

The Taxation of Interest in Europe: A Minimum Withholding Tax?

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Abstract. This paper provides an analysis of the proposal for introducing a minimum withholding tax on interest in the EU. We present a model with three countries: a typical EU country, an 'inside' tax haven, and an 'outside' tax haven. In the initial non-cooperative solution, the former two countries impose withholding taxes on interest. We investigate what happens to welfare in these countries, if the 'inside' tax haven is forced to raise its withholding tax. From the model we proceed to a broader evaluation of the minimum withholding tax proposal.¹

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1. Introduction

The increasing international mobility of production factors, especially capital, poses well-known problems for tax authorities in open economies. Of great importance to EU countries is the challenge to national tax authorities posed by the liberalization of capital flows between EU countries, as evidenced by the European Council directive of June 1988. This directive was one of several initiatives to support the functioning of the Single Market in the EU. According to the directive, member countries were to completely liberalize international movements of capital before July 1, 1990. To further financial integration in the Community, the European Commission felt that additional steps were called for. A genuine market for financial services should be established, as promoted by a series of directives. Second, it was deemed important to lessen the obstacles to financial integration arising from differences in taxation across member countries and across financial instruments, and from tax evasion. In this light, the Commission proposed a directive in May 1989 concerning a common system of source tax on interest income in the EU.

The Commission specifically proposed the introduction of a minimum Community-wide withholding tax on interest payments made to all Community residents to counter the risks of distortion, evasion, and avoidance in the present system. The minimum tax rate should be 15 pct., corresponding to about the average of existing withholding taxes on interest in EC countries.

The proposal, however, allowed several exemptions from the 15 pct. withholding tax, so that hardly all interest payments accruing to EC citizens would be subject to the tax. Many economists and laymen were to different degrees critical of the proposal. One point was the failure of the proposal to take into account third countries. Giovannini (1989, pp. 369-70) notes: "Europe is not a closed economy, and taxing capital income at the same rate within the EEC, given the current structure of tax systems, will not avoid an outflow to tax havens. This outflow could occur through countries which are presently imposing few or no capital controls, giving rise to a boom of financial intermediaries in those countries, unless strict controls vis-a-vis the rest of the world are imposed." And Tanzi (1995, p. 129) notes, that "... even if countries of the European Union would agree on some policy among themselves, the existence of tax havens and of countries outside the European Union that would not be party to the agreement would raise questions about the degree to which the agreed solution would solve the problem."

This paper reconsiders the EU proposal. Previous research has – mainly verbally – focused on issues such as the possible shortcomings of the proposal in the incomplete coverage of withholding taxes, the expected aversion on the part of some countries against

accepting the proposal, and the effects on financial markets and institutions (cfr., e.g., Frank (1991) and Huizinga (1994)). We instead concentrate on some of the analytics of the proposal. In line with the above quotes, we stress the connection between minimum withholding taxes in the EU and the competition for financial business activity between tax havens inside and outside of the EU.

The paper presents a three-country model of withholding taxation and banking activity. One country is a typical, large, EU country; the second country is a tax haven inside EU; and the third country is a tax haven outside EU. The large country's residents can place deposits in all three countries. Similarly, firms in the first country may borrow at home or abroad. The country of destination of deposits will generally be determined by the withholding tax policies of the two EU countries, interest rates, profit (cost) margins of banks, and any idiosyncratic costs associated with households or firms undertaking financial transactions abroad rather than at home.

In a non-cooperative withholding tax equilibrium (in which the outside tax haven for simplicity is assumed to abstain from withholding taxes), both EU countries make use of the withholding tax, although for reasonable parameter values that of the inside tax haven is much lower than that of the typical EU country. We then consider the effects of forcing the inside tax haven to levy a minimum withholding tax above the non-cooperative level. While welfare in that country is not affected by a slight increase in its withholding tax, the typical EU country experiences a first-order effect on its welfare. A higher withholding tax in the inside tax haven will induce some households in the typical EU country to invest at home instead of in the tax haven. Thereby, the typical EU country's withholding tax revenue and profits from domestic banking operations increase, improving welfare. On the other hand, those households who a fortiori place funds in the inside tax haven will end up paying higher taxes there, and this lowers welfare. In principle, therefore, a marginal increase in the withholding tax in the inside tax haven has ambiguous welfare consequences for the EU partner.

To get some feel for the possible magnitudes we undertake some simulations. These show, as a general rule, that it is welfare-improving for the typical EU country to have the inside tax haven raise its tax. This is especially so, if the typical EU country is allowed to adjust its own withholding tax in response to the rise in the tax in the partner country. The inside tax haven, on the contrary, generally loses from the requirement to raise its tax. The main reason for this is the loss of banking business to the outside tax haven and to the EU partner.

