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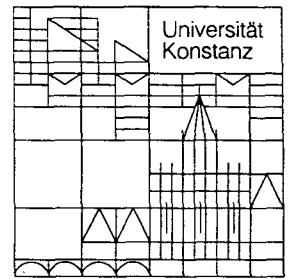
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„Internationalisierung der Wirtschaft“

Diskussionsbeiträge



Juristische
Fakultät

Fakultät für Wirtschafts-
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Sebastian Killinger

**Indirect Internationalization of
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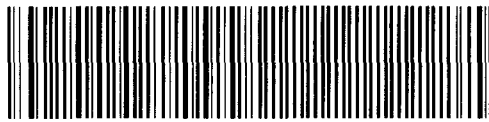
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Juni 1995

Indirect Internalization of International Environmental Externalities*

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Abstract

The paper deals with the analysis of nationally optimal tax structures as to internalize cross-border externalities. Furthermore, the existence of a double dividend arising from the implementation of pollution taxes is evaluated. In the presence of lump-sum taxes both pollution taxes and capital taxes serve to internalize the externalities, and to strategically influence the capital rent at the world capital market. In the case where lump-sum taxes are not available, conditions are found under which a double dividend can be reaped from the introduction of a pollution tax, i.e. that environmental quality improves and, additionally, private incomes rise.

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1 Introduction

International environmental externalities are gaining growing attention due to their foreseeable or feared irreversibility. The main characteristic of for instance global warming or acid rain is that damages are imposed not only on the country of origin but also across borders. In the absence of a supranational authority having the competence to efficiently internalize the externalities by means of e.g. a PIGOU-tax we observe a prisoner's dilemma. Rationally acting national governments that wish to maximize utility of their consumers do not take into consideration damages the country imposes on others. Consequently environmental externalities are generated at a level which is too high under global efficiency considerations. The failure of the EUROPEAN UNION to implement a common energy tax in its member states as it was discussed for a long time, as well as the inability of the participating countries at the succeeding Rio conference in Berlin to agree on binding and coordinated actions against environmental degradation, show that decentralized solutions increasingly move into the centre of interest, again. In deriving optimal national environmental tax policies the advancing integration of the world economy has extended the public debate as well as economic analysis to additional aspects:¹

First, the interaction of international trade and the environment. Can relatively lax environmental regulations serve as a substitute for trade policy? Do polluting industries move to areas with low environmental standards? Due to the increasing integration national internalization instruments lose their first-best feature since environment-depleting industries can circumvent these taxes by leaving the country. The global character of the externality implies that the environmental situation of an internalizing country does not necessarily improve.²

Second, the interaction of factor mobility and environmental regulation. Does competition for internationally mobile factors lead to a downward regulation of environmental standards?³

¹Policy instruments being considered in this paper are restricted to taxes — regulations or emission permit schemes are excluded.

²For carbon dioxide this is called the carbon leakage effect. [25] Snape (1992) analyses the characteristics and particularities of international environmental externalities in detail. [15] Markusen (1975) was the first to analyse allocational impacts of national policy measures in the context of cross-border externalities. The linkage between international trade and cross-border externalities has also been subject of papers by e.g. [13] Krutilla (1991), [17] Merrifield (1988), and [16] Mc Guire (1982). Their emphasis is on the derivation of optimal policy interventions. [6] Copeland (1994) and [20] OECD (1994) both investigate piecemeal reforms in a small open economy and use a dual approach for their analysis. [6] Copeland (1994), [16] Mc Guire (1982), and [17] Merrifield (1988) extend the analysis to international factor mobility.

³[22] Rauscher (1993) derives optimal policy reforms in a model with internationally mobile capital. His analysis is based on the standard approach to international factor mobility developed by [14] MacDougall (1960) and [12] Kemp (1964). A survey over this and other approaches to international factor mobility is given by [23] Ruffin (1984). Rauscher's model is extended by an international externality. [19] Oates et al. (1988) embed the problem into the local public finance literature. They analyse how jurisdictions within a federal state will optimally set capital taxes as well as environmental standards as to maximize utility of the representative consumer. [11] Kanbur et al. (1993) direct the question of strategic actions in the context of environmental regulations to

Third, the possibility to indirectly internalize externalities generated by a foreign country. International integration enables a big country being a victim of cross-border externalities to position a lever at the foreign externality generation and to at least partly internalize it by manipulating world market prices. In contrast to this a small country that faces fixed prices at the world market can only internalize domestically generated externalities. Due to its reduced marginal productivity capital will be driven out of the country if other countries do not as well implement an environmental policy. If the externality has the characteristic of an international public good (as it is the case e.g. for carbon dioxide) environmental quality will not significantly change in the internalizing country, but its income situation will deteriorate due to lower production possibilities.

The paper analyses nationally optimal tax structures in the presence of cross-border externalities by taking respect of the mentioned aspects. The insights gained are then used to evaluate ecological tax reforms in a second-best framework. The underlying idea is that if national governments are restricted by a budget constraint with lump-sum taxes not being available, a second dividend can be reaped from environmental taxes apart from the amelioration of the environment.⁴ Tax income from environmental taxes could be used to cut back other distortionary taxes in order to reduce the excess burden of national tax systems. This combination of the RAMSEY and the PIGOU objectives of taxation was first addressed by [8] Diamond (1973) and [24] Sandmo (1975). With the growing awareness concerning environmental depletion in the last few years the discussion was taken up again for instance by [21] Pearce (1991) and [18] Oates (1993). But since their contributions were restricted to partial analytical considerations, interdependencies of pollution taxes with other taxes were neglected. General equilibrium analyses taking respect also of repercussions which environmental taxes have on other markets show for distorted economies that there is a negative tax-interaction effect apart from the revenue-recycling effect.⁵ The presence of prior taxes implies higher gross costs from the environmental tax — even when revenues are recycled through cuts in the distortionary tax.⁶ The double dividend quality has so far mainly been analysed for closed economies without international factor mobility. Thus, it needs further illumination in an open economy where environmental damage is caused across national borders and where tax bases can erode due to international factor movements.

In this paper a two-country model is used where both countries are connected by international capital movements and a cross-border externality. Aspects of retaliation are neglected by assuming that countries do not react to the measures undertaken by the other. The double dividend

the aspects of harmonization and the agreement on minimum standards.

⁴The existence of two dividends has been called the double dividend characteristic of environmental taxes in the literature.

⁵This termination in the context of a double dividend quality of environmental taxes is used by [10] Goulder (1994). He also gives three definitions of double dividend notions (strong, medium, and weak form).

⁶See for example [3] Bovenberg et al. (1994), [4] Bovenberg et al. (1994), [5] Bovenberg et al. (1994).

analysis takes place against the background of a distorted international allocation of capital through the existence of capital taxes.

In a context where lump-sum taxes are available to the government for financing the budget, we find that both, pollution taxes and capital taxes aim at manipulating world market prices and additionally at directly and indirectly internalizing the externality. The targeting of the aims is more effective if both tax instruments are simultaneously implemented. Optimal environmental tax rates as well as optimal capital tax levels are found to be higher in the case of joint implementation. For lump-sum taxes not being available, conditions for the existence of a double dividend of environmental taxes are derived. We consider the case where the distortionary capital tax is cut back by means of the environmental tax proceeds.

The paper proceeds as follows. In section 2 we first lay out the model. Section 3 then deals with the aspects of optimal national internalization policies in the case of lump-sum taxes. The results are then used as a reference point for section 4 where we address the question if a double dividend can be reaped from environmental taxes. Section 5 concludes. Details of the comparative statics are given in an appendix.

2 The Model

We consider a two country model based on [22] Rauscher (1993) with international factor mobility where country A is the home country and country B is the foreign country.⁷ In the following lowercase letters or superscript A are used for country A , uppercase letters or superscript B for country B . Each economy is endowed with m factors of production. Among these are capital, an environmental resource⁸, and a third one which can be thought of as labour. Factor supplies of capital and labour are assumed to be inelastic. Capital is taken to be internationally mobile which means that it flows towards the most attractive use across countries and therefore balances differences in capital rents. In the presence of international mobility, national capital supply is endogenous even if international capital supply is fixed. Both countries produce n goods. Without loss of generality one good is chosen as numéraire with its price being normalized to unity. The production of goods in each country is connected with the generation of a cross-border externality. These national externality productions add up to a global externality level which lowers the utility of individuals in each country.

⁷[9] Dixit et al. (1980) provide an exposition of the standard model which is here altered as to include international factor movements.

⁸For instance clean air or drinking water reservoirs.

2.1 Consumer behaviour

In both countries there is only one representative consumer so that we abstract from distributional aspects. The utility function of the representative individual in country A is $u(\mathbf{c}, \epsilon)$ with \mathbf{c} as the consumption vector being a choice variable for the consumer. Pollution ϵ in contrast takes the form of a public bad, and hence the level of its consumption is beyond the consumer's control.⁹ Preferences in the home country may then be represented by the expenditure function

$$e(\mathbf{p}, u_0, \epsilon) = \min_{\mathbf{c}} \{ \mathbf{p}^T \cdot \mathbf{c} : u \geq u_0 \} \quad .$$

$e(\cdot)$ is increasing in u and ϵ and is defined as the minimum cost of attaining utility level u_0 given the vector of prices of the consumption goods \mathbf{p} and the current pollution level ϵ . An increase in the level of the pollutant harms the representative consumer and therefore raises the minimum cost of attaining a given utility level. The partial derivative of the expenditure function with respect to the level of pollution $\frac{\partial e}{\partial \epsilon} \equiv e_\epsilon$ is the marginal willingness to pay for reductions in pollution and equals the marginal damage caused by pollution. The optimization problem for the household in country B is analogous.

2.2 Firm behaviour

For modelling the production side of the economy we work with the aggregate revenue function which is also known as the GNP function. The function has the properties of a restricted profit function: Given the price of the consumption good and the level of either pollution taxes or capital taxes which we are going to analyse in the following sections firms maximize their individual profits. In doing so they collectively maximize GNP at domestic prices which in our setting are equal to prices at the world market, i.e. $\mathbf{p} = \mathbf{P}$. The private sector of the economy thus acts as if it solves the problem

$$\begin{aligned} r(\mathbf{p}, \mathbf{v}, \epsilon^A, k) &= \max_{\mathbf{x}} \{ \mathbf{p}^T \cdot \mathbf{x} : \mathbf{x} \in T^A(\mathbf{v}, k, \epsilon^A) \} \\ R(\mathbf{P}, \mathbf{V}, \epsilon^B, K) &= \max_{\mathbf{X}} \{ \mathbf{P}^T \cdot \mathbf{X} : \mathbf{X} \in T^B(\mathbf{V}, K, \epsilon^B) \} \end{aligned}$$

in the home and in the foreign country, respectively. \mathbf{v} and \mathbf{V} describe the vectors of factor endowments.¹⁰ The resource input ϵ^A and ϵ^B used in country A and in country B , respectively, is defined as the share of the resource which is used up during the production process. It can alternatively be interpreted as emissions resulting from the production process — the pollution levels of both countries contributing to the global externality level $\epsilon = \epsilon(\epsilon^A, \epsilon^B)$ which is negatively perceived by the individuals.¹¹ The assumed substitutability of emissions and capital

⁹For the modelling of a public bad as a quantity constraint see [7] Cornes (1992).

¹⁰The other factors of production are additionally made explicit for reasons of clarity.

¹¹E.g. [16] Mc Guire (1982) and [22] Rauscher (1993) model emissions as an input into the production process rather than as a joint output.

implies that there is a capital-intensive pollution abatement technology which is not modelled explicitly ([22] Rauscher (1993), p. 4). However, the substitutability is restricted to only a certain range which implies that the costless factor environmental resource cannot alone produce consumption goods. Let us denote initial capital endowments in both countries by k^0 and K^0 , respectively, and the amount of capital which is exported from country A to country B or vice versa by ξ . The amount of capital k and K , respectively, used in the production process in each country is then composed of the country's initial endowment with capital, altered by the inflow of foreign capital or the outflow of domestic capital due to arbitrage considerations. We have:

$$\begin{aligned} k &= k^0 - \xi \\ K &= K^0 + \xi \end{aligned} \tag{1}$$

for country A as a net capital exporter, and

$$\begin{aligned} k &= k^0 + \xi \\ K &= K^0 - \xi \end{aligned} \tag{2}$$

for country A as a net capital importer. T^A and T^B are the technology sets in both countries, \mathbf{x} and \mathbf{X} are the vectors of output. Partial derivatives $\frac{\partial r}{\partial \epsilon^A} \equiv r_{\epsilon^A}$ and $\frac{\partial R}{\partial \epsilon^B} \equiv R_{\epsilon^B}$ represent the marginal product of pollution in the production process which is positive. The production function underlying the GNP-function in both countries is linearly homogeneous, concave, and non-decreasing.¹² For solutions to be unique we need decreasing returns to scale in the factors capital and environmental resource at the level of the GNP-function (as will be seen later). This is achieved by assuming one third factor of production to be fix in supply. The environmental resource is a public domain and therefore, if there is no environmental regulation, is used up to the point where its marginal product is zero. Since the externality is assumed to be of an eyesore type, it only enters the utility function and does not generate detrimental effects on the countries' production possibilities. An increase in the level of pollution produced by one firm does not affect the costs of any other firm.

