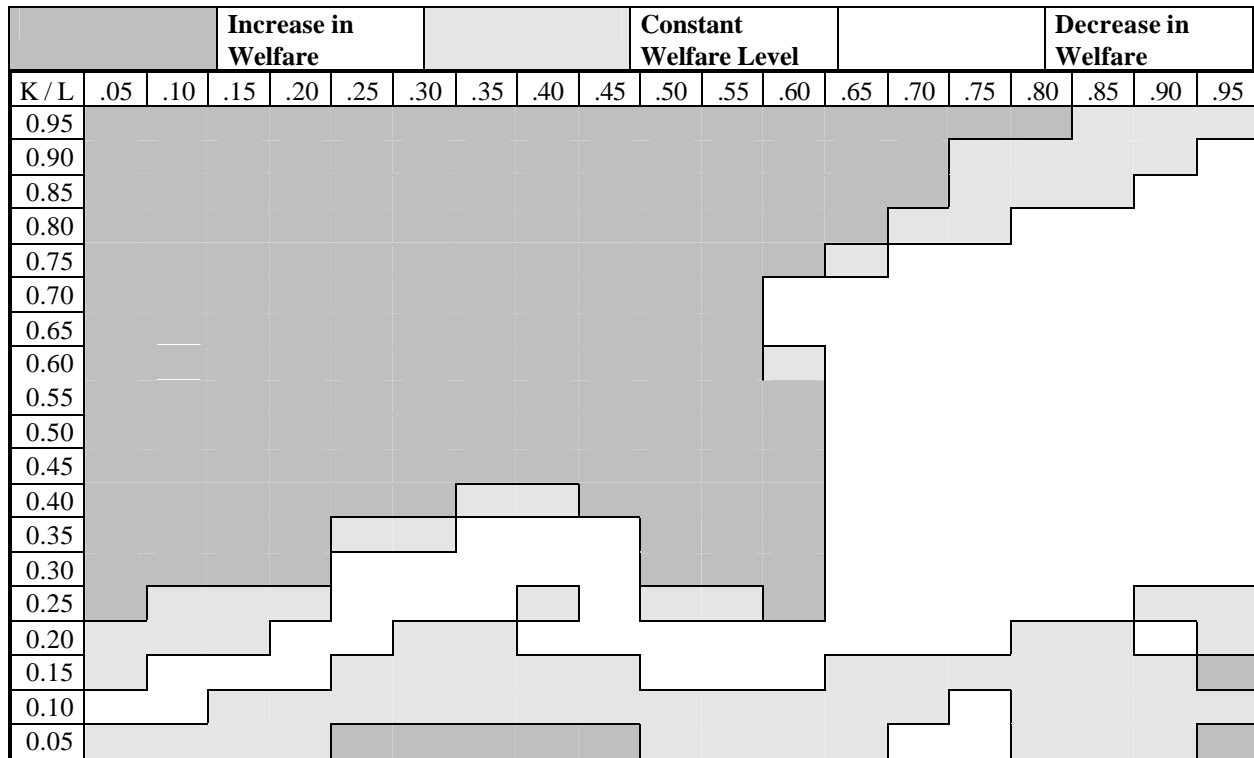
Figure 6: Changes in Foreign Welfare due to Domestic Source Tax on Capital Income

Figure 7 shows that the introduction of a capital income tax does not merely redistribute rents among the two countries but that it exerts an influence on the world welfare level as well. Without covering individual cases, it is obvious that the introduction of a source-based capital income tax reduces world welfare if the tax-imposing country is big and labor-abundant. In these cases, the allocation of the world capital stock becomes inefficient as not enough capital is invested in the labor-abundant country. Unfortunately it was shown in Figure 5 that a big labor-abundant country has an incentive to impose such a tax as it increases national welfare. Increases in world welfare mostly occur when the tax-imposing country is relatively capital-abundant, more or less independent of its size. Here, the effect seems to be working in the opposite direction. By taxing the returns on capital in the domestic country it drives capital to the foreign, labor-abundant country.