Our analysis suggests that previous attempts to analyze the withholding tax proposal,

focusing exclusively on EU countries, are too narrow.¹ It seems vital to incorporate tax evasion opportunities arising outside EU, even if it paints a bleaker picture of the overall proposal. Since the effects on inside tax havens is expected to be negative, some transfer of resources to these countries may be needed to persuade them to accept an increase in minimum withholding taxes on interest in EU.

We structure the remainder of the paper as follows. Section 2 briefly describes the motivation for the Commission's proposal for a minimum withholding tax in the EU as well as the main effects of the proposal itself, including envisaged exemptions. Section 3 then presents the three-country model, and lays out the deposit (borrowing) pattern of households (firms) in the typical EU country. Next, section 4 characterizes the non-cooperative withholding tax equilibrium and considers the effect of a marginal rise in the inside tax haven's tax rate. Subsequently, section 5 presents the numerical simulations characterizing how a requirement for the inside tax haven to discretely raise its withholding tax affects welfare in that country and in its EU partner.

Section 6 offers a broader evaluation of the model and of the EU minimum withholding tax proposal. It also looks at other possible solutions to the interest tax evasion problem in Europe. Our overall conclusion is somewhat distressing. While the minimum withholding tax proposal may have some favorable features, there are also drawbacks associated with outside tax havens and with implementing the tax within an increasingly complex international financial system. So it may certainly not be an ideal response to the widespread evasion of residence-based taxation of interest in today's EU. But the prospects for alternatives such as greatly strengthened multilateral assistance or a complete EU-wide reporting system for interest payments are even more gloomy.

¹This holds for instance for Janeba and Peters (1996); see section 6.

2. The proposal for a minimum withholding tax on interest

This proposal was shaped by the EC Commission during the first half of 1989. A thorough 'communication' from the Commission to the EC Council motivates and describes the proposal, leading not only to the 'proposal for a Council directive on a common system of withholding tax on interest income'² itself, but also to an additional 'proposal for a directive concerning mutual assistance by the competent authorities of the Member States in the field of direct taxation and value-added tax' (cfr. COM(89) 60 final 3, 1989).

The immediate reason for these initiatives was that article 6(5) of Council Directive 55/361/EEC of 24 June 1988 stated that "the Commission shall submit to the Council, by December 1988, proposals aimed at eliminating or reducing risks of distortion, tax evasion and tax avoidance linked to the diversity of national systems for the taxation of savings and for controlling the application of these systems. The Council shall take a position on these proposals by 30 June 1989."

The two proposals were generally designed to deal with the increased risks of avoidance or evasion of capital income tax which could result from the liberalization of capital movements. The liberalization entails that Community residents are free to transfer their savings into bank accounts in any other Member State. If residents then do not declare their foreign interest income to their national tax authorities and evade payment of tax, it can cause a substantial loss of tax revenue in Member States.

In considering what measures to propose in this context, the Commission took the following factors into account: "(a) the risk that savings will be shifted to banks and other financial institutions in third countries; (b) the possible loss of business for Community banks and financial institutions; (c) the risk of an appreciable increase in interest rates and hence of a rise in the cost of money for European firms and governments; (d) the risk of significant increase in administrative costs for both the public authorities and financial institutions resulting from the measures to be taken; (e) the need to maintain the internal balance of the systems for the taxation of income in the different Member States, while at the same time encouraging closer alignment of national tax systems." (COM(89) 60 final 3, communication p. 4). Previously, the Commission had indicated that three (not mutually exclusive) ways of reducing distortions and evasion in the field of portfolio investment would be: (i) the introduction of a central system with automatic information transfer to authorities; (ii) the introduction of a general withholding tax; and (iii) the strengthening of mutual assistance between national tax authorities. With the twin proposals of 1989, the Commission decided not to pursue the first route. Instead, the second route was considered

²The term 'interest' in the proposal is supposed to cover all income from claims of any kind, including capital gains etc.; see the Commission's comments to article 2 in the proposal.

the most appropriate response and led to the minimum withholding tax proposal. (The third route was represented by the – weak – additional proposal.)

The main feature of the proposals is a minimum rate of withholding tax on interest paid by debtors residing in the Community. Member States would be free to apply a higher rate of withholding tax either to their own domestic taxpayers only or to all recipients of interest. However, a series of exemptions were permitted: Member States would be free not to apply the withholding tax to tax-exempt savings income, to interest payments constituting industrial or commercial income, and to interest payments made to residents of third countries or to international loans (Eurobonds). The Commission finally suggested a minimum rate of withholding tax of 15 percent.

The supplementary proposal amends Directive 77/799/EEC to remove purely administrative restrictions on mutual assistance, and to facilitate the exchange of information in cases where the tax authorities of the Member State of the investor in question can show that there are clear grounds for a presumption of fraud.