2.3 Government behaviour

The government of each country is assumed to maximize utility of its representative consumer by means of the policy instruments at hand. Its calculus is constrained by the need to raise public funds, e.g. in order to finance the provision of public goods. Here, the provision will not be modelled explicitly so that the budget constraint is assumed to be exogenously fixed at the level \bar{P} . The budget constraint P has to be financed with the country's tax proceeds it reaps

¹²We have $\frac{\partial^2 r}{\partial \epsilon^A \partial \epsilon^A} \equiv r_{\epsilon^A \epsilon^A} < 0$ and $\frac{\partial^2 r}{\partial k \partial k} \equiv r_{kk} < 0$. Further we assume $\frac{\partial^2 r}{\partial \epsilon^A \partial k} \equiv r_{\epsilon^A k} > 0$ and $\frac{\partial^2 r}{\partial k \partial \epsilon^A} \equiv r_{k \epsilon^A} > 0$. For further discussion of the GNP function see e.g. [7] Cornes (1992) and [9] Dixit et al. (1980).

from different sources:

$$P = \bar{P} = h + \tau^A \epsilon^A + \theta^A \xi \quad , \quad (3)$$

where h is a non-distortionary head tax, and τ^A and θ^A are pollution taxes and taxes on repatriated capital rents, respectively.¹³ The head tax serves to fill the gap between the tax proceeds of both other tax instruments implemented at their optimal levels and the governmental budgetary needs. This scenario will be used as a benchmark case. In section 4 we will abstract from lump-sum taxes in order to analyse the double dividend character of environmental taxes.¹⁴ The implementation of tax instruments will only be considered for the home country. In country B tax instruments are not available for neither strategic nor environmental ends. Consequently, the question of retaliation is excluded from the analysis.

The internationally mobile capital provides country A with a leverage to strategically influence the factor reward for the capital it lends to or borrows from the rest of the world and to influence the foreign production of cross-border externalities. With its policy tools the government hence pursues three aims in favour of the representative consumer:

- First, influencing the capital rent at the world market through the strategic control of domestic capital supply or demand.
- Second, internalizing the domestically produced externalities as to improve the environmental quality.
- Third, indirectly internalizing the externalities caused abroad which are also perceived in the home country by manipulating the international allocation of mobile capital.

3 Indirect Internalization and Lump-Sum Taxes

In order to make the analysis less complicated we will in the following abstract from changes in goods' prices. Therefore it is assumed that both countries produce only one composite good which is chosen as numéraire with its price being normalized to unity.¹⁵ Trade in the good serves to pay the factor reward to the mobile factor capital. The production of the composite good in each country is connected with the generation of a cross-border externality.¹⁶

¹³The latter of the taxes may also be negative, i.e. a subsidy.

¹⁴The non-environmental dividend attributed to pollution taxes is the reduction of the excess burden in a distortionary tax system.

¹⁵The general framework outlined in section 2 will in future work be used to generalize the results derived in this paper.

¹⁶Although private consumption is restricted to only one composite consumption good the dual approach is useful to illustrate also the effects of environmental degradation which enters the expenditure function of the

The analysis is now restricted to only three factors of production: capital, the environmental resource, and labour. The latter is analytically taken to be hidden which means that it is not made explicit in the revenue function.

We consider a standard model of two perfectly competitive open economies which have the market power to influence factor prices at the world markets. In the analysis we will take the stance of country A and hence we will derive its optimal policy measures whereas country B can be regarded as the rest of the world.

3.1 Pollution taxes

First we want to investigate the general equilibrium effects of the introduction of a pollution tax in country A as the only policy instrument being available to the government apart from the head tax. The pollution tax is designed as being proportionately levied on the input of the externality in the production process. Given a pollution tax only in country A with country A being a net capital exporter, the conditions for an international equilibrium are:¹⁷

$$e(1, u, \epsilon) = r(1, \epsilon^A, k) + R_K(1, \epsilon^B, K) \cdot \xi - \bar{P} \quad (4a)$$

$$E(1, U, \epsilon) = R(1, \epsilon^B, K) - R_K(1, \epsilon^B, K) \cdot \xi \quad (4b)$$

$$\epsilon = \epsilon(\epsilon^A, \epsilon^B) \quad (4c)$$

$$r_{\epsilon^A}(1, \epsilon^A, k) = \tau^A \quad (4d)$$

$$R_{\epsilon^B}(1, \epsilon^B, K) = 0 \quad (4e)$$

$$r_k(1, \epsilon^A, k) = R_K(1, \epsilon^B, K) \quad (4f)$$

$$\bar{P} = h + \tau^A \epsilon^A \quad (4g)$$

Subequations (4a) and (4b) reflect the national income identity for each country. (4c) illustrates that the aggregate externality level perceived by the representative consumers in both countries consists of the discharge of pollutants arising from production in either country. Conditions (4d) and (4e) determine the marginal product of the environmental resource in equilibrium. Since the resource (or in the alternative interpretation pollution) is not privately owned, it will be used in the production process up to the point where its marginal productivity equals zero (as in condition (4e) for country B). Alternatively, in the case where a price is assigned to the resource by means of an environmental tax its rate constitutes the lower bound of the resource's productivity in production. (4f) is the arbitrage condition which indicates that capital

representative consumer as a quantity constraint. The analysis of consumer choice between the consumption good and environmental quality which will be optimized by the national government is facilitated, and general equilibrium effects on all variables like for instance the level of pollution can easily be determined.

¹⁷The conditions for an international equilibrium in the case of country A being a net importer of capital can be found in Appendix A.1 on page 24.

is reallocated until its marginal productivity is internationally equalized. In (4g) only the head tax and the pollution tax contribute to financing \bar{P} . For \bar{P} being equal to zero the analysis is analogous to the common assumption of a lump-sum redistribution of PIGOU-tax receipts. Assume that in the initial equilibrium \bar{P} is completely financed with the help of head taxes. The marginal introduction of a pollution tax with \bar{P} remaining unchanged implies that the head tax contribution must diminish. The endogenous determination of the head tax also applies to the case where the pollution tax is already in place in the initial equilibrium. Thus, system (4) determines $u, U, \xi, \epsilon, \epsilon^A, \epsilon^B$, and h .

For the comparative static analysis with country A as a net capital exporter, equation system (4) is totally differentiated. According to (1) we have $-dk = dK = d\xi$. The variable being exogenous to the system is country A 's policy instrument τ^A .

Written in matrix notation we find:¹⁸

$$\underbrace{\begin{bmatrix} 1 & 0 & e_\epsilon & -\tau^A & -\xi R_{K\epsilon B} & -\xi R_{KK} & 0 \\ 0 & 1 & E_\epsilon & 0 & \xi R_{K\epsilon B} & \xi R_{KK} & 0 \\ 0 & 0 & 1 & -\epsilon_{\epsilon A} & -\epsilon_{\epsilon B} & 0 & 0 \\ 0 & 0 & 0 & r_{\epsilon A \epsilon A} & 0 & -r_{\epsilon A k} & 0 \\ 0 & 0 & 0 & 0 & R_{\epsilon B \epsilon B} & R_{\epsilon B K} & 0 \\ 0 & 0 & 0 & -r_{k \epsilon A} & R_{K \epsilon B} & (r_{kk} + R_{KK}) & 0 \\ 0 & 0 & 0 & \tau^A & 0 & 0 & 1 \end{bmatrix}}_D \begin{bmatrix} e_u du \\ E_U dU \\ d\epsilon \\ d\epsilon^A \\ d\epsilon^B \\ d\xi \\ dh \end{bmatrix} = \begin{bmatrix} -d\bar{P} \\ 0 \\ 0 \\ d\tau^A \\ 0 \\ 0 \\ d\bar{P} - \epsilon^A d\tau^A \end{bmatrix}, \quad (5)$$

with $(r_k - R_K)$ being equal to zero according to (4f) and $r_{\epsilon A}$ being equal to τ^A , the tax on pollution.

For deriving the effects of the introduction of an environmental tax on utility in country A first the sign of the determinant of matrix D has to be determined:

$$\begin{aligned} |D| &= r_{\epsilon A \epsilon A} R_{\epsilon B \epsilon B} (r_{kk} + R_{KK}) \\ &\quad - r_{\epsilon A k} r_{k \epsilon A} R_{\epsilon B \epsilon B} \\ &\quad - r_{\epsilon A \epsilon A} R_{\epsilon B K} R_{K \epsilon B} \\ &= R_{\epsilon B \epsilon B} H^A + r_{\epsilon A \epsilon A} H^B < 0, \end{aligned} \quad (6)$$

with $H^A = r_{\epsilon A \epsilon A} r_{kk} - r_{\epsilon A k} r_{k \epsilon A} > 0$ and $H^B = R_{\epsilon B \epsilon B} R_{KK} - R_{\epsilon B K} R_{K \epsilon B} > 0$. Both terms H^A and H^B reflect the diminishing marginal products of the hidden factor in production of country A and B , respectively.¹⁹

¹⁸Total differentials of system (4) being written as a system of equations can be found in Appendix A.1 on page 24.

¹⁹If capital and the externality were the only factors of production, both terms H^A and H^B would be equal

Now the different effects can be isolated and their implications on welfare in the country under consideration can be determined. We have:²⁰

$$\begin{aligned} \frac{e_u du}{d\tau^A} = & \underbrace{-e_\epsilon \epsilon_{\epsilon A} \frac{1}{r_{\epsilon A \epsilon A}}}_{(1)} + \underbrace{\tau^A \frac{1}{r_{\epsilon A \epsilon A}}}_{(2)} \\ & + \frac{1}{|D|} \left[\underbrace{-e_\epsilon \epsilon_{\epsilon A} \frac{r_{k\epsilon A} r_{\epsilon A k}}{r_{\epsilon A \epsilon A}} R_{\epsilon B \epsilon B}}_{(3)} + \underbrace{e_\epsilon \epsilon_{\epsilon B} r_{k\epsilon A} R_{\epsilon B K}}_{(4)} + \underbrace{\tau^A \frac{r_{k\epsilon A} r_{\epsilon A k}}{r_{\epsilon A \epsilon A}} R_{\epsilon B \epsilon B}}_{(5)} + \underbrace{r_{k\epsilon A} \xi H^B}_{(6)} \right]. \quad (7) \end{aligned}$$

The only difference for country A being a net capital importer is that term (6) changes to $(-r_{k\epsilon A} \xi H^B)$.²¹ The determinant $|D|$ is identical in both cases. Terms (1) and (2) reflect the direct impact of an environmental tax: Since the tax attaches a positive price to the externality its use in domestic production diminishes. The first term (1) represents a direct positive effect on the domestic environmental situation with regard to domestic externality production. For $\tau^A = r_{\epsilon A}$ being positive, term (2) reflects the loss in domestic production which results from the positive price now being attached to pollution as an input. Consequently it is used less intensively in the production process. The effect on domestic utility is negative and can alternatively be interpreted as a diminution of the tax base. Terms (3) to (6) reflect the effects resulting from the induced reallocation of the internationally mobile capital: The diminished input of pollution into domestic production *ceteris paribus* means a decrease in the marginal productivity of capital invested in country A . Capital is driven out of the country and marginal productivity of the factor pollution in country A diminishes, that in country B rises. Hence there is an additional positive environmental effect in the home country (term (3)), whereas term (4) reflects the corresponding change in foreign pollution due to a reallocation of the internationally mobile capital. The production of foreign pollution consequently increases and will be perceived also in country A due to the international dimension of the externality. Since there is substitutability between capital and pollution in both countries, a marginal rise in the domestic environmental tax with respect to the reaction of foreign pollution hence lowers domestic utility. Term (5) again is a negative tax base effect on the environmental tax induced by the international capital reallocation. The negative sign of the last term (6) in equation (7) (taking respect of the sign of $|D|$) reveals that an increase in the pollution tax rate in a capital exporting country runs counter to the reduction of capital supply at the world capital market in order to strategically increase the factor reward. The opposite applies to a country which is a net borrower at the

to zero for the revenue function being linearly homogeneous in inputs. Under this assumption a unique solution would not exist as can be seen from the determinant of matrix D being then equal to zero. For τ^A deviating from zero all capital would flow out of the country for being invested in country B , and the system would not be differentiable anymore.

²⁰For a more detailed presentation of the derivation see Appendix A.1 on page 25.

²¹The analysis for country A being a net capital importing country can be found in Appendix A.1 on page 25.

world capital market with the effect hence being positive. In this case the strategic component in national calculations serves as a substitute for the denied internalization of environmental damages imposed on other countries.

Summing up, terms (1) and (3) reflect the valuation of a change in the global pollution level due to the change in domestic externality contribution induced by the marginal augmentation in the pollution tax. With respect to this effect the environmental tax augments utility of the representative consumer. Term (4) reflects the valuation of a change in the foreign externality generation. Terms (2) and (5) are only different from zero if there is a pollution tax already in place in the initial equilibrium.

First-order conditions for an optimal domestic pollution tax in a setting with internationally mobile capital and cross-border externalities can be derived by setting equations (7) and (A-5) in Appendix A.1 on page 26, respectively, equal to zero, and solving for the pollution tax τ^A . This condition for the tax rate only consists of endogenous variables. In combination with equation system (4) and (A-1), respectively, combined with potential other conditions which guarantee the whole system to be sufficient for the derivation of an optimum, the optimal level of the pollution tax can be determined.

The above derived result in an open setting proves that the environmental tax loses its first-best character if the jurisdiction is smaller than the area where the externality is perceived. This is due to two reasons:

- Countries maximize utility of their own representative consumer and hence ignore the detrimental effects of their externality generation on consumers abroad.
- For the same reasoning they exploit the ability of a big country to strategically alter prices at the world markets in their own favour.