Figure 7: Changes in World Welfare due to Domestic Source Tax on Capital Income

K / L	Increase in Welfare				Constant Welfare Level				Decrease in Welfare				
	.10	.20	.30	.35	.40	.45	.50	.55	.60	.65	.70	.80	.90
0.90													
0.80													
0.70													
0.65													
0.60													
0.55													
0.50													
0.45													
0.40													
0.35													
0.30													
0.20													
0.10													

5. Tax Competition

Up to now, the analysis was confined to one country imposing a tax and the other country holding still and suffer or enjoy the effects. The model, however, also provides a way of looking at the tax competition issue. Assume that both countries can either impose a 10 percent source-based income tax or no tax at all. Assume further that they make their choices in a strictly non-cooperative way, i.e. the resulting equilibrium is of the Nash type.

The presumption of many contributions to the economic literature is that capital market integration would ultimately lead the abolishment of capital income taxation. Counter-arguments include that this results hinges in some way upon the negligence of what a government can do with the tax receipts. Tax competition would reduce national tax rate until the marginal costs and benefits of that tax are equalized.

Simulations of the model show that the results of tax competition are also determined by the absolute and relative factor endowments of the tax-imposing countries. Figure 8a presents the pay-off matrix for a case in which the world labor pool is distributed evenly among the two countries whereas one country owns 60 percent and the other country 40 percent of the world capital stock.

The first figure in the table presents the normalized value of the Hicksian equivalent for the capital-abundant country, the second one is the value for the labor-abundant country. It is easy to see that tax competition leads both countries to choose the no-tax policy option.

Figure 8a: National Welfare Levels

Capital-abundant (big) country	Labor-abundant (small) country		
		t = 0.0	t = 0.1
	t = 0.0	(1.062 0.938)	(1.067 0.931)
t = 0.1	(1.054 0.946)	(1.061 0.939)	

Figure 8b repeats the exercise for a different distribution of world resources. Now one country is home to 80 percent of the world labor pool and to 65 percent of the world capital stock, making this country relatively labor-abundant and big in size. For this factor distribution, both countries would opt for the capital income tax and tax competition would not lead to the abolishment of capital income taxation.

Figure 8b: National Welfare Levels

Capital-Abundant (small) country	Labor-abundant (big) country		
		t = 0.0	t = 0.1
	t = 0.0	(0.301 1.716)	(0.295 1.720)
t = 0.1	(0.303 1.717)	(0.296 1.721)	

6. Conclusions

The paper analyzed the effects of a source-based capital income tax. The main result was that the imposition of such a tax can have very different effects depending on the absolute and relative factor endowments of the tax-imposing country. In particular it was shown that capital income taxation affects the competitive balance between different firm types. While (domestically producing) exporters stand little chance to avoid the tax, MNE can partly do so by investing abroad. Therefore a capital income tax in one country favors (a) MNEs of that country compared to exporters of the same country and (b) exporters of the other country compared to MNEs of that country.

The change in the competitiveness of the four firm types and the ensuing changes in market structures also exert a strong influence on trade flows, goods and factor prices as well as the national welfare levels. With respect to welfare it was shown that big and labor-abundant countries have an incentive to impose capital income taxes because it redistributes welfare from the other country to the tax-imposing country. Since world welfare was reduced by the tax it would pay for the other country to prevent the imposition of the tax by means of side payments.

Finally, the aspect of tax competition was introduced. When both countries had the choice between tax rates of either zero or 10 percent, the non-cooperative equilibrium tax policies, again, depended on the absolute and relative factor endowments. All combinations were found, including the two presented in the paper in which both countries (a) did not and (b) did impose a tax on capital income.

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Appendix

The model consists of two countries (i), with fixed stocks of the two factors of production, capital (K_i) and labor (L_i). There are two homogeneous goods, Y and X. Good Y is produced in both countries according to the following CES technology:

$$(1) \quad Y_i = (L_{iy}^\rho + K_{iy}^\rho)^{1/\rho} \quad i = d, f$$

where ρ stands for the elasticity of substitution.