As seen from point (a) above, the Commission was well aware of the risk of capital outflows to third countries as a means of escaping taxation; in particular, it suggested that the Community should open negotiations with the major third countries involved, either bilaterally or within a multilateral framework such as the OECD.

Article 6, par. 5 in the Directive of June 24, 1988, stipulated that "any tax provisions of a Community nature shall, in accordance with the Treaty, be adopted unanimously." As one would expect, this requirement determined the fate of the two proposals on minimum withholding tax and mutual assistance.³ Delegations of four of the then twelve Member States – United Kingdom, Germany, Luxembourg, and the Netherlands – voted against the adoption of the minimum tax proposals. The former three opposed it because they regarded it as too much of a constraint, whereas the Dutch did so because they thought it inefficient. All that came out of the initiative was a completely toothless compromise proposed by the Presidency of the Council following the summit of EC Heads of State and Government in Strasbourg in December 1989. Since then, the question of a minimum withholding tax has come up a few times (Belgium in 1993 reintroduced the idea of a minimum 15 percent withholding tax on only international interest payments; see Huizinga (1994)) without this leading to any action.

³Frank (1991) even writes: "the effect of this provision is to compromise and even to render impossible, the adoption by the Council of Ministers of truly effective measures against distortion, tax evasion, and tax avoidance." (p. 42).

3. A simple three-country model

Introduction

In this section we consider a simple model outlining some of the issues associated with the minimum withholding tax proposal. The model necessarily is very stylized.⁴

The model has three countries. Country A is a typical EU country. Country B, another EU country, is an 'inside' tax haven. Further, country C is an 'outside' tax haven. In the background there is a rest of the world, determining the international rate of interest applicable to inter-bank operations, denoted i^* . This interest rate is the 'raw' cost of funds for financial institutions in all three countries. Countries B and C are taken to be small relative to country A. We wish to concentrate on capital flight from A into these countries and disregard households and firms in countries B and C in the following. Banks in all countries are included, though. We concentrate on two groups of non-bank private agents: households and firms in country A. All households wish to deposit one unit of the numeraire good each. All firms instead need a loan of one unit to carry out projects. The words 'households' and 'firms' should not be taken literally – households stand for all depositors and firms for all borrowers.

Households (firms) in country A can deposit with (borrow from) domestic banks. They can also transact abroad, although this will involve costs which vary across households (firms). Applying an idea from Gros (1991), we index households (firms) from 0 to 1 reflecting these costs. Households (firms), for simplicity, are uniformly distributed on $[0, 1]$.

In general, all transactions between a bank and a private agent (household or firm) give rise to small amounts of profits accruing to the bank.⁵ Inter-bank transactions, however, yield no such profits as they occur at the base-line international interest rate. In what follows, we look at households in country A, banks in all three countries, and finally the governments in countries A and B.

Households

When depositing at home, households earn a before-tax interest rate of $i^* - \delta_A$, where

⁴Tax competition models can become very complicated. The purpose of our model is the same as that of Kanbur and Keen (1993, p. 877) who in their commodity tax competition article wish to "...develop a model that is rich enough to capture some of the central features of the interaction between national tax systems in an integrated world but simple enough to yield sharp insights into some of the central questions..."

⁵More broadly, 'profits' may represent increased remuneration or utilization of local production factors. This way, profits are still counted as a net contribution to national income, as opposed to the case where they represent the cost of labor inputs that otherwise would be employed elsewhere in the economy.

i^* is the bank cost-of-funds,⁶ and δ_A is the contribution to profits demanded by banks in country A on deposits from households. Households are subject to a withholding tax at the rate of t_A . For convenience, we take this tax to be a specific tax. This should not affect any qualitative results below.

Alternatively, households may place funds abroad. If they deposit in country B, they earn the going bank cost-of-funds, i^* , minus bank profits, $\delta_B = \delta^* \leq \delta_A$ and minus the withholding tax in country B, t_B . Depositing in country B, however, involves costs of βh for household h (h in $[0, 1]$). These costs represent transportation and communication expenses, and efforts to conceal the transaction to domestic tax authorities. Country A formally has a residence-based capital income tax system. In principle, then, interest earned by country A households abroad is subject to country A's tax, t_A . We assume, though, that households in A do not report any interest income earned abroad to their domestic tax authorities, and that the latter cannot monitor the foreign investments undertaken by domestic residents. In particular, no agreement exists between the domestic and foreign tax authorities that would ensure an adequate transfer of information.