The implementation of an optimal tax rate that can be derived from multiplier (7) and (A-5), respectively, thus leads to a *national* second-best result. It is only *second-best* in nature because the various national aims concerning the strategic exploitation of a country's market power at the world capital market as well as the direct and indirect internalization of the cross-border externality are attacked with only one policy instrument — the pollution tax.²²

We know that in a closed setting the optimal environmental tax, the so called PIGOU-tax, demands to levy a tax on the externality equal to the marginal damage it globally generates in the optimum. This result can be reproduced in a world with two or more countries without a supranational authority being in place if countries agree upon a cooperation. Such a cooperation aiming at maximizing global utility is tantamount to a complete internalization of all technological as well as fiscal externalities as we will see now.

²²This reasoning is known as target principle.

Pareto-optimality

A globally PARETO-efficient result by means of taxes can only be reached if both countries jointly implement a pollution tax. In this case there is only one change in the equation system (4):²³ If we denote the foreign environmental tax with τ^B , equation (4e) changes to

$$R_{\epsilon B} (1, \epsilon^B, K) = \tau^B. \quad (4e')$$

By totally differentiating the altered set of equilibrium conditions, we can determine the effects of both tax instruments on domestic and foreign utility in the case of simultaneous implementation.²⁴

$$\begin{aligned} \frac{e_u du}{d\tau^A} = & -e_{\epsilon} \epsilon_{\epsilon A} \frac{1}{r_{\epsilon A \epsilon A}} + \tau^A \frac{1}{r_{\epsilon A \epsilon A}} \\ & + \frac{1}{|D|} \left[-e_{\epsilon} \epsilon_{\epsilon A} \frac{r_{k\epsilon A} r_{\epsilon A k}}{r_{\epsilon A \epsilon A}} R_{\epsilon B \epsilon B} + e_{\epsilon} \epsilon_{\epsilon B} r_{k\epsilon A} R_{\epsilon B K} \right. \\ & \left. + \tau^A \frac{r_{k\epsilon A} r_{\epsilon A k}}{r_{\epsilon A \epsilon A}} R_{\epsilon B \epsilon B} + r_{k\epsilon A} \xi H^B \right], \end{aligned} \quad (8)$$

$$\begin{aligned} \frac{E_U dU}{d\tau^A} = & \frac{1}{|D|} \left[-E_{\epsilon} \epsilon_{\epsilon A} (r_{kk} R_{\epsilon B \epsilon B} - H^B) + E_{\epsilon} \epsilon_{\epsilon B} r_{k\epsilon A} R_{\epsilon B K} \right. \\ & \left. - \tau^B r_{k\epsilon A} R_{\epsilon B K} - r_{k\epsilon A} \xi H^B \right], \end{aligned} \quad (9)$$

$$\begin{aligned} \frac{E_U dU}{d\tau^B} = & -E_{\epsilon} \epsilon_{\epsilon B} \frac{1}{R_{\epsilon B \epsilon B}} + \tau^B \frac{1}{R_{\epsilon B \epsilon B}} \\ & \frac{1}{|D|} \left[E_{\epsilon} \epsilon_{\epsilon A} r_{\epsilon A k} R_{K \epsilon B} - E_{\epsilon} \epsilon_{\epsilon B} \frac{R_{K \epsilon B} R_{\epsilon B K}}{R_{\epsilon B \epsilon B}} r_{\epsilon A \epsilon A} \right. \\ & \left. + \tau^B \frac{R_{K \epsilon B} R_{\epsilon B K}}{R_{\epsilon B \epsilon B}} r_{\epsilon A \epsilon A} - R_{K \epsilon B} \xi H^A \right], \end{aligned} \quad (10)$$

$$\begin{aligned} \frac{e_u du}{d\tau^B} = & \frac{1}{|D|} \left[e_{\epsilon} \epsilon_{\epsilon A} r_{\epsilon A k} R_{K \epsilon B} - e_{\epsilon} \epsilon_{\epsilon B} (r_{\epsilon A \epsilon A} R_{KK} + H^A) \right. \\ & \left. - \tau^A r_{\epsilon A k} R_{K \epsilon B} + R_{K \epsilon B} \xi H^A \right]. \end{aligned} \quad (11)$$

For the result to be PARETO-efficient also the impacts of a country's policy measures on the other country have to be taken into account. Therefore multipliers (8) and (9) as well as (10)

²³We restrict the analysis to the case of country A being a capital exporting country. For a capital importing country it is analogous.

²⁴For the system of total differentials see Appendix A.1 on page 26.

and (11) must sum up to zero:

$$\begin{aligned} \frac{e_u du}{d\tau^A} + \frac{E_U dU}{d\tau^A} = \frac{1}{|D|} \left[- (e_\epsilon + E_\epsilon) \epsilon_{\epsilon A} (r_{kk} R_{\epsilon B \epsilon B} + H^B) \right. \\ + (e_\epsilon + E_\epsilon) \epsilon_{\epsilon B} r_{k\epsilon A} R_{\epsilon B K} \\ + \tau^A (r_{kk} R_{\epsilon B \epsilon B} + H^B) \\ \left. - R_{\epsilon B} r_{k\epsilon A} R_{\epsilon B K} \right] \stackrel{!}{=} 0 \end{aligned} \quad (12)$$

and

$$\begin{aligned} \frac{e_u du}{d\tau^B} + \frac{E_U dU}{d\tau^B} = \frac{1}{|D|} \left[(e_\epsilon + E_\epsilon) \epsilon_{\epsilon A} r_{\epsilon A k} R_{K \epsilon B} \right. \\ - (e_\epsilon + E_\epsilon) \epsilon_{\epsilon B} (r_{\epsilon A \epsilon A} R_{KK} + H^A) \\ - \tau^A r_{\epsilon A k} R_{K \epsilon B} \\ \left. + R_{\epsilon B} (r_{\epsilon A \epsilon A} R_{KK} + H^A) \right] \stackrel{!}{=} 0 \end{aligned} \quad (13)$$

Both conditions solved simultaneously determine the optimal pollution tax rates in both countries that guarantee global efficiency:

$$\tau^{A*} = r_{\epsilon A} = (e_\epsilon + E_\epsilon) \epsilon_{\epsilon A} \quad (14)$$

$$\tau^{B*} = R_{\epsilon B} = (e_\epsilon + E_\epsilon) \epsilon_{\epsilon B} \quad (15)$$

This is just the PIGOU-tax which in the optimum should equal *global* marginal damage caused by either country. One tax instrument in each country is hence sufficient to yield PARETO-optimality since strategic aspects cancel out. The resulting allocation is first-best from the global perspective.

3.2 Taxes on repatriated capital rents

In this section the effects of a tax on repatriated capital rents are analysed. System (4) of equilibrium conditions depicted in subsection 3.1 for country *A* being a capital exporter remains unchanged except for conditions (4d), (4f), and (4g) which change to (16d), (16f), and (16g), respectively:²⁵

$$r_{\epsilon A} (1, \epsilon^A, k) = 0 \quad (16d)$$

$$r_k (1, \epsilon^A, k) + \theta^A = R_K (1, \epsilon^B, K) \quad (16f)$$

$$\bar{P} = h + \theta^A \xi \quad (16g)$$

²⁵The equilibrium conditions in the case of country *A* being a net capital importer can be found in Appendix A.2 on page 26.

The variable being exogenous to the system is country A 's policy instrument θ^A which drives a wedge between the domestic and the foreign marginal productivity of capital as can be seen from (16f). Due to the lack of an environmental tax the price attached to the environmental input equals zero.

Taking total differentials of the new equation system composed of (4) and (16) with the determinant of matrix D remaining unchanged negative, the influence of a tax on repatriated capital rents on domestic utility in country A can be determined to be²⁶

$$\frac{e_u du}{d\theta^A} = \frac{1}{|D|} \left[\underbrace{-e_{\epsilon\epsilon A} r_{\epsilon A k} R_{\epsilon B \epsilon B}}_{(1)} + \underbrace{e_{\epsilon\epsilon B} r_{\epsilon A \epsilon A} R_{\epsilon B K}}_{(2)} + \underbrace{\theta^A r_{\epsilon A \epsilon A} R_{\epsilon B \epsilon B}}_{(3)} + \underbrace{r_{\epsilon A \epsilon A} \xi H^B}_{(4)} \right] , \quad (17)$$

with $(r_k - R_K)$ being equal to $(-\theta^A)$ according to (16f).

For country A being a net capital importer the multiplier is:²⁷

$$\frac{e_u du}{d\theta^A} = \frac{1}{|D|} \left[\underbrace{e_{\epsilon\epsilon A} r_{\epsilon A k} R_{\epsilon B \epsilon B}}_{(1)} - \underbrace{e_{\epsilon\epsilon B} r_{\epsilon A \epsilon A} R_{\epsilon B K}}_{(2)} + \underbrace{\theta^A r_{\epsilon A \epsilon A} R_{\epsilon B \epsilon B}}_{(3)} + \underbrace{r_{\epsilon A \epsilon A} \xi H^B}_{(4)} \right] , \quad (18)$$

with $(r_k - R_K)$ being equal to θ^A according to (A-7f) in Appendix A.2 on page 26.

The multipliers reveal that in contrast to multiplier (7) for the pollution tax there are no direct effects. Effects (1) to (4) all result from an induced reallocation of the internationally mobile capital. The first underbraced term (1) is the valuation of an induced change in domestic externality generation as we already know it from effect (3) for the pollution tax in multiplier (7). For country A to be a capital exporter (multiplier (17)) the introduction of the tax lowers the marginal productivity of capital invested abroad. Consequently less capital will be invested in country B which ceteris paribus lowers capital productivity but raises pollution productivity in the home country. More pollution will hence be generated in the home country which lowers domestic utility. Therefore the sign of effect (1) in contrast to that for the environmental tax is negative taking respect of the sign of $|D|$. Term (2) corresponds to term (4) in multiplier (7), its sign this time being positive due to the induced diminution of foreign pollution for country A being a net capital exporter. The reasoning is opposite for country A being a net capital importing country (multiplier (18)). In this case the tax on repatriated capital rents drives foreign direct investment out of the country which implies a positive effect on domestic externality generation, but a negative one on foreign externality generation. The third underbraced term in both multipliers reflects the erosion of the tax base due to an increase in the tax rate and corresponds to effect (5) in the multiplier for the pollution tax. This effect is only different from

²⁶For the system of total differentials and a more detailed presentation of the derivation in the case of country A being a capital exporter see Appendix A.2 on page 27.

²⁷For the system of total differentials and a more detailed presentation of the derivation — this time for country A being a capital importer — see Appendix A.2 on page 28.

zero if the tax has already been in place in the initial equilibrium. For θ^A being positive the effect has a negative impact on domestic utility. The last term (4) for both a capital exporting as well as a capital importing country is a positive tax rate effect of the tax on repatriated capital rents. The effect is the counterpart to effect (3) and embodies the rise in tax income due to the increase in the tax rate. Strategically spoken the country as a capital exporter tries to create an excess demand for capital at the world capital market in order to raise the capital rent. As a capital importer the country instead tries to induce an excess supply for capital at the world capital market in order to lower the capital rent.

We see that the tax on repatriated capital rents again can either be used to exploit the country's monopolistic position in the world capital market or to directly and indirectly internalize externalities caused by the own country and the foreign country, respectively.

For deriving the optimal tax rate the expressions in square brackets in (17) and (18), respectively, have to be set equal to zero. This means that an optimal tax on repatriated capital rents balances both positive and negative effects on the environment as well as on the country's income situation. Due to the consideration of the strategic aspects and the neglect of environmental damages imposed on country B , the optimal tax rate again is only second-best from a *national* point of view. Global-efficiency with a tax on repatriated capital rents available to the governments in both countries is not achievable because the effects are just diametral. Both means being implemented at the same time have no additional effect than only one of them since they have exact the opposite impact on foreign as well as on domestic utility. A tax on repatriated capital rents is hence no perfect substitute for a pollution tax in a situation where a pollution tax can realize its first-best qualities as we know it from the PIGOU-tax.

3.3 Pollution taxes and taxes on repatriated capital rents

Now that we have analysed the two potential tax instruments for the government separately we turn to the effects of a joint reliance on both taxes.

The equilibrium conditions in this case are a synthesis of both former scenarios. Considering first the case of country A being a net capital exporter, in equation system (4) conditions (4f) and (4g) change to

$$r_k(1, \epsilon^A, k) + \theta^A = R_K(1, \epsilon^B, K) \quad (19f)$$

$$\bar{P} = h + \tau^A \epsilon^A + \theta^A \xi \quad , \quad (19g)$$

respectively.²⁸ That is the government in country A can directly tax domestically generated externalities as well as modify the return to a capital investment abroad undertaken by its representative consumer (or by the foreign representative consumer for country A being a capital

²⁸The equation system for country A being a net capital importer can be found in Appendix A.3 on page 28.

importer). The interesting point is how the interactive effects arising from the joint implementation of both instruments can be brought into line as to optimize domestic utility.