In both countries, good X can be produced by exporters and by MNEs. Each exporter (E) produces good X according to the following cost function:

$$(2) \quad w_i L_{Ei} + r_i K_{Ei} = w_i [FL_{Ei} + PL_{Ei} + (c_{iL} + c_{iF}) X_{Eii} + (c_{iL} + c_{iF} + \tau) X_{Eij}] + \\ r_i [FK_{Ei} + PK_{Ei} + (c_{iK} + c_{iF}) (X_{Eii} + X_{Eij})] \quad i, j = d, f \quad i \neq j$$

where w_i denotes the wage rate in country i and r the rate of interest. L_{Ei} stands for total labor demand of one exporter of country i whereas K_{Ei} is the exporter's total demand for capital. FL_{Ei} (PL_{Ei}) denote total labor demand of a country i exporter for firm-specific (plant-specific) fixed costs. Likewise FK_{Ei} and PK_{Ei} denote an exporter's demand for capital for firm-specific and plant-specific fixed costs. The parameters c_{iL} and c_{iF} stand for marginal labor requirements for the pro-

duction of the intermediate input and final production. Likewise, c_{IK} and c_{FK} denote marginal capital requirements for the intermediate input and for final production. The parameter τ denotes fixed transport costs measured in units of domestic labor which are independent of the direction of trade. Finally, X_{Eii} is the quantity of output produced by an exporter of country i to be sold in the home market whereas X_{Eij} denotes the same exporter's output for sales in the foreign market.

A multinational enterprise (for simplicity denoted by M in the equations) serves both markets by producing the final output in the respective country. Total production costs of a multinational enterprise of country i are:

$$(3) \quad w_i L_{Mii} + w_j L_{Mij} + r_i K_{Mii} = w_i [FL_{Mii} + PL_{Mii} + c_{FL} X_{Mii}] + \\ r_i [FK_{Mii} + PK_{Mii} + PK_{Mij} + c_{IK} (X_{Mii} + X_{Mij}) + c_{FK} (X_{Mii} + X_{Mij})] + \\ w_j [PL_{Mij} + c_{IL} (X_{Mii} + X_{Mij}) + c_{FL} X_{Mij}] \quad i, j = d, f \quad i \neq j$$

where L_{Mii} stands for a multinational's total demand for domestic labor and L_{Mij} for its labor demand abroad. The firm's demand for capital K_{Mii} is strictly limited to domestic sources. FL_{Mii} (PL_{Mii}) are again labor requirements for firm-specific fixed costs (domestic plant-specific fixed costs). FK_{Mii} (PK_{Mii} , PK_{Mij}) denote the demand for capital for firm-specific and (domestic and foreign) plant-specific fixed costs. Since all capital requirements are fulfilled through the parent company in the domestic country, PK_{Mij} dwells on the domestic capital stock as well. PL_{Mij} constitutes the labor requirements for the plant-specific fixed costs abroad. The parameters c_{IL} and c_{FL} (c_{IK} and c_{FK}) again denote per unit requirements of labor (capital) for intermediate and final production. Finally, X_{Mii} and X_{Mij} are the quantities of X produced and sold by an MNE of country i in countries i and j , respectively.

The labor market in country i clears if the domestic labor supply (L_i) equals total labor demand generated by exporters of country i and multinational firms from both countries:

$$(4) \quad L_i = L_y + e_i L_{Ei} + m_i L_{Mii} + m_j L_{Mji}$$

where e_i is an endogenous variable denoting the number of exporters in country i . Accordingly, $e_i L_{Ei}$ equals total labor demand of exporters in country i . Likewise, m_i (m_j) is the number of multinationals of country i (j) so that $m_i L_{Mii}$ ($m_j L_{Mji}$) equal total labor demand of country i (country j) multinationals in country i .

The national capital markets clear if the domestic capital supply (K_i) equals total capital demand of domestic exporters and domestic multinational firms:

$$(5) \quad K_i = K_{iy} + e_i K_{Ei} + m_i K_{Mii}.$$

In order to endogenize the number of firms in the oligopolistic market (e_i , m_i) there is free entry and exit. With free entry and exit, no profits are made in the oligopolistic sector. Therefore income in country i (I_i) consists of the sum of factor rewards for domestic capital and labor:

$$(6) \quad I_i = w_i L_i + r_i K_i.$$

Income can be spent on the two goods. With p_i representing the relative price of good X in terms of the numeraire, the budget constraint is:

$$(7) \quad I_i = p_i X_i + Y_i$$

with X_i representing total supply of good X in country i :