If the households deposit in country C, there is for simplicity no withholding tax levied. Households then earn the cost-of-funds, i^* , minus the local contribution to bank profits, $\delta_C = \delta^*$. Further, there is a transactions cost of γh . We shall assume that depositing funds in country C, the outside tax haven, is less convenient than doing so in country B, the inside tax haven. This may reflect a greater distance, a lower awareness of this opportunity, etc. To capture this, the transactions cost parameter γ for country C is assumed to exceed the corresponding parameter β for country B

$$\gamma > \beta \quad (1)$$

Next, we characterize which of country A's households prefer to invest at home rather than abroad. To start, investing in A is preferred to investing in B, if

$$i^* - \delta_A - t_A \geq i^* - \delta^* - t_B - \beta h \quad (2)$$

Let the value of h at which households are indifferent be denoted h_2 , so that

$$h_2 = \frac{t_A - t_B + \delta_A - \delta^*}{\beta} \quad (3)$$

For values of h greater than h_2 , country A's households prefer to deposit at home, and vice versa.

⁶An appendix with a more general version of our model, featuring imperfect competition and interest rate setting in the banking sector in country A, is available as from the authors upon request. The qualitative results with the more general model are comparable to those that follow here.

Similarly, country A's households prefer investing at home rather than in country C, if

$$i^* - \delta_A - t_A \geq i^* - \delta^* - \gamma h \quad (4)$$

Households are indifferent between the two investment opportunities at a borderline parameter h_0 with

$$h_0 = \frac{t_A + \delta_A - \delta^*}{\gamma} \quad (5)$$

For values of h in excess of h_0 , it is more attractive to invest in A, and vice versa.

Finally, investing in country B is preferred to investing in C, if

$$i^* - \delta^* - t_B - \beta h \geq i^* - \delta^* - \gamma h \quad (6)$$

with indifference occurring if $h = h_1$, where

$$h_1 = \frac{t_B}{\gamma - \beta} \quad (7)$$

With γ exceeding β and a positive tax rate t_B in country B,⁷ country C is preferred at very low values of h , i.e. for $h \leq \min(h_0, h_1)$. Accordingly, households with very low transactions costs turn to the outside tax haven rather than domestic banks or the inside tax haven. In the following, we further assume that for intermediate values of h , country B is the preferred investment destination, while for very high values of h , households prefer to place their funds at home, in country A. For this to be the case, we should have

$$h_1 < h_0 < h_2 \quad (8)$$

while the borderline h_0 between countries A and C becomes irrelevant, as with $h = h_0$ country B is the preferred destination. Condition (8) is equivalent to

$$\frac{t_B}{\gamma - \beta} < \frac{t_A + \delta_A - \delta^*}{\gamma} < \frac{t_A - t_B + \delta_A - \delta^*}{\beta} \quad (8')$$

Figure 1 illustrates how households with different h choose the country of destination for their deposits. On the horizontal axis is the excess return from investing in country B (rather than in A), and on the vertical axis the similar excess return from investing in C (rather than in A). Point E in the figure represents the two excess returns for a household with negligible transactions costs, i.e. for $h = 0$. Clearly, with $t_B > 0$, E lies above the 45 degree line, so that country C is the preferred destination.

⁷Naturally, we take the tax rate in country A to be greater than zero, too. The validity of the assumptions of positive tax rates will be checked later on.

Raising h above zero corresponds to moving down along the line EFGH. When reaching F, h has increased to h_1 , and investment opportunities in B and C are equivalent in terms of net returns. Both opportunities are a fortiori preferred to A. Raising h further, country B is the preferred destination until we reach point G, where the returns from investing in A and B are identical. Point G corresponds to $h = h_2$. For even greater h , tax havens lose their appeal, and households deposit domestically. Finally, point H corresponds to maximum transactions costs, i.e. $h = 1$.

Firms

Country A's firms can in principle borrow either at home or abroad. At home, the cost of borrowing equals the sum of the base-line interest rate, i^* , and the contribution to profits, δ_A . Alternatively, they may borrow abroad,⁸ resulting in a cost of borrowing of i^* , plus bank profits of δ^* , and transactions costs of ηf , where f is the index of domestic firms and η a transactions cost parameter. If the profit parameter δ_A exceeds δ^* , then some of country A's firms indeed borrow internationally. Domestic borrowing is preferred to international borrowing, if

$$i^* + \delta_A \leq i^* + \delta^* + \eta f \quad (9)$$

with indifference occurring at $f = f_1$, where

$$f_1 = \frac{\delta_A - \delta^*}{\eta} \quad (10)$$

Obviously, for $f < f_1$ firms wish to borrow abroad, and vice versa.