The new system again is totally differentiated. The variables being exogenous to the system are country A 's policy instruments θ^A and τ^A . The head tax again is endogenously determined. We get the multipliers for the pollution tax and the tax on repatriated capital rents, respectively, with the determinant of matrix D remaining unchanged and for country A being a net capital exporter:²⁹

$$\begin{aligned} \frac{e_u du}{d\tau^A} = & -e_\epsilon \epsilon_{\epsilon A} \frac{1}{r_{\epsilon A \epsilon A}} + \tau^A \frac{1}{r_{\epsilon A \epsilon A}} \\ & + \frac{1}{|D|} \left[-e_\epsilon \epsilon_{\epsilon A} \frac{r_{k\epsilon A} r_{\epsilon A k}}{r_{\epsilon A \epsilon A}} R_{\epsilon B \epsilon B} + e_\epsilon \epsilon_{\epsilon B} r_{k\epsilon A} R_{\epsilon B K} + \theta^A r_{k\epsilon A} R_{\epsilon B \epsilon B} \right. \\ & \left. + \tau^A \frac{r_{k\epsilon A} r_{\epsilon A k}}{r_{\epsilon A \epsilon A}} R_{\epsilon B \epsilon B} + r_{k\epsilon A} \xi H^B \right], \end{aligned} \quad (20)$$

$$\begin{aligned} \frac{e_u du}{d\theta^A} = & \frac{1}{|D|} \left[-e_\epsilon \epsilon_{\epsilon A} r_{\epsilon A k} R_{\epsilon B \epsilon B} + e_\epsilon \epsilon_{\epsilon B} r_{\epsilon A \epsilon A} R_{\epsilon B K} + \theta^A r_{\epsilon A \epsilon A} R_{\epsilon B \epsilon B} \right. \\ & \left. + \tau^A r_{\epsilon A k} R_{\epsilon B \epsilon B} + r_{\epsilon A \epsilon A} \xi H^B \right], \end{aligned} \quad (21)$$

with $(r_k - R_K)$ now not being equal to zero but equal to $(-\theta^A)$ according to (19f). As can be seen from (20) and (21) both tax instruments are interconnected since the pollution tax rate ($\tau^A = r_{\epsilon A}$) appears in the multiplier of the capital tax and vice versa. It is exactly the appearance of these tax base effects on the other tax instrument by which the above multipliers deviate from those derived in subsections 3.1 and 3.2. They are different from zero only if the taxes are already in place in the initial equilibrium.

Setting multipliers (20) and (21) of both instruments equal to zero and simultaneously solving for τ^A and θ^A determines optimal national tax rates:

$$\frac{e_u du}{d\tau^A} \stackrel{!}{=} 0 \quad \text{and} \quad \frac{e_u du}{d\theta^A} \stackrel{!}{=} 0, \quad (22)$$

which leads to the first-order conditions for optimal values of both tax instruments

$$r_{\epsilon A} = \tau^{A*} = e_\epsilon \epsilon_{\epsilon A} \quad (23)$$

$$\text{and} \quad \theta^{A*} = \frac{-1}{R_{\epsilon B \epsilon B}} [e_\epsilon \epsilon_{\epsilon B} R_{\epsilon B K} + \xi H^B]. \quad (24)$$

For country A being a capital importing country, the first-order conditions for optimal national

²⁹The complete system of the totally differentiated equilibrium conditions and a more detailed calculation of the multipliers can be found in Appendix A.3 on page 29.

tax rates are:³⁰

$$r_{\epsilon A} = \tau^{A*} = e_{\epsilon} \epsilon_{\epsilon A} \quad (25)$$

$$\text{and} \quad \theta^{A*} = \frac{-1}{R_{\epsilon B \epsilon B}} [-e_{\epsilon} \epsilon_{\epsilon B} R_{\epsilon B K} + \xi H^B] \quad (26)$$

The optimal level of the domestic pollution tax in both cases is just the well known PIGOU-tax. The reason why this first-best instrument as we know it from the closed setting regains its efficiency quality is that now the tax on repatriated capital rents shields the home country by offsetting the negative effects it induces with respect to foreign externality generation and concerning the capital rent determination at the world capital market. Since the first-order condition for the domestic pollution tax takes respect only of domestic damages generated by domestic production, it is evident that this PIGOU-tax can only lead to a *national* first-best solution. For the home country being a net capital exporting country, the optimal rate of the tax on repatriated capital rents is unambiguously positive, i.e. capital exports are restricted via tax policy for environmental and strategic ends. A positive tax rate on repatriated capital rents serves as a means to generate an excess demand for capital at the world capital market. For the country being a capital importer, we observe contrary effects on the optimal tax rate since foreign externality generation demands the tax to be negative (i.e. that the domestic government subsidizes foreign investors), whereas strategic considerations ask for an excess supply of capital at the world market being induced by a positive tax on repatriated capital rents.

3.4 Interpretation of the results

From the results for the optimal tax rates derived in this section it can be seen that in an open setting with cross-border externalities the traditional PIGOU-tax loses its characteristic feature to achieve a global first-best allocation. Countries maximize national welfare and neglect both fiscal and also technological externalities they impose on other countries. In the decentralized equilibrium global pollution generation is too high and the amount of international capital movements deviates from its global optimum. In this case the isolated use of a tax on repatriated capital rents has similar effects on a country's welfare as the implementation of solely a pollution tax. Both instrument are appropriate to address both ends at the same time: internalization and exploitation of market power. Only if the joint implementation of both instruments is possible, the traditional PIGOU-tax (though restricted to national considerations) regains its optimality character. But again it has to be emphasized that the resulting allocation is only first-best from the *national* point of view, not from the global one.

On the other hand, if countries agree upon a cooperation to internalize cross-border externalities,

³⁰The complete system of the totally differentiated equilibrium conditions and a more detailed calculation of the multipliers for country *A* being a capital importer can be found in Appendix A.3 on page 30.

the global first-best result can only be reached by means of national PIGOU-taxes that take into account also the environmental damages from domestic production imposed on other countries. A tax on repatriated capital rents — even if implemented in both countries at the same time — is not appropriate to achieve global efficiency.

In the following section we will assume that lump-sum taxes are not available anymore to the government. The analysis focuses on the question how matters change if the proceeds of a marginal introduction of a pollution tax are used to drive back tax income generated by means of a distortionary tax on repatriated capital rents. Specifically, we want to investigate whether a double dividend can be reaped from the implementation of an environmental tax — the amelioration of environmental conditions and additionally the generation of public funds which can be used to reduce the excess burden of the tax system consisting of distortionary taxes.

4 Indirect Internalization and Double Dividend

In this setting two distortions prevail: the misallocation of factors first due to environmental externalities not being internalized, and second due to the existence of a tax on repatriated capital rents. The latter is assumed to completely finance the government's budgetary needs in the initial equilibrium. Since again there are more targets than instruments, the analysis takes place in a second-best framework. The marginal implementation of a pollution tax in this setting can either yield a double dividend by alleviating both distortions. Alternatively it can yield only one dividend by improving the environmental situation of the country, thereby simultaneously increasing the other distortion. The result of such a second-best consideration completely hinges on the specific formulation of the model.

For country A being a capital exporter compared to equation system (4) only equations (4f) and (4g) change:³¹

$$r_k(1, \epsilon^A, k) + \theta^A = R_K(1, \epsilon^B, K) \quad (27f)$$

$$\bar{P} = \theta^A \xi + \tau^A \epsilon^A \quad (27g)$$

Equation (27g) reflects that τ^A and θ^A are the only tax instruments available to the government. Totally differentiating the synthesis of equation systems (4) and (27) for country A being a capital exporter with θ^A being endogenously determined and the pollution tax τ^A as the policy

³¹The equation system for country A being a capital importer can be found in Appendix A.4 on page 31.

instrument being exogenously altered we get:³²

$$\underbrace{\begin{bmatrix} 1 & 0 & e_\epsilon & -\tau^A & -\xi R_{K\epsilon B} & -(\theta^A + \xi R_{KK}) & 0 \\ 0 & 1 & E_\epsilon & 0 & \xi R_{K\epsilon B} & \xi R_{KK} & 0 \\ 0 & 0 & 1 & -\epsilon_{\epsilon A} & -\epsilon_{\epsilon B} & 0 & 0 \\ 0 & 0 & 0 & r_{\epsilon A \epsilon A} & 0 & -r_{\epsilon A k} & 0 \\ 0 & 0 & 0 & 0 & R_{\epsilon B \epsilon B} & R_{\epsilon B K} & 0 \\ 0 & 0 & 0 & -r_{k \epsilon A} & R_{K \epsilon B} & (r_{kk} + R_{KK}) & -1 \\ 0 & 0 & 0 & \tau^A & 0 & \theta^A & \xi \end{bmatrix}}_{D^*} \begin{bmatrix} e_u du \\ E_U dU \\ d\epsilon \\ d\epsilon^A \\ d\epsilon^B \\ d\xi \\ d\theta^A \end{bmatrix} = \begin{bmatrix} -d\bar{P} \\ 0 \\ 0 \\ d\tau^A \\ 0 \\ 0 \\ d\bar{P} - \epsilon^A d\tau^A \end{bmatrix}, \quad (28)$$

with $(r_k - R_K)$ being equal to $(-\theta^A)$ according to (27f) and $r_{\epsilon A}$ being equal to τ^A , the tax on pollution.

The determinant of matrix D^* is different from that in equation system (4) and has therefore to be determined. For the home country being a net capital exporter the determinant is equal to:

$$|D^*| = \underbrace{\theta^A r_{\epsilon A \epsilon A} R_{\epsilon B \epsilon B}}_{(+)} + \underbrace{\tau^A r_{\epsilon A k} R_{\epsilon B \epsilon B}}_{(-)} + \underbrace{\xi |D|}_{(-)} \quad (29)$$

For country A being a net capital importer it is equal to:

$$|D^*| = \underbrace{\theta^A r_{\epsilon A \epsilon A} R_{\epsilon B \epsilon B}}_{(+)} - \underbrace{\tau^A r_{\epsilon A k} R_{\epsilon B \epsilon B}}_{(+)} + \underbrace{\xi |D|}_{(-)} \quad (30)$$

The sign of the determinant of matrix D^* in both scenarios cannot be determined unambiguously. The first two terms reflect the impacts of the revenue-recycling on the tax base of the capital tax and on that of the environmental tax, respectively. The tax base effect on the capital tax in both cases is positive due to the implicit diminution of its tax rate. The tax base effect on the environmental tax is only positive in the case of country A being a capital importing country. In this case the diminution of the tax rate on repatriated capital rents resulting from the revenue-recycling induces an inflow of capital towards the home country which in turn increases the tax base of the environmental tax. The last term represents the negative tax rate effect attached to the decrease in the tax rate on repatriated capital rents. In both cases it is sensible to assume that the determinant of D is negative in sign since then the results we derived in section 3 are being preserved.

³²Total differentials of the system of equilibrium conditions for country A being a capital importing country can be found in Appendix A.4 on page 31.

For the effects of a marginal alteration of the pollution tax on domestic welfare in the case of country A being a capital exporting country we get: ³³

$$\begin{aligned}
\frac{e_u du}{d\tau^A} = & -e_\epsilon \epsilon_{\epsilon A} \frac{1}{r_{\epsilon A \epsilon A}} + \tau^A \frac{1}{r_{\epsilon A \epsilon A}} \\
& + \frac{1}{|D^*|} \left[\xi \left(-e_\epsilon \epsilon_{\epsilon A} \frac{r_{k\epsilon A} r_{\epsilon A k}}{r_{\epsilon A \epsilon A}} R_{\epsilon B \epsilon B} + e_\epsilon \epsilon_{\epsilon B} r_{k\epsilon A} R_{\epsilon B K} + \theta^A r_{k\epsilon A} R_{\epsilon B \epsilon B} \right. \right. \\
& \quad \left. \left. + \tau^A \frac{r_{k\epsilon A} r_{\epsilon A k}}{r_{\epsilon A \epsilon A}} R_{\epsilon B \epsilon B} + r_{k\epsilon A} \xi H^B \right) \right. \\
& - \epsilon^A \left(-e_\epsilon \epsilon_{\epsilon A} r_{\epsilon A k} R_{\epsilon B \epsilon B} + e_\epsilon \epsilon_{\epsilon B} r_{\epsilon A \epsilon A} R_{\epsilon B K} + \theta^A r_{\epsilon A \epsilon A} R_{\epsilon B \epsilon B} \right. \\
& \quad \left. + \tau^A r_{\epsilon A k} R_{\epsilon B \epsilon B} + r_{\epsilon A \epsilon A} \xi H^B \right) \\
& - \tau^A \frac{1}{r_{\epsilon A \epsilon A}} \left(-e_\epsilon \epsilon_{\epsilon A} r_{\epsilon A k} R_{\epsilon B \epsilon B} + e_\epsilon \epsilon_{\epsilon B} r_{\epsilon A \epsilon A} R_{\epsilon B K} + \theta^A r_{\epsilon A \epsilon A} R_{\epsilon B \epsilon B} \right. \\
& \quad \left. + \tau^A r_{\epsilon A k} R_{\epsilon B \epsilon B} + r_{\epsilon A \epsilon A} \xi H^B \right) \left. \right] , \quad (31)
\end{aligned}$$

with $(r_k - R_K)$ being equal to $(-\theta^A)$ according to (27f). The effects of a marginal increase in the environmental tax rate on domestic utility in the case of country A being a capital importer can be found in Appendix A.4 on page 33.