$$(8) \quad X_i = e_i X_{Eii} + e_j X_{Eji} + m_i X_{Mii} + m_j X_{Mji}.$$

It is assumed that consumers in both countries have identical homothetic preferences. The utility function of country i is assumed to be of the Cobb-Douglas type:

$$(9) \quad U_i = X_i^\alpha Y_i^{1-\alpha}.$$

Maximizing (9) subject to the household budget constraint (7) results in the following demand functions for the two goods:

$$(10) \quad X_i = \alpha I_i / p_i \quad Y_i = (1 - \alpha) I_i$$

Exporters and MNEs maximize their profits subject to the constraints that production quantities and profits be nonnegative. Their behavior is strictly noncooperative. In order to maximize profits firms set marginal revenues to be not higher than marginal costs. In other words, if marginal costs exceed marginal revenues the company will not exist in equilibrium. The pricing equations are given in complementary slackness form:

$$(11) \quad p_i(1 - z_{Eii}) - [w_i(c_{IL} + c_{FL}) + r_i(c_{IK} + c_{FK})] \leq 0; \quad X_{Eii} \geq 0;$$

$$\{p_i(1 - z_{Eii}) - [w_i(c_{IL} + c_{FL}) + r_i(c_{IK} + c_{FK})]\}X_{Eii} = 0$$

$$(12) \quad p_j(1 - z_{Eij}) - [w_i(c_{IL} + c_{FL} + \tau) + r_i(c_{IK} + c_{FK})] \leq 0; \quad X_{Eij} \geq 0;$$

$$\{p_j(1 - z_{Eij}) - [w_i(c_{IL} + c_{FL} + \tau) + r_i(c_{IK} + c_{FK})]\}X_{Eij} = 0$$

$$(13) \quad p_i(1 - z_{Mii}) - [w_i c_{FL} + w_j c_{IL} + r_i(c_{IK} + c_{FK})] \leq 0; \quad X_{Mii} \geq 0;$$

$$\{p_i(1 - z_{Mii}) - [w_i c_{FL} + w_j c_{IL} + r_i(c_{IK} + c_{FK})]\}X_{Mii} = 0$$

$$(14) \quad p_j(1 - z_{Mij}) - [w_j(c_{IL} + c_{FL}) + r_i(c_{IK} + c_{FK})] \leq 0; \quad X_{Mij} \geq 0;$$

$$\{p_j(1 - z_{Mij}) - [w_j(c_{IL} + c_{FL}) + r_i(c_{IK} + c_{FK})]\} = 0$$

The parameters z_{Eii} (z_{Eij}) and z_{Mii} (z_{Mij}) denote markups which the companies charge in order to recover their fixed costs. In a Cournot model with homogeneous products, the optimal markups can be approximated by dividing a firm's market share by the Marshallian price elasticity of demand in the respective market. In this model, the price elasticity of demand equals one. Therefore the optimal markups are equal to a firm's market share in the two markets:

$$(15) \quad z_{Eii} = p_i X_{Eii} / \alpha I_i \quad z_{Eij} = p_j X_{Eij} / \alpha I_j \quad i, j = d, f$$

$$z_{Mii} = p_i X_{Mii} / \alpha I_i \quad z_{Mij} = p_j X_{Mij} / \alpha I_j$$

Given that there are no barriers to free entry and exit in the oligopolistic sector, companies must make zero profits, i.e. total markup revenues must be equal to total fixed costs. The zero profit conditions for the four firm types are given in comparative slackness form with the associated variables in parentheses:

$$(16) \quad p_i X_{Eii} z_{Eii} + p_j X_{Eij} z_{Eij} \leq w_i (FL_{Ei} + PL_{Ei}) + r_i (FK_{Ei} + PK_{Ei}) \quad (e_i) \quad i, j = d, f; \quad i \neq j$$

$$(17) \quad p_i X_{Mii} z_{Mii} + p_j X_{Mij} z_{Mij} \leq w_i (FL_{Mii} + PL_{Mii}) + w_j PL_{Mij} + r_i (FK_{Mii} + PK_{Mii} + PK_{Mij}) \quad (m_j) \quad i, j = d, f; \quad i \neq j$$

¹ The model has been laid out in more detail in Koop (1997, 2000, 2001), for the mathematical structure of the model see the Appendix..

² The model was simulated using the GAMS subsystem MPSGE (Rutherford 1989).