Banks in the three countries

Banks in all three countries can borrow and lend in the international inter-bank market at the rate i^* . As a result, they can always meet the demand for deposits and loans from households and firms in country A. Country C's banks receive deposits from households in A in the amount h_1 to yield the following profits,

$$P_C = h_1 \delta^* \quad (11)$$

Country B's banks receive deposits of $h_2 - h_1$ from A, yielding profits of

$$P_B = (h_2 - h_1) \delta^* \quad (12)$$

⁸For simplicity, we assume that firms borrow from the rest of the world, not from the tax havens.

Finally, Country A's banks receive $(1 - f_1)(i^* + \delta_A)$ in interest from firms and $i^*(f_1 - h_2)$ on net from interbank operations, while paying $(1 - h_2)(i^* - \delta_A)$ in interest to households in A. Their total profits therefore amount to,

$$P_A = [2 - (h_2 + f_1)]\delta_A \quad (13)$$

Governments

Next, we consider the optimal tax policies in countries A and B. In setting its withholding tax rate so as to maximize national surplus, each of the two governments takes the withholding tax of the other country as given. Further, it takes into account how a change in its own tax affects deposit decisions by country A's households. The two governments thus play a Nash non-cooperative tax game.⁹

Tax revenue is assumed to be scarce in both countries. As a result, the marginal costs of public funds (MCPF) in the two countries, denoted by ρ_A and ρ_B , are assumed to exceed unity. The surplus to be maximized in the two countries comprises bank profits, tax revenues¹⁰ and (for country A) the difference between the total net interest earned by households (at home and abroad) and the total cost of borrowing for firms (at home and abroad). To see that this is the appropriate criterion, consider first the situation where the two profit parameters δ_A and δ^* are identical and no withholding tax is levied in country A. In this instance there is no incentive for either households or firms to transact abroad, and the total national surplus becomes equal to zero. (Bank profits in country A exactly correspond to the difference between the total borrowing costs of firms and the net interest received by households and therefore are a simple transfer between agents in the private sector.) The introduction of a withholding tax in country A – motivated by a need for tax revenue – generally lowers the net earnings of households on their deposits while not affecting the borrowing costs on the part of firms.¹¹ The lower interest receipts by households are registered as part of the surplus in country A. In the surplus expressions, tax revenues are weighted by the respective MCPF (to generate the value of the public goods financed by the tax revenues).

To start with country B, tax revenue, denoted by T_B , equals $t_B(h_2 - h_1)$. The government thus maximizes the following surplus,

$$S_B = \rho_B T_B + P_B = (\rho_B t_B + \delta^*)(h_2 - h_1) \quad (14)$$

⁹Alternatively, the authorities in country A could act as a Stackelberg leader and those in country B as Stackelberg follower. See the appendix for the consequences of choosing this particular formulation.

¹⁰Tax revenues represent the amount of public goods made possible by the revenues.

¹¹In the more general model referred to in fn. 6, borrowing costs on the part of firms are affected via a change in the endogenous interest rate in country A.

Substituting for h_1 and h_2 , we get

$$S_B = \frac{(\rho_B t_B + \delta^*)}{\beta(\gamma - \beta)} [(\gamma - \beta)(t_A + \delta_A - \delta^*) - \gamma t_B] \quad (14')$$

The value of t_B that maximizes this surplus is given by,

$$t_B = \frac{(\gamma - \beta)(t_A + \delta_A - \delta^*) - \gamma \delta^* / \rho_B}{2\gamma} \quad (15)$$

As expected, t_B goes up, if t_A is increased. Similarly, t_B declines, if the profit contribution, δ^* , rises. Thus, if banking services in country B become more profitable, then the withholding tax, t_B , will be lowered to attract more deposits from country A. Further, if public funds in B become scarcer, as represented by a higher ρ_B , then more weight is put on tax revenues, leading to an increase in the tax rate t_B . Finally, if bank transactions in country A involve a higher profit margin δ_A , there is room to increase the withholding tax for country B.

Next, we consider country A's surplus. As stated, it generally consists of (i) tax revenues, weighed by the appropriate MCPF, (ii) bank profits, and (iii) the difference between the total earnings on deposits of households and the total cost of borrowing for firms. Tax revenue, T_A , equals $t_A(1 - h_2)$. Bank profits, P_A , are as in equation (13) above. The net interest receipts of domestic households from abroad can, with the aid of Figure 2, be found as

$$i^* - \delta_A - t_A + \frac{1}{2}(\beta h_2^2 + (\gamma - \beta)h_1^2)$$

Further, with the aid of Figure 3, the gross borrowing costs to firms can be written as

$$i^* + \delta_A - \frac{1}{2}\eta f_1^2$$

In toto, country A's surplus is simply expressed as

$$S_A = \rho_A t_A(1 - h_2) - t_A - \delta_A(h_2 + f_1) + \frac{\beta}{2}h_2^2 + \frac{\gamma - \beta}{2}h_1^2 + \frac{\eta}{2}f_1^2 \quad (16)$$