The first line of both multipliers reflects the direct impact of the environmental tax on domestic utility through attaching a positive price to the environment, i.e. to the externality. The remaining effects all result from an international reallocation of capital. Lines one to three in the multipliers for both scenarios reflect the isolated effect of a change in the environmental tax rate as we already know it from section 3. Lines four to seven reflect the impact of an induced reduction in the tax rate on repatriated capital rents. The term in both brackets in lines four to seven hence is the effect we derived for the capital tax in section 3. Lines four and five are the effects directly resulting from the revenue-recycling. Since the proceeds of an increase in the environmental tax rate can be used to lower the tax rate on repatriated capital rents, the effects — taking care of the negative sign of the determinant — are inverse to those in multipliers (17) and (18), respectively, derived in section 3 for a marginal increase in the capital tax. Lines six and seven reflect that the introduction of a pollution tax has a negative tax base effect on its own tax base. This tax base erosion in turn diminishes the extent to which the capital tax can be replaced by the environmental tax. The effect hence lessens the revenue-recycling effect in lines four and five of multiplier (31).

In order to evaluate whether a double dividend can be raised from the introduction of environmental taxes, for a capital exporting country multiplier (31) with the pollution tax partly replacing the distorting capital tax has to be compared to multiplier (7) which was derived under the assumption that the environmental tax replaces a lump-sum tax. In the case of country A

³³For a more detailed presentation of the derivation see Appendix A.4 on page 32.

being a capital importing country, multiplier (A-22) on page 33 has to be compared to multiplier (A-5) on page 26. The values of the derivatives in each pair of multipliers and additionally the determinants of both systems differ since the observed equilibria are not identical. Yet, the comparison of the multipliers is appropriate for our purposes since it is their structure and not the absolute value of their components that matters concerning a double dividend evaluation. Double dividend only means that there is a second dividend apart from the environmental one. For facilitating matters we consider a marginal implementation of environmental taxes (i.e. initial tax rates are zero) such that effects on its tax base cancel out. If multipliers (31) and (A-22) were greater than multipliers (7) and (A-5), respectively, this would indicate the existence of a double dividend: the representative consumer's utility reaches a relatively higher level due to the introduction of the environmental tax since the tax indeed contributes to a reduction of the distortions in the tax system generated by the tax on repatriated capital rents. For multipliers (31) and (A-22) being smaller than (7) and (A-5), respectively, the environmental tax obviously enlarges the prevailing distortions in the tax system in the presence of international capital mobility.

The double dividend notion underlying this comparison is that in the weak sense which is the relevant one from the point of view of welfare economics.³⁴

Ignoring tax base effects of the environmental tax, the multiplier for a capital exporting country (31) reduces to:

$$\begin{aligned} \frac{e_u du}{d\tau^A} = & -e_{\epsilon\epsilon A} \frac{1}{r_{\epsilon A \epsilon A}} \\ & + \frac{1}{|D^*|} \left[\xi \left(-e_{\epsilon\epsilon A} \frac{r_{k\epsilon A} r_{\epsilon A k}}{r_{\epsilon A \epsilon A}} R_{\epsilon B \epsilon B} + e_{\epsilon\epsilon B} r_{k\epsilon A} R_{\epsilon B K} + \theta^A r_{k\epsilon A} R_{\epsilon B \epsilon B} + r_{k\epsilon A} \xi H^B \right) \right. \\ & \left. - \epsilon^A \left(-e_{\epsilon\epsilon A} r_{\epsilon A k} R_{\epsilon B \epsilon B} + e_{\epsilon\epsilon B} r_{\epsilon A \epsilon A} R_{\epsilon B K} + \theta^A r_{\epsilon A \epsilon A} R_{\epsilon B \epsilon B} + r_{\epsilon A \epsilon A} \xi H^B \right) \right]. \end{aligned} \quad (31')$$

For a capital importing country, (A-22) reduces to:

$$\begin{aligned} \frac{e_u du}{d\tau^A} = & -e_{\epsilon\epsilon A} \frac{1}{r_{\epsilon A \epsilon A}} \\ & + \frac{1}{|D^*|} \left[\xi \left(-e_{\epsilon\epsilon A} \frac{r_{k\epsilon A} r_{\epsilon A k}}{r_{\epsilon A \epsilon A}} R_{\epsilon B \epsilon B} + e_{\epsilon\epsilon B} r_{k\epsilon A} R_{\epsilon B K} - \theta^A r_{k\epsilon A} R_{\epsilon B \epsilon B} - r_{k\epsilon A} \xi H^B \right) \right. \\ & \left. - \epsilon^A \left(e_{\epsilon\epsilon A} r_{\epsilon A k} R_{\epsilon B \epsilon B} - e_{\epsilon\epsilon B} r_{\epsilon A \epsilon A} R_{\epsilon B K} + \theta^A r_{\epsilon A \epsilon A} R_{\epsilon B \epsilon B} + r_{\epsilon A \epsilon A} \xi H^B \right) \right]. \end{aligned} \quad (A-22')$$

It can be seen that it is only the last line, apart from the tax base effect on the tax on repatriated capital rents (the third term in brackets in line two), by which the structure of both multipliers

³⁴The definition introduced by [10] Goulder (1994) claims that returning tax revenues through cuts in distortionary taxes leads to cost savings relative to the case where revenues are returned lump sum.

differs from that derived in section 3 for the environmental tax replacing a head tax. This tax base effect is positive for country A being a capital exporter and negative for country A being a capital importer. As mentioned before, the last line reflects the effects resulting from a decrease in the capital tax due to revenue-recycling. Let us assume that the tax on repatriated capital rents in the initial equilibrium has to be levied at a level higher than that just balancing the positive and negative effects on the country's environmental as well as its income situation. In this case the term in brackets in the third line of multipliers (31') and (A-22') would be equal to zero. This tax rate qualitatively — not with respect to the exact value — corresponds to the optimal capital tax rate that can be derived from multiplier (A-21) in section 3, i.e. in a setting where the tax partly replaces a lump-sum tax. Thus, the assumption that the capital tax in a setting where no lump-sum tax is available is greater than this optimal value as to meet the governmental budget constraint appears to be reasonable. In this case a reduction in the capital tax is advantageous since the extent to which its negative effects are reduced is larger than that of the positive effects. In this context a double dividend hence can be reaped by a capital exporting country through the implementation of a pollution tax. For country A being a capital importer the net positive effect has to more than offset the negative tax base effect of the environmental tax on the tax on repatriated capital rents (the third term in brackets in line two).

We now turn to the question whether there is a double dividend in the *strong* form which means that the revenue-neutral substitution of the environmental tax for the capital tax involves a zero or negative gross cost.³⁵ Hence, abstracting from welfare effects associated with policy-related changes in environmental quality, and still assuming the initial level of the pollution tax to be equal to zero, the multiplier for a capital exporting country (31) changes to:

$$\frac{e_u du}{d\tau^A} = \frac{1}{|D^*|} \left[\xi (\theta^A r_{k\epsilon^A} R_{\epsilon^B \epsilon^B} + r_{k\epsilon^A} \xi H^B) - \epsilon^A (\theta^A r_{\epsilon^A \epsilon^A} R_{\epsilon^B \epsilon^B} + r_{\epsilon^A \epsilon^A} \xi H^B) \right]. \quad (31'')$$

For a capital importing country, (A-22) reduces to:

$$\frac{e_u du}{d\tau^A} = \frac{1}{|D^*|} \left[\xi (-\theta^A r_{k\epsilon^A} R_{\epsilon^B \epsilon^B} - r_{k\epsilon^A} \xi H^B) - \epsilon^A (\theta^A r_{\epsilon^A \epsilon^A} R_{\epsilon^B \epsilon^B} + r_{\epsilon^A \epsilon^A} \xi H^B) \right]. \quad (A-22'')$$

The condition for the double dividend to exist in both scenarios, i.e. the term in square brackets

³⁵[10] Goulder (1994). Costs in this definition are "the monetary equivalents to the policy-induced changes in individual welfare (abstracting from welfare effects associated with policy-related changes in environmental quality" (p.7)).

in multipliers (31'') and (A-22'') to be positive, is:

$$\begin{aligned} \theta^A R_{\epsilon B \epsilon B} &\stackrel{!}{<} -\xi H^B \\ \Leftrightarrow \quad \theta^A &\stackrel{!}{>} -\frac{1}{R_{\epsilon B \epsilon B}} \xi H^B, \end{aligned} \quad (32)$$

which means that tax base effects resulting from a marginal change in the tax rate on repatriated capital rents have to be larger than tax rate effects.³⁶ Thus, a double dividend in the strong sense can be reaped if the capital tax in the initial equilibrium is greater than the level which just balances tax rate effects and tax base effects. Qualitatively, condition (32) as an equality corresponds to the first-order condition determining the optimal value of the capital tax rate in section 3.2 which can be derived from multipliers (17) and (18), respectively.

For an evaluation of the *optimal* value of the environmental tax in a setting where it partly replaces a distorting capital tax, also tax base effects on its own tax base have to be taken into consideration. For a capital exporting country the condition for an optimal environmental tax to be higher than the benchmark tax rate following from multiplier (7) in subsection 3.1 is

$$\begin{aligned} \left(\epsilon^A + \tau^A \frac{1}{r_{\epsilon A \epsilon A}} \right) & (-e_{\epsilon} \epsilon_{\epsilon A} r_{\epsilon A k} R_{\epsilon B \epsilon B} + e_{\epsilon} \epsilon_{\epsilon B} r_{\epsilon A \epsilon A} R_{\epsilon B K} \\ & + \theta^A r_{\epsilon A \epsilon A} R_{\epsilon B \epsilon B} + \tau^A r_{\epsilon A k} R_{\epsilon B \epsilon B} + r_{\epsilon A \epsilon A} \xi H^B) \stackrel{!}{>} \xi \theta^A r_{k \epsilon A} R_{\epsilon B \epsilon B}, \end{aligned} \quad (33)$$

which follows from multiplier (31). The optimal tax rate is higher if the net revenue-recycling effect — i.e. the direct revenue-recycling effect net of the tax erosion effect the environmental tax induces on its own tax base — is greater than the inverse of the positive tax base effect the environmental tax has on the capital tax.

For country *A* being a capital importing country, the tax base effect of the environmental tax on the capital tax is negative. The condition in this case is:

$$\begin{aligned} \left(\epsilon^A + \tau^A \frac{1}{r_{\epsilon A \epsilon A}} \right) & (e_{\epsilon} \epsilon_{\epsilon A} r_{\epsilon A k} R_{\epsilon B \epsilon B} - e_{\epsilon} \epsilon_{\epsilon B} r_{\epsilon A \epsilon A} R_{\epsilon B K} \\ & + \theta^A r_{\epsilon A \epsilon A} R_{\epsilon B \epsilon B} - \tau^A r_{\epsilon A k} R_{\epsilon B \epsilon B} + r_{\epsilon A \epsilon A} \xi H^B) \stackrel{!}{>} -\xi \theta^A r_{k \epsilon A} R_{\epsilon B \epsilon B}, \end{aligned} \quad (34)$$

which follows from multiplier (A-22) on page 33. The net revenue-recycling effect has to be greater than the absolute value of the negative tax base effect of the environmental tax on the capital tax.

³⁶The assumption underlying condition (32) for a capital importing country is that $\xi r_{k \epsilon A} + \epsilon^A r_{\epsilon A \epsilon A} < 0$, i.e. that the marginal productivity of the environmental resource rises also with respect to an increase in the input of the third factor.

5 Conclusions

For the case where public funds are generated with the help of lump-sum taxes we see that there is a similarity between the two national tax instruments pollution tax and a tax on repatriated capital rents. Both are appropriate to simultaneously manipulate prices at the world market and to directly and indirectly internalize externalities arising from domestic or foreign production. We observe that the target principle applies so that the joint implementation of two tax instruments dominates the result achieved by the implementation of only one. If the government aims at two objectives, the target principle implies that the government should employ an equal number of instruments: One policy is aimed at improving the quality of the environment (i.e. the pollution tax) and the other policy at shifting the tax burden to foreigners (e.g. a tax on repatriated capital rents). In particular, if explicit taxes on international capital movements are excluded, pollution taxes raise non-environmental national welfare by acting as an implicit optimal tax on capital.

Apart from these *national* considerations *global* efficiency on the other hand is only available through the introduction of environmental taxes in both countries taking respect of global damages.

Furthermore, concerning the double dividend character of environmental taxes their introduction into a tax system without lump-sum taxes was analysed. The results were then compared to those derived in the presence of lump-sum taxes. Assuming the initial level of the environmental tax to be zero and thereby neglecting tax base effects on the environmental tax, conditions for a double dividend to exist in the weak form as well as in the strong form were derived.

An important difference to the double dividend analysis in a closed economy or in a small open economy is that in the big country case with endogenous factor prices the nationally optimal tax rates of distortionary taxes even in the absence of international externalities are not equal to zero due to strategic calculations.

Future work will aim at generalizing the analysis to more goods and therefore international trade in private goods. This could enable an analysis of the double dividend character of environmental taxes also with respect to tariffs.