Again, we substitute for h_2 , h_1 , and f_1 from (3), (7), and (10). Next, we differentiate S_A with respect to t_A and solve for country A's optimal tax rate

$$t_A = \frac{(\rho_A - 1)t_B + \beta(\rho_A - 1) - \rho_A(\delta_A - \delta^*) - \delta^*}{2\rho_A - 1} \quad (17)$$

Note that the withholding tax in country A is higher, the higher is the withholding tax t_B in country B. Further, with the profit parameters δ_A and δ^* small enough and t_B non-negative, the optimum tax rate in country A is positive. Also note that a higher profit margin abroad (at home) leads to a higher (lower) withholding tax in country A. Finally, the withholding tax in A is seen to increase with the transaction cost parameter β .

4. The non-cooperative withholding tax equilibrium

The two expressions for withholding tax rates in countries A and B, (15) and (17), in effect represent the reaction functions of the two governments. These Nash reaction functions are illustrated in Figure 4 for moderate values of the profit parameters δ_A and δ^* . The reaction function for country A, denoted R_A , cuts the vertical axis at a positive rate of t_A , as long as $\delta^* + \rho_A(\delta_A - \delta^*) < \beta(\rho_A - 1)$. The reaction function for country B, denoted R_B , instead cuts the horizontal axis for a negative value of t_B , if $(\gamma - \beta)(\delta_A - \delta^*) - \gamma\delta^*/\rho_B < 0$. Hence, we cannot be completely certain that the Nash equilibrium implies positive withholding tax rates in both countries. However, with profit parameters sufficiently small and the MCPF's sufficiently large, the Nash equilibrium tax rates will certainly be positive.

The Nash reaction functions yield the following explicit expressions for the optimal withholding tax rates in the two countries

$$t_B = \frac{(\gamma - \beta)\beta(\rho_A - 1) + (\delta_A - \delta^*)(\gamma - \beta)(\rho_A - 1) - \delta^*(\gamma - \beta + \gamma(2\rho_A - 1)/\rho_B)}{2\gamma(2\rho_A - 1) - (\gamma - \beta)(\rho_A - 1)} \quad (18)$$

$$t_A = \frac{2\gamma\beta(\rho_A - 1) - (\delta_A - \delta^*)(2\gamma\rho_A - (\rho_A - 1)(\gamma - \beta)) - \delta^*\gamma(2 + (\rho_A - 1)/\rho_B)}{2\gamma(2\rho_A - 1) - (\gamma - \beta)(\rho_A - 1)} \quad (19)$$

From these expressions, we confirm that both withholding tax rates are positive, provided the national MCPF in country A, ρ_A , is sufficiently large and the profit parameters, δ_A and δ^* , are sufficiently small. In other words, taxes are positive, if tax revenue is badly needed, and the profitability of banking business is limited. In the real world, this seems realistic enough.

It is interesting to consider the special case with profit parameters $\delta_A = \delta^* = 0$. This is the situation in which banking business adds nothing to local profits or the remuneration of local factors in general. With MCPF's greater than unity in the two countries, the ratio between the optimal withholding tax rates in countries B and A is simply given by $t_B/t_A = (\gamma - \beta)/(2\gamma)$. In other words, with only tax revenue and not the amount of bank business mattering, country B chooses a positive withholding tax rate that is less than half of country A's tax rate.

A marginal increase in the withholding tax in country B

The government in country B is assumed to maximize the social surplus with respect to the withholding tax, t_B , in the Nash equilibrium. A marginal increase in this tax then leaves the surplus in B unchanged, as

$$dS_B/dt_B = 0$$

However, a change in B's withholding tax generally has a first order effect on country A's surplus. To be precise, we find that the cross effect dS_A/dt_B is given by the following surprisingly simple formula (using $dS_A/dt_A = 0$)

$$\frac{dS_A}{dt_B} = (1 - h_2)(\rho_A - 1) - (h_2 - h_1) \quad (20)$$

From this expression, we see that an increase in country B's withholding tax from the Nash equilibrium rate will not necessarily benefit country A. At first glance, it looks as if a sufficiently large MCPF in country A ensures that expression (20) is positive. However, a large MCPF in country A will, as seen above, work towards a high withholding tax in that country, implying a big loss of banking business to tax haven countries and a high value of h_2 . It is useful to rewrite (20) as

$$\frac{dS_A}{dt_B} = \left(\frac{\rho_A t_A}{\beta} + \frac{\delta_A}{\beta}\right) - (h_2 - h_1) \quad (20')$$