A Appendix

A.1 Appendix to subsection 3.1

Conditions for an international equilibrium in the case of country A being a net capital importer

$$e(1, u, \epsilon) = r(1, \epsilon^A, k) - R_K(1, \epsilon^B, K) \cdot \xi - \bar{P} \quad (\text{A-1a})$$

$$E(1, U, \epsilon) = R(1, \epsilon^B, K) + R_K(1, \epsilon^B, K) \cdot \xi \quad (\text{A-1b})$$

$$\epsilon = \epsilon(\epsilon^A, \epsilon^B) \quad (\text{A-1c})$$

$$r_{\epsilon^A}(1, \epsilon^A, k) = \tau^A \quad (\text{A-1d})$$

$$R_{\epsilon^B}(1, \epsilon^B, K) = 0 \quad (\text{A-1e})$$

$$r_k(1, \epsilon^A, k) = R_K(1, \epsilon^B, K) \quad (\text{A-1f})$$

$$\bar{P} = h + \tau^A \epsilon^A \quad (\text{A-1g})$$

Equation (A-1a) again is the income identity of the home country. Since country A is a net capital importer, only the revenue of domestic production net of after tax capital reward to the other country and net of public budgetary needs can be used for consumption purposes.

System of total differentials with country A as a net capital exporter

Taking total differentials of equation system (4) on page 7 we find:

$$e_u du + e_\epsilon d\epsilon - r_{\epsilon^A} d\epsilon^A - \xi R_{K\epsilon^B} d\epsilon^B + (r_k - R_K - \xi R_{KK}) d\xi = -d\bar{P} \quad (\text{A-2a})$$

$$E_U dU + E_\epsilon d\epsilon + (\xi R_{K\epsilon^B} d\epsilon^B - R_{\epsilon^B}) d\epsilon^B + \xi R_{KK} d\xi = 0 \quad (\text{A-2b})$$

$$d\epsilon - \epsilon_{\epsilon^A} d\epsilon^A - \epsilon_{\epsilon^B} d\epsilon^B = 0 \quad (\text{A-2c})$$

$$r_{\epsilon^A \epsilon^A} d\epsilon^A - r_{\epsilon^A k} d\xi = d\tau^A \quad (\text{A-2d})$$

$$R_{\epsilon^B \epsilon^B} d\epsilon^B + R_{\epsilon^B K} d\xi = 0 \quad (\text{A-2e})$$

$$r_{k\epsilon^A} d\epsilon^A - R_{K\epsilon^B} d\epsilon^B - (r_{kk} + R_{KK}) d\xi = 0 \quad (\text{A-2f})$$

$$dh + \tau^A d\epsilon^A = d\bar{P} - \epsilon^A d\tau^A \quad (\text{A-2g})$$

Effect of a pollution tax for country A being a net capital exporter

Effect of a pollution tax on utility in country A for country A being a capital exporter:

$$\begin{aligned}
 \frac{e_u du}{d\tau^A} &= \frac{1}{|D|} \left[e_\epsilon \begin{vmatrix} -\epsilon_{\epsilon^A} & -\epsilon_{\epsilon^B} & 0 \\ 0 & R_{\epsilon^B \epsilon^B} & R_{\epsilon^B K} \\ -r_{k\epsilon^A} & R_{K\epsilon^B} & (r_{kk} + R_{KK}) \end{vmatrix} - \begin{vmatrix} -\tau^A & -\xi R_{K\epsilon^B} & -\xi R_{KK} \\ 0 & R_{\epsilon^B \epsilon^B} & R_{\epsilon^B K} \\ -r_{k\epsilon^A} & R_{K\epsilon^B} & (r_{kk} + R_{KK}) \end{vmatrix} \right] \\
 &= -e_\epsilon \epsilon_{\epsilon^A} \frac{1}{r_{\epsilon^A \epsilon^A}} + \tau^A \frac{1}{r_{\epsilon^A \epsilon^A}} \\
 &\quad + \frac{1}{|D|} \left[-e_\epsilon \epsilon_{\epsilon^A} \frac{r_{k\epsilon^A} r_{\epsilon^A k}}{r_{\epsilon^A \epsilon^A}} R_{\epsilon^B \epsilon^B} + e_\epsilon \epsilon_{\epsilon^B} r_{k\epsilon^A} R_{\epsilon^B K} \right. \\
 &\quad \left. + \tau^A \frac{r_{k\epsilon^A} r_{\epsilon^A k}}{r_{\epsilon^A \epsilon^A}} R_{\epsilon^B \epsilon^B} + r_{k\epsilon^A} \xi H^B \right], \tag{A-3}
 \end{aligned}$$

with $(r_k - R_K)$ being equal to zero according to (4f) on page 7. Equation (A-3) is the same as (7) on page 9.

Effects of an environmental tax for country A being a net capital importer

According to (2) we now have $dk = -dK = d\xi$. Taking total differentials in equation system (A-1) and writing it in matrix notation we find:

$$\underbrace{\begin{bmatrix} 1 & 0 & e_\epsilon & -\tau^A & \xi R_{K\epsilon^B} & -\xi R_{KK} & 0 \\ 0 & 1 & E_\epsilon & 0 & -\xi R_{K\epsilon^B} & \xi R_{KK} & 0 \\ 0 & 0 & 1 & -\epsilon_{\epsilon^A} & -\epsilon_{\epsilon^B} & 0 & 0 \\ 0 & 0 & 0 & r_{\epsilon^A \epsilon^A} & 0 & r_{\epsilon^A k} & 0 \\ 0 & 0 & 0 & 0 & R_{\epsilon^B \epsilon^B} & -R_{\epsilon^B K} & 0 \\ 0 & 0 & 0 & r_{k\epsilon^A} & -R_{K\epsilon^B} & (r_{kk} + R_{KK}) & 0 \\ 0 & 0 & 0 & \tau^A & 0 & 0 & 1 \end{bmatrix}}_D \begin{bmatrix} e_u du \\ E_U dU \\ d\epsilon \\ d\epsilon^A \\ d\epsilon^B \\ d\xi \\ dh \end{bmatrix} = \begin{bmatrix} -d\bar{P} \\ 0 \\ 0 \\ d\tau^A \\ 0 \\ 0 \\ d\bar{P} - \epsilon^A d\tau^A \end{bmatrix}, \tag{A-4}$$

with $(r_k - R_K)$ being equal to zero according to (A-1f) and r_{ϵ^A} being equal to τ^A , the tax on pollution. The determinant is identical to that in the case with country A being a net capital exporter, i.e. it is negative.

The effect of a pollution tax on utility in country A in this case is:

$$\begin{aligned}
\frac{e_u du}{d\tau^A} &= \frac{1}{|D|} \left[e_\epsilon \begin{vmatrix} -\epsilon_{\epsilon A} & -\epsilon_{\epsilon B} & 0 \\ 0 & R_{\epsilon B \epsilon B} & -R_{\epsilon B K} \\ r_{k\epsilon A} & -R_{K\epsilon B} & (r_{kk} + R_{KK}) \end{vmatrix} - \begin{vmatrix} -\tau^A & \xi R_{K\epsilon B} & -\xi R_{KK} \\ 0 & R_{\epsilon B \epsilon B} & -R_{\epsilon B K} \\ r_{k\epsilon A} & -R_{K\epsilon B} & (r_{kk} + R_{KK}) \end{vmatrix} \right] \\
&= -e_\epsilon \epsilon_{\epsilon A} \frac{1}{r_{\epsilon A \epsilon A}} + \tau^A \frac{1}{r_{\epsilon A \epsilon A}} \\
&\quad + \frac{1}{|D|} \left[-e_\epsilon \epsilon_{\epsilon A} \frac{r_{k\epsilon A} r_{\epsilon A k}}{r_{\epsilon A \epsilon A}} R_{\epsilon B \epsilon B} + e_\epsilon \epsilon_{\epsilon B} r_{k\epsilon A} R_{\epsilon B K} \right. \\
&\quad \left. + \tau^A \frac{r_{k\epsilon A} r_{\epsilon A k}}{r_{\epsilon A \epsilon A}} R_{\epsilon B \epsilon B} - r_{k\epsilon A} \xi H^B \right], \tag{A-5}
\end{aligned}$$

System of total differentials for derivation of globally efficient pollution tax rates

By totally differentiating the equilibrium conditions in the case where the home country is a net capital exporter we get:

$$\underbrace{\begin{bmatrix} 1 & 0 & e_\epsilon & -\tau^A & -\xi R_{K\epsilon B} & -\xi R_{KK} & 0 \\ 0 & 1 & E_\epsilon & 0 & (\xi R_{K\epsilon B} - R_{\epsilon B}) & \xi R_{KK} & 0 \\ 0 & 0 & 1 & -\epsilon_{\epsilon A} & -\epsilon_{\epsilon B} & 0 & 0 \\ 0 & 0 & 0 & r_{\epsilon A \epsilon A} & 0 & -r_{\epsilon A k} & 0 \\ 0 & 0 & 0 & 0 & R_{\epsilon B \epsilon B} & R_{\epsilon B K} & 0 \\ 0 & 0 & 0 & -r_{k\epsilon A} & R_{K\epsilon B} & (r_{kk} + R_{KK}) & 0 \\ 0 & 0 & 0 & \tau^A & 0 & 0 & 1 \end{bmatrix}}_D \begin{bmatrix} e_u du \\ E_U dU \\ d\epsilon \\ d\epsilon^A \\ d\epsilon^B \\ d\xi \\ dh \end{bmatrix} = \begin{bmatrix} -d\bar{P} \\ 0 \\ 0 \\ d\tau^A \\ d\tau^B \\ 0 \\ d\bar{P} - \epsilon^A d\tau^A \end{bmatrix}, \tag{A-6}$$

with $(r_k - R_K)$ being equal to zero according to (4f). We still have $-dk = dK = d\xi$.

A.2 Appendix to subsection 3.2

Equilibrium conditions for the home country being a capital importer

System (A-1) of equilibrium conditions depicted in Appendix A.1 for country A being a capital importer remains unchanged except for conditions (A-1d), (A-1f), and (A-1g) which change to (A-7d), (A-7f), and (A-7g), respectively.

$$r_{\epsilon A}(1, \epsilon^A, k) = 0 \tag{A-7d}$$

$$r_k(1, \epsilon^A, k) - \theta^A = R_K(1, \epsilon^B, K) \tag{A-7f}$$

$$\bar{P} = h + \theta^A \xi \tag{A-7g}$$

Effects of a marginal change in the tax on repatriated capital rents for home country being a capital exporter

Totally differentiating the equation system composed of (4) and (16) where according to (1) we still have $-dk = dK = d\xi$ yields in matrix notation:

$$\underbrace{\begin{bmatrix} 1 & 0 & e_\epsilon & 0 & -\xi R_{K\epsilon B} & -(\theta^A + \xi R_{KK}) & 0 \\ 0 & 1 & E_\epsilon & 0 & \xi R_{K\epsilon B} & \xi R_{KK} & 0 \\ 0 & 0 & 1 & -\epsilon_{\epsilon A} & -\epsilon_{\epsilon B} & 0 & 0 \\ 0 & 0 & 0 & r_{\epsilon A \epsilon A} & 0 & -r_{\epsilon A k} & 0 \\ 0 & 0 & 0 & 0 & R_{\epsilon B \epsilon B} & R_{\epsilon B K} & 0 \\ 0 & 0 & 0 & -r_{k \epsilon A} & R_{K \epsilon B} & (r_{kk} + R_{KK}) & 0 \\ 0 & 0 & 0 & 0 & 0 & \theta^A & 1 \end{bmatrix}}_D \begin{bmatrix} e_u du \\ E_U dU \\ d\epsilon \\ d\epsilon^A \\ d\epsilon^B \\ d\xi \\ dh \end{bmatrix} = \begin{bmatrix} -d\bar{P} \\ 0 \\ 0 \\ 0 \\ 0 \\ d\theta^A \\ d\bar{P} - \xi d\theta^A \end{bmatrix}, \quad (\text{A-8})$$

with τ^A being equal to zero according to (16d).

The influence of a tax on repatriated capital rents on domestic utility in country A is:

$$\begin{aligned} \frac{e_u du}{d\theta^A} &= \frac{1}{|D|} \left[e_\epsilon \begin{vmatrix} -\epsilon_{\epsilon A} & -\epsilon_{\epsilon B} & 0 \\ r_{\epsilon A \epsilon A} & 0 & -r_{\epsilon A k} \\ 0 & R_{\epsilon B \epsilon B} & R_{\epsilon B K} \end{vmatrix} - \begin{vmatrix} 0 & -\xi R_{K\epsilon B} & -(\theta^A + \xi R_{KK}) \\ r_{\epsilon A \epsilon A} & 0 & -r_{\epsilon A k} \\ 0 & R_{\epsilon B \epsilon B} & R_{\epsilon B K} \end{vmatrix} \right] \\ &= \frac{1}{|D|} \left[-e_\epsilon \epsilon_{\epsilon A} r_{\epsilon A k} R_{\epsilon B \epsilon B} + e_\epsilon \epsilon_{\epsilon B} r_{\epsilon A \epsilon A} R_{\epsilon B K} + \theta^A r_{\epsilon A \epsilon A} R_{\epsilon B \epsilon B} + r_{\epsilon A \epsilon A} \xi H^B \right], \quad (\text{A-9}) \end{aligned}$$

with $(r_k - R_K)$ being equal to $(-\theta^A)$ according to (16f). (A-9) corresponds to (17) on page 13.

Effects of a marginal change in the tax on repatriated capital rents for home country being a capital importer

Totally differentiating the equation system composed of (A-1) and (A-7) where according to (2) we have $dk = -dK = d\xi$ yields in matrix notation:

$$\underbrace{\begin{bmatrix} 1 & 0 & e_\epsilon & 0 & \xi R_{K\epsilon B} & -(\theta^A + \xi R_{KK}) & 0 \\ 0 & 1 & E_\epsilon & 0 & -\xi R_{K\epsilon B} & \xi R_{KK} & 0 \\ 0 & 0 & 1 & -\epsilon_{\epsilon A} & -\epsilon_{\epsilon B} & 0 & 0 \\ 0 & 0 & 0 & r_{\epsilon A \epsilon A} & 0 & r_{\epsilon A k} & 0 \\ 0 & 0 & 0 & 0 & R_{\epsilon B \epsilon B} & -R_{\epsilon B K} & 0 \\ 0 & 0 & 0 & r_{k \epsilon A} & -R_{K \epsilon B} & (r_{kk} + R_{KK}) & 0 \\ 0 & 0 & 0 & 0 & 0 & \theta^A & 1 \end{bmatrix}}_D \begin{bmatrix} e_u du \\ E_U dU \\ d\epsilon \\ d\epsilon^A \\ d\epsilon^B \\ d\xi \\ dh \end{bmatrix} = \begin{bmatrix} -d\bar{P} \\ 0 \\ 0 \\ 0 \\ 0 \\ d\theta^A \\ d\bar{P} - \xi d\theta^A \end{bmatrix}, \quad (\text{A-10})$$

with τ^A being equal to zero according to (A-7d).

The influence of a tax on repatriated capital rents on domestic utility in country A in this case is:

$$\begin{aligned} \frac{e_u du}{d\theta^A} &= \frac{1}{|D|} \left[e_\epsilon \begin{vmatrix} -\epsilon_{\epsilon A} & -\epsilon_{\epsilon B} & 0 \\ r_{\epsilon A \epsilon A} & 0 & r_{\epsilon A k} \\ 0 & R_{\epsilon B \epsilon B} & -R_{\epsilon B K} \end{vmatrix} - \begin{vmatrix} 0 & \xi R_{K\epsilon B} & -(\theta^A + \xi R_{KK}) \\ r_{\epsilon A \epsilon A} & 0 & r_{\epsilon A k} \\ 0 & R_{\epsilon B \epsilon B} & -R_{\epsilon B K} \end{vmatrix} \right] \\ &= \frac{1}{|D|} \left[e_\epsilon \epsilon_{\epsilon A} r_{\epsilon A k} R_{\epsilon B \epsilon B} - e_\epsilon \epsilon_{\epsilon B} r_{\epsilon A \epsilon A} R_{\epsilon B K} + \theta^A r_{\epsilon A \epsilon A} R_{\epsilon B \epsilon B} + r_{\epsilon A \epsilon A} \xi H^B \right], \quad (\text{A-11}) \end{aligned}$$

with $(r_k - R_K)$ being equal to θ^A according to (A-7f). (A-11) corresponds to (18) on page 13.

A.3 Appendix to subsection 3.3

System of equilibrium conditions with country A being a capital importer

In equation system (A-1) conditions (A-1f) and (A-1g) change to

$$r_k(1, \epsilon^A, k) - \theta^A = R_K(1, \epsilon^B, K) \quad (\text{A-12f})$$

$$\bar{P} = h + \tau^A \epsilon^A + \theta^A \xi, \quad (\text{A-12g})$$

respectively.

Effects of a joint implementation of environmental taxes and taxes on repatriated capital rents for country A being a capital exporter

The complete system of the totally differentiated equilibrium conditions composed of (4) and (19) with $-dk = dK = d\xi$ according to (1) written in matrix notation is:

$$\underbrace{\begin{bmatrix} 1 & 0 & e_\epsilon & -\tau^A & -\xi R_{K\epsilon B} & -(\theta^A + \xi R_{KK}) & 0 \\ 0 & 1 & E_\epsilon & 0 & \xi R_{K\epsilon B} & \xi R_{KK} & 0 \\ 0 & 0 & 1 & -\epsilon_{\epsilon A} & -\epsilon_{\epsilon B} & 0 & 0 \\ 0 & 0 & 0 & r_{\epsilon A \epsilon A} & 0 & -r_{\epsilon A k} & 0 \\ 0 & 0 & 0 & 0 & R_{\epsilon B \epsilon B} & R_{\epsilon B K} & 0 \\ 0 & 0 & 0 & -r_{k \epsilon A} & R_{K \epsilon B} & (r_{kk} + R_{KK}) & 0 \\ 0 & 0 & 0 & \tau^A & 0 & \theta^A & 1 \end{bmatrix}}_D \begin{bmatrix} e_u du \\ E_U dU \\ d\epsilon \\ d\epsilon^A \\ d\epsilon^B \\ d\xi \\ dh \end{bmatrix} = \begin{bmatrix} -d\bar{P} \\ 0 \\ 0 \\ d\tau^A \\ 0 \\ d\theta^A \\ d\bar{P} - \epsilon^A d\tau^A - \xi d\theta^A \end{bmatrix} \quad (\text{A-13})$$

With the determinant of matrix D remaining unchanged, we get the multipliers for the pollution tax and the tax on repatriated capital rents, respectively:

$$\begin{aligned} \frac{e_u du}{d\tau^A} &= \frac{1}{|D|} \left[e_\epsilon \begin{vmatrix} -\epsilon_{\epsilon A} & -\epsilon_{\epsilon B} & 0 \\ 0 & R_{\epsilon B \epsilon B} & R_{\epsilon B K} \\ -r_{k \epsilon A} & R_{K \epsilon B} & (r_{kk} + R_{KK}) \end{vmatrix} - \begin{vmatrix} -\tau^A & -\xi R_{K\epsilon B} & -(\theta^A + \xi R_{KK}) \\ 0 & R_{\epsilon B \epsilon B} & R_{\epsilon B K} \\ -r_{k \epsilon A} & R_{K \epsilon B} & (r_{kk} + R_{KK}) \end{vmatrix} \right] \\ &= -e_\epsilon \epsilon_{\epsilon A} \frac{1}{r_{\epsilon A \epsilon A}} + \tau^A \frac{1}{r_{\epsilon A \epsilon A}} \\ &\quad + \frac{1}{|D|} \left[-e_\epsilon \epsilon_{\epsilon A} \frac{r_{k \epsilon A} r_{\epsilon A k}}{r_{\epsilon A \epsilon A}} R_{\epsilon B \epsilon B} + e_\epsilon \epsilon_{\epsilon B} r_{k \epsilon A} R_{\epsilon B K} + \theta^A r_{k \epsilon A} R_{\epsilon B \epsilon B} \right. \\ &\quad \left. + \tau^A \frac{r_{k \epsilon A} r_{\epsilon A k}}{r_{\epsilon A \epsilon A}} R_{\epsilon B \epsilon B} + r_{k \epsilon A} \xi H^B \right] \end{aligned} \quad (\text{A-14})$$

$$\begin{aligned} \frac{e_u du}{d\theta^A} &= \frac{1}{|D|} \left[e_\epsilon \begin{vmatrix} -\epsilon_{\epsilon A} & -\epsilon_{\epsilon B} & 0 \\ r_{\epsilon A \epsilon A} & 0 & -r_{\epsilon A k} \\ 0 & R_{\epsilon B \epsilon B} & R_{\epsilon B K} \end{vmatrix} - \begin{vmatrix} -\tau^A & -\xi R_{K\epsilon B} & -(\theta^A + \xi R_{KK}) \\ r_{\epsilon A \epsilon A} & 0 & -r_{\epsilon A k} \\ 0 & R_{\epsilon B \epsilon B} & R_{\epsilon B K} \end{vmatrix} \right] \\ &= \frac{1}{|D|} \left[-e_\epsilon \epsilon_{\epsilon A} r_{\epsilon A k} R_{\epsilon B \epsilon B} + e_\epsilon \epsilon_{\epsilon B} r_{\epsilon A \epsilon A} R_{\epsilon B K} + \theta^A r_{\epsilon A \epsilon A} R_{\epsilon B \epsilon B} \right. \\ &\quad \left. + \tau^A r_{\epsilon A k} R_{\epsilon B \epsilon B} + r_{\epsilon A \epsilon A} \xi H^B \right] \end{aligned} \quad (\text{A-15})$$

with $(r_k - R_K)$ now not being equal to zero but equal to $(-\theta^A)$ according to (19f).

Effects of a joint implementation of environmental taxes and taxes on repatriated capital rents for country A being a capital importer

The complete system of the totally differentiated equilibrium conditions composed of (A-1) and (A-12) written in matrix notation with $dk = -dK = d\xi$ according to (2) is:

$$\underbrace{\begin{bmatrix} 1 & 0 & e_\epsilon & -\tau^A & \xi R_{K\epsilon B} & -(\theta^A + \xi R_{KK}) & 0 \\ 0 & 1 & E_\epsilon & 0 & -\xi R_{K\epsilon B} & \xi R_{KK} & 0 \\ 0 & 0 & 1 & -\epsilon_{\epsilon A} & -\epsilon_{\epsilon B} & 0 & 0 \\ 0 & 0 & 0 & r_{\epsilon A \epsilon A} & 0 & r_{\epsilon A k} & 0 \\ 0 & 0 & 0 & 0 & R_{\epsilon B \epsilon B} & -R_{\epsilon B K} & 0 \\ 0 & 0 & 0 & r_{k \epsilon A} & -R_{K \epsilon B} & (r_{kk} + R_{KK}) & 0 \\ 0 & 0 & 0 & \tau^A & 0 & \theta^A & 1 \end{bmatrix}}_D \begin{bmatrix} e_u du \\ E_U dU \\ d\epsilon \\ d\epsilon^A \\ d\epsilon^B \\ d\xi \\ dh \end{bmatrix} = \begin{bmatrix} -d\bar{P} \\ 0 \\ 0 \\ d\tau^A \\ 0 \\ d\theta^A \\ d\bar{P} - \epsilon^A d\tau^A - \xi d\theta^A \end{bmatrix}. \quad (\text{A-16})$$

With the determinant of matrix D remaining unchanged, we get the multipliers for the pollution tax and the tax on repatriated capital rents, respectively:

$$\begin{aligned} \frac{e_u du}{d\tau^A} &= \frac{1}{|D|} \left[e_\epsilon \begin{vmatrix} -\epsilon_{\epsilon A} & -\epsilon_{\epsilon B} & 0 \\ 0 & R_{\epsilon B \epsilon B} & -R_{\epsilon B K} \\ r_{k \epsilon A} & -R_{K \epsilon B} & (r_{kk} + R_{KK}) \end{vmatrix} - \begin{vmatrix} -\tau^A & \xi R_{K \epsilon B} & -(\theta^A + \xi R_{KK}) \\ 0 & R_{\epsilon B \epsilon B} & -R_{\epsilon B K} \\ r_{k \epsilon A} & -R_{K \epsilon B} & (r_{kk} + R_{KK}) \end{vmatrix} \right] \\ &= -e_\epsilon \epsilon_{\epsilon A} \frac{1}{r_{\epsilon A \epsilon A}} + \tau^A \frac{1}{r_{\epsilon A \epsilon A}} \\ &\quad + \frac{1}{|D|} \left[-e_\epsilon \epsilon_{\epsilon A} \frac{r_{\epsilon A k} r_{k \epsilon A}}{r_{\epsilon A \epsilon A}} R_{\epsilon B \epsilon B} + e_\epsilon \epsilon_{\epsilon B} r_{k \epsilon A} R_{\epsilon B K} - \theta^A r_{k \epsilon A} R_{\epsilon B \epsilon B} \right. \\ &\quad \left. + \tau^A \frac{r_{\epsilon A k} r_{k \epsilon A}}{r_{\epsilon A \epsilon A}} R_{\epsilon B \epsilon B} - r_{k \epsilon A} \xi H^B \right], \quad (\text{A-17}) \end{aligned}$$

$$\begin{aligned} \frac{e_u du}{d\theta^A} &= \frac{1}{|D|} \left[e_\epsilon \begin{vmatrix} -\epsilon_{\epsilon A} & -\epsilon_{\epsilon B} & 0 \\ r_{\epsilon A \epsilon A} & 0 & r_{\epsilon A k} \\ 0 & R_{\epsilon B \epsilon B} & -R_{\epsilon B K} \end{vmatrix} - \begin{vmatrix} -\tau^A & \xi R_{K \epsilon B} & -(\theta^A + \xi R_{KK}) \\ r_{\epsilon A \epsilon A} & 0 & r_{\epsilon A k} \\ 0 & R_{\epsilon B \epsilon B} & -R_{\epsilon B K} \end{vmatrix} \right] \\ &= \frac{1}{|D|} \left[e_\epsilon \epsilon_{\epsilon A} r_{\epsilon A k} R_{\epsilon B \epsilon B} - e_\epsilon \epsilon_{\epsilon B} r_{\epsilon A \epsilon A} R_{\epsilon B K} + \theta^A r_{\epsilon A \epsilon A} R_{\epsilon B \epsilon B} \right. \\ &\quad \left. - \tau^A r_{\epsilon A k} R_{\epsilon B \epsilon B} + r_{\epsilon A \epsilon A} \xi H^B \right], \quad (\text{A-18}) \end{aligned}$$

with $(r_k - R_K)$ now not being equal to zero but equal to θ^A according to (A-12f).

A.4 Appendix to section 4

Equation system for country A being a capital importer

Compared to equation system (A-1) only equations (A-1f) and (A-1g) change:

$$r_k(1, \epsilon^A, k) - \theta^A = R_K(1, \epsilon^B, K) \quad (\text{A-19f})$$

$$\bar{P} = \theta^A \xi + \tau^A \epsilon^A \quad (\text{A-19g})$$

Equation (A-19g) reflects that τ^A and θ^A are the only tax instruments available to the government.