Equation (20') reflects that an increase in country B's tax has two offsetting effects on country A's surplus. First, some investors switch from country B to country A. This is beneficial to country A, as it now can tax additional deposits, and bank profits increase. Second, depositors who remain in country B now face a higher tax with negative implications for country A's surplus. As an aside, note that some marginal depositors switch from country B to country C without any implications for country A's surplus. To see how expression (20) depends on model fundamentals, we substitute for h_2 and h_1 using (3), (7), (18), and (19) to yield

$$\begin{aligned} \frac{dS_A}{dt_B} = & [N(\gamma - \beta)\beta]^{-1} [(\rho_A - 1)(2\rho_A - 1)(\gamma - \beta)\gamma\beta \\ & - (\delta_A - \delta^*)(\rho_A - 1)(\gamma - \beta)(\gamma\rho_A + \beta(\rho_A - 1)) \\ & + \frac{\delta^*}{\rho_B}(\gamma^2[\rho_A(\rho_B - \rho_A)] + \gamma\beta[1 - \rho_B - 2\rho_A + \rho_A^2] - \beta^2[\rho_B(\rho_A - 1)])] \end{aligned} \quad (21)$$

in which

$$N \equiv 2\gamma(2\rho_A - 1) - (\gamma - \beta)(\rho_A - 1) > 0$$

It is in fact possible to sign this expression under certain circumstances. The first of the three major terms on the right hand side is always positive (or zero for $\rho_A = 1$). The sign of the second term is negative under the maintained assumption of $\gamma > \beta$ (zero for $\delta_A = \delta^*$), whereas the sign of the third term depends on the relative size of the transaction cost parameters γ and β , of the two profit parameters, and on the size of the MCPF's

in the two countries. With $\rho_A \geq \rho_B$ and $\delta_A \geq \delta^*$, the sign of the third term could well be negative. However, if the profit parameters are small enough and the MCPF's greater than unity, the right hand side of (21) will be positive, so that in this instance the welfare effect in country A of forcing country B to raise its withholding tax marginally in fact is positive. More indirectly, using (20') and the definitions of h_1 and h_2 it is easy to see that $dS_A/dt_B > 0$, provided $t_A(\gamma - \beta)(\rho_A - 1) + t_B\gamma > 0$. As a corollary, if the Nash tax rates are both positive, then the welfare effect in country A of a higher tax in country B will be positive.

We sum up these theoretical insights in the following proposition,

PROPOSITION. With γ exceeding β , with the marginal cost of public funds in either country above unity, and with low values of the profit parameters, the Nash equilibrium in withholding taxes features positive tax rates. In this case, a forced increase in the withholding tax rate on the part of country B will be beneficial to country A.

5. Some simulations with the model

In the end, we are interested in analyzing not only a marginal increase in the withholding tax in country B, but also a discrete change up to some agreed minimum withholding tax rate for both countries A and B. To do this, we present some simple numerical simulations.

We proceed as follows: on the basis of reasonable model parameters, we first compute the Nash withholding tax rates in countries A and B, the amount of cross-border deposits (of households) and borrowing (of firms), and the two countries' surplus levels. We select a handful of alternative binding minimum tax rates for country B in the interval between the Nash rates of countries B and A. Country A is either assumed to keep its withholding tax rate unchanged at the Nash level, or to respond in an optimal fashion (as given by its withholding tax reaction function) to the new value of the withholding tax in country B. We then compute the ensuing values of the surpluses in the two countries to see, whether a minimum withholding tax in country B can in fact be Pareto-improving.

In the numerical calculations the following parameter values are used: $\beta = .04$, $\gamma = .10$, $\delta_A = .002$, $\delta^* = .001$, $\rho_A = 1.5$, $\rho_B = 1.4$ and $\eta = .02$. The ensuing Nash withholding tax equilibrium, the extent of cross-border financial transactions, national surpluses, and bank profits are given in Table 1. We see that the withholding tax rates of countries A and B are .00944 and .00278, respectively. With an international interest rate of, say, $i^* = .06$, these specific tax rates correspond to ad-valorem rates of 15.7 and 4.6 percent, respectively.

The effect on country A's surplus of a marginal increase in country B's withholding tax is computed at .259 and hence is positive. Consequently, country A prefers the inside tax haven to raise its withholding tax.

Table 1 further illustrates the consequences of forcing B to increase its withholding tax by 20 pct., 40 pct., etc., until a doubling of the tax rate, with the withholding tax rate in country A constant. While the experiments obviously are harmful to country B, they unambiguously benefit A (with the values of parameters chosen). A careful weighing of the effects on national surpluses in the two countries is needed to determine whether the forced increase in the minimum withholding tax constitutes a potential Pareto improvement. A transfer of public funds from the authorities in A to the authorities in B has to be undertaken to ensure that the surplus in B does not fall. With the parameter values selected, there is certainly scope for country A to compensate country B for its forced tax increase.