Total differentials of system of equilibrium conditions for country A being a capital importer

$$\underbrace{\begin{bmatrix} 1 & 0 & e_\epsilon & -\tau^A & \xi R_{K\epsilon^B} & -(\theta^A + \xi R_{KK}) & 0 \\ 0 & 1 & E_\epsilon & 0 & -\xi R_{K\epsilon^B} & \xi R_{KK} & 0 \\ 0 & 0 & 1 & -\epsilon_{\epsilon^A} & -\epsilon_{\epsilon^B} & 0 & 0 \\ 0 & 0 & 0 & r_{\epsilon^A \epsilon^A} & 0 & r_{\epsilon^A k} & 0 \\ 0 & 0 & 0 & 0 & R_{\epsilon^B \epsilon^B} & -R_{\epsilon^B K} & 0 \\ 0 & 0 & 0 & r_{k \epsilon^A} & -R_{K \epsilon^B} & (r_{kk} + R_{KK}) & -1 \\ 0 & 0 & 0 & \tau^A & 0 & \theta^A & \xi \end{bmatrix}}_{D^*} \begin{bmatrix} e_u du \\ E_U dU \\ d\epsilon \\ d\epsilon^A \\ d\epsilon^B \\ d\xi \\ d\theta^A \end{bmatrix} = \begin{bmatrix} -d\bar{P} \\ 0 \\ 0 \\ d\tau^A \\ 0 \\ 0 \\ d\bar{P} - \epsilon^A d\tau^A \end{bmatrix}, \quad (\text{A-20})$$

with $(r_k - R_K)$ being equal to θ^A according to (A-19f) and r_{ϵ^A} being equal to τ^A , the tax on pollution.

Effects of marginal increase in the pollution tax for country A being a capital exporter

Effect of a pollution tax on utility in country A :

$$\begin{aligned}
\frac{e_u du}{d\tau^A} &= \frac{1}{|D^*|} \left[e_c \begin{vmatrix} -\epsilon_{cA} & -\epsilon_{cB} & 0 \\ 0 & R_{cB\epsilon B} & R_{cBK} \\ \tau^A & 0 & \theta^A \end{vmatrix} - \xi \begin{vmatrix} -\tau^A & -\xi R_{K\epsilon B} & -(\theta^A + \xi R_{KK}) \\ 0 & R_{cB\epsilon B} & R_{cBK} \\ -r_{k\epsilon A} & R_{K\epsilon B} & (r_{kk} + R_{KK}) \end{vmatrix} \right. \\
&\quad + \xi e_c \begin{vmatrix} -\epsilon_{cA} & -\epsilon_{cB} & 0 \\ 0 & R_{cB\epsilon B} & R_{cBK} \\ -r_{k\epsilon A} & R_{K\epsilon B} & (r_{kk} + R_{KK}) \end{vmatrix} - \begin{vmatrix} -\tau^A & -\xi R_{K\epsilon B} & -(\theta^A + \xi R_{KK}) \\ 0 & R_{cB\epsilon B} & R_{cBK} \\ \tau^A & 0 & \theta^A \end{vmatrix} \\
&\quad \left. - \epsilon^A e_c \begin{vmatrix} -\epsilon_{cA} & -\epsilon_{cB} & 0 \\ r_{cA\epsilon A} & 0 & -r_{cAk} \\ 0 & R_{cB\epsilon B} & R_{cBK} \end{vmatrix} + \epsilon^A \begin{vmatrix} -\tau^A & -\xi R_{K\epsilon B} & -(\theta^A + \xi R_{KK}) \\ r_{cA\epsilon A} & 0 & -r_{cAk} \\ 0 & R_{cB\epsilon B} & R_{cBK} \end{vmatrix} \right] \\
&= - e_c \epsilon_{cA} \frac{1}{r_{cA\epsilon A}} + \tau^A \frac{1}{r_{cA\epsilon A}} \\
&\quad + \frac{1}{|D^*|} \left[\xi \left(-e_c \epsilon_{cA} \frac{r_{k\epsilon A} r_{cAk}}{r_{cA\epsilon A}} R_{cB\epsilon B} + e_c \epsilon_{cB} r_{k\epsilon A} R_{cBK} + \theta^A r_{k\epsilon A} R_{cB\epsilon B} \right. \right. \\
&\quad \left. \left. + \tau^A \frac{r_{k\epsilon A} r_{cAk}}{r_{cA\epsilon A}} R_{cB\epsilon B} + r_{k\epsilon A} \xi H^B \right) \right. \\
&\quad - \epsilon^A \left(-e_c \epsilon_{cA} r_{cAk} R_{cB\epsilon B} + e_c \epsilon_{cB} r_{cA\epsilon A} R_{cBK} + \theta^A r_{cA\epsilon A} R_{cB\epsilon B} \right. \\
&\quad \left. + \tau^A r_{cAk} R_{cB\epsilon B} + r_{cA\epsilon A} \xi H^B \right) \\
&\quad \left. - \tau^A \frac{1}{r_{cA\epsilon A}} \left(-e_c \epsilon_{cA} r_{cAk} R_{cB\epsilon B} + e_c \epsilon_{cB} r_{cA\epsilon A} R_{cBK} + \theta^A r_{cA\epsilon A} R_{cB\epsilon B} \right. \right. \\
&\quad \left. \left. + \tau^A r_{cAk} R_{cB\epsilon B} + r_{cA\epsilon A} \xi H^B \right) \right] , \quad (A-21)
\end{aligned}$$

with $(r_k - R_K)$ being equal to $(-\theta^A)$ according to (27f) on page 17.

Effects of marginal increase in the pollution tax for country A being a capital importer

Effect of a pollution tax on utility in country A :

$$\begin{aligned}
\frac{e_u du}{d\tau^A} &= \frac{1}{|D^*|} \left[e_\epsilon \begin{vmatrix} -\epsilon_{\epsilon A} & -\epsilon_{\epsilon B} & 0 \\ 0 & R_{\epsilon B \epsilon B} & -R_{\epsilon B K} \\ \tau^A & 0 & \theta^A \end{vmatrix} - \xi \begin{vmatrix} -\tau^A & \xi R_{K \epsilon B} & -(\theta^A + \xi R_{KK}) \\ 0 & R_{\epsilon B \epsilon B} & -R_{\epsilon B K} \\ r_{k \epsilon A} & -R_{K \epsilon B} & (r_{kk} + R_{KK}) \end{vmatrix} \right. \\
&\quad + \xi e_\epsilon \begin{vmatrix} -\epsilon_{\epsilon A} & -\epsilon_{\epsilon B} & 0 \\ 0 & R_{\epsilon B \epsilon B} & -R_{\epsilon B K} \\ r_{k \epsilon A} & -R_{K \epsilon B} & (r_{kk} + R_{KK}) \end{vmatrix} - \begin{vmatrix} -\tau^A & \xi R_{K \epsilon B} & -(\theta^A + \xi R_{KK}) \\ 0 & R_{\epsilon B \epsilon B} & -R_{\epsilon B K} \\ \tau^A & 0 & \theta^A \end{vmatrix} \\
&\quad \left. - \epsilon^A e_\epsilon \begin{vmatrix} -\epsilon_{\epsilon A} & -\epsilon_{\epsilon B} & 0 \\ r_{\epsilon A \epsilon A} & 0 & r_{\epsilon A k} \\ 0 & R_{\epsilon B \epsilon B} & -R_{\epsilon B K} \end{vmatrix} + \epsilon^A \begin{vmatrix} -\tau^A & \xi R_{K \epsilon B} & -(\theta^A + \xi R_{KK}) \\ r_{\epsilon A \epsilon A} & 0 & r_{\epsilon A k} \\ 0 & R_{\epsilon B \epsilon B} & -R_{\epsilon B K} \end{vmatrix} \right] \\
&= - e_\epsilon \epsilon_{\epsilon A} \frac{1}{r_{\epsilon A \epsilon A}} + \tau^A \frac{1}{r_{\epsilon A \epsilon A}} \\
&\quad + \frac{1}{|D^*|} \left[\xi \left(-e_\epsilon \epsilon_{\epsilon A} \frac{r_{k \epsilon A} r_{\epsilon A k}}{r_{\epsilon A \epsilon A}} R_{\epsilon B \epsilon B} + e_\epsilon \epsilon_{\epsilon B} r_{k \epsilon A} R_{\epsilon B K} - \theta^A r_{k \epsilon A} R_{\epsilon B \epsilon B} \right. \right. \\
&\quad \left. \left. + \tau^A \frac{r_{k \epsilon A} r_{\epsilon A k}}{r_{\epsilon A \epsilon A}} R_{\epsilon B \epsilon B} - r_{k \epsilon A} \xi H^B \right) \right. \\
&\quad - \epsilon^A \left(e_\epsilon \epsilon_{\epsilon A} r_{\epsilon A k} R_{\epsilon B \epsilon B} - e_\epsilon \epsilon_{\epsilon B} r_{\epsilon A \epsilon A} R_{\epsilon B K} + \theta^A r_{\epsilon A \epsilon A} R_{\epsilon B \epsilon B} \right. \\
&\quad \left. - \tau^A r_{\epsilon A k} R_{\epsilon B \epsilon B} + r_{\epsilon A \epsilon A} \xi H^B \right) \\
&\quad \left. - \tau^A \frac{1}{r_{\epsilon A \epsilon A}} \left(e_\epsilon \epsilon_{\epsilon A} r_{\epsilon A k} R_{\epsilon B \epsilon B} - e_\epsilon \epsilon_{\epsilon B} r_{\epsilon A \epsilon A} R_{\epsilon B K} + \theta^A r_{\epsilon A \epsilon A} R_{\epsilon B \epsilon B} \right. \right. \\
&\quad \left. \left. - \tau^A r_{\epsilon A k} R_{\epsilon B \epsilon B} + r_{\epsilon A \epsilon A} \xi H^B \right) \right] , \quad (A-22)
\end{aligned}$$

with $(r_k - R_K)$ being equal to θ^A according to (A-19f) on page 31.

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Workshop 1995

Environmental Policy in Open Economies

June 5-7, 1995
Waldhaus Jakob, Eichhornstrasse 84, D-78464 Konstanz

Monday, June 5, 1995

19.00 - 21.00 Welcome Reception.

Tuesday, June 6, 1995

Chairman: Heinrich Ursprung.

9.00 - 9.45 *Opening Address:* Hans-Jürgen Vosgerau (Speaker of the SFB 178, Konstanz).

Introduction: Bernd Genser (SFB 178, Konstanz).

9.45 - 10.30 Coffee Break.

10.30 - 12.00 James R. Markusen (University of Colorado, Boulder):
Costly Pollution Abatement, Competitiveness, and Plant Location Decisions.
Discussant: Ulrich Landwehr (University of Mannheim).

Gunter Stephan (University of Bern):
Laissez-Faire, International Cooperation or National Greenhouse Policy:
A CGE Study.

Discussant: Andreas Haufler (University of Konstanz).

12.00 - 14.00 Lunch Break.

14.00 - 15.30 Roger D. Congleton (George Mason University):
Return to Rio: On the Political Economy of Environmental Treaties.
Discussant: Hans Peter Grüner (University of Konstanz).

Rolf Bommer (SFB 178, Konstanz):
Endogenous Environmental Policy and Trade Liberalization - A Signaling Approach.

Discussant: Ronald Jones (University of Rochester).

15.30 - 16.00 Coffee Break.

- 16.00 - 17.30 Michael Rauscher (University of Kiel):
Protectionists, Environmentalists, and the Formation of Environmental Policy in an Open Economy.
 Discussant: John S. Chipman (University of Minnesota).
 Achim Körber (SFB 178, Konstanz):
Raising Rivals' Costs with Environmental Policy - A Lobbying Approach.
 Discussant: Hans Gersbach (University of Basel).

Wednesday, June 7, 1995

Chairman: Bernd Genser.

- 9.00 - 10.30 Ernst Mohr (University of Kiel, Hochschule St.Gallen):
Sustainable Development and International Distribution: Theory and Application to Rainforests as Carbon Sinks.
 Discussant: Carsten Schmidt (University of Konstanz).
 Sebastian Killinger (SFB 178, Konstanz):
Decentralized Internalization of International Externalities.
 Discussant: Lucas Bretschger (University of Zürich).
- 10.30 - 11.00 Coffee Break.
- 11.00 - 12.30 Ronnie Schöb (University of München):
Choosing the Right Instrument: Environmental Policy in the Presence of a Double Dividend.
 Discussant: Frank Hettich (SFB 178, Konstanz).
 Günther Schulze and Rolf Bommer (SFB 178, Konstanz):
 Economic Integration and Economic Policy. Does NAFTA Increase Pollution?
 Discussant: Sven Arndt (McKenna College).
- 12.30 - 14.30 Lunch Break.
- 14.30 - 16.00 Albert Schweinberger (SFB 178, Konstanz):
Environmental and Commercial Policies in More or Less Populous Open Economies.
 Discussant: James R. Markusen (University of Colorado, Boulder).
 Ruud de Mooij (Ministry of Economic Affairs, The Hague) and
 Lans A. Bovenberg (University of Tilburg):
Environmental Taxation and the Double Dividend: The Role of Factor Substitution and Capital Mobility.
 Discussant: Gebhard Kirchgässner (University of St. Gallen).
- 16.00 Closing Address: Heinrich Ursprung (SFB 178, Konstanz).