Alternatively, we assume that country A optimally adjusts its withholding tax rate following country B's tax increase in accordance with (17). For the same higher values of the withholding tax in B, the simulation results are reported in Table 1. In all cases, the authorities in A are led to raise the domestic tax. This obviously raises the surplus in A relative to the previous experiments. The surplus in B also goes up (relative to the first set of experiments), as the increase in A's withholding tax limits the loss of banking business and tax revenue in country B. In fact, due to the positive slope of country A's reaction function, a small increase in B's tax with response in A's actually improves both countries' welfare. For the parameters selected, this occurs for increases in t_B of between zero and some 22 percent.¹²

Overall, the simulations suggest that for the typical EU country, an EU-wide minimum withholding tax could be rather beneficial. Conversely, any inside tax haven will be negatively affected, regardless of whether other EU countries take the opportunity to adjust their withholding tax to the higher minimum tax levels or not. As noted, the exception to this statement occurs for the case of a small forced increase in the tax haven's rate with a derived response in the typical EU country's tax. Anyhow, on the basis of our stylized model and the selected parameter values, it appears likely that the winner is able to compensate the loser.

The Nash equilibrium is depicted in Figure 5 in the lower left corner of the figure. Close to it is the Stackelberg equilibrium as calculated in the appendix. We have also drawn the efficiency locus (contract curve) consisting of all Pareto-efficient withholding tax combinations for countries A and B. This locus is found by maximizing a weighted sum of the two countries' surpluses, $\mu S_A + (1 - \mu)S_B$, with μ varying from 0 to 1. The locus is positioned

¹²If country B is forced to raise t_B about 11 percent or so, the gain in country B will be maximized, given that t_A is adjusted. In a way, this scenario replicates a Stackelberg equilibrium with country B as the leader and country A as the follower.

somewhat further up and to the right of the Nash and Stackelberg equilibria, indicating that Pareto-efficient tax combinations generally have higher withholding tax rates for both countries than the two non-cooperative equilibria. Note that there is a tendency to opt for high tax rates, when country B receives a high weight in the weighted objective function. For weights to country A lower than circa 0.29, all deposits of households in that country are made in tax havens. Hence, country B only has to worry about competition with the outside tax haven, and the only relevant tax instrument becomes t_B . On the other hand, for weights to A exceeding about 0.49 it is efficient (for the two countries together) to eliminate the tax haven status of country B, with no deposits going from A to B. Then, de facto the surplus in A is maximized, using only its own withholding tax rate t_A .

6. Discussion

Remarks on the model

The model of sections 3-5 has allowed us to come to grips with some of the key analytical aspects of the minimum withholding tax proposal. The different roles of typical EU countries, inside tax havens, and outside tax havens appear to be captured well by the model, as are the considerations governing withholding tax policy in the former two types of countries. The non-cooperative tax rates in the model are determined, in an intuitive way, by a trade off between securing public funds, on the one hand, and bank profits, as a proxy for the benefits of banking business, on the other. Moreover, numerical simulations give an idea of the magnitudes of changes in tax rates and cross-border financial transactions, if the inside tax haven were to be forced to increase its withholding tax on account of a minimum withholding tax agreement.

Of course, the model is simplified to maintain tractability. First, we have focused on two particular aspects of tax competition: (i) competition between a typical EU country and tax havens, inside or outside EU; and (ii) competition between tax havens in EU and outside of it. In some sense, typical EU countries conceivably also compete with each other, but this aspect is of lesser importance and therefore excluded from the model. Second, we have ignored private agents in the inside tax haven. In principle, withholding tax policy in that country might also be governed by a desire to raise revenue from domestic savers, or to prevent these savers from directing funds abroad. Other EU countries might attempt to attract savings from the inside tax haven country. Tax haven countries, however, tend to be rather small relative to typical large EU countries, so that these countries' savings are not a major concern for tax policy in any other country. The model's asymmetric treatment of the private sectors in the two EU countries therefore seems warranted.

Third, the model maintains a rather simple assumption as to the incidence of withhold-

ing taxes. Because of banks' unlimited access to the international inter-bank market with a fixed world rate of interest, depositors bear the full incidence of taxes in the model. In reality, the picture is more complicated, and there is evidence that a major part of the incidence may lie with debtors (see Huizinga (1994) and Eijffinger et al. (1996)).¹³

Fourth, the model contains some strong assumptions as to the tax treatment of savings. In the course of analysis we have explicitly assumed that every saver in the typical EU country who places funds abroad is in principle liable to capital income taxes at home equal to the domestic withholding tax. Only the foreign withholding tax, however, is in fact paid when the investment is allocated abroad. Furthermore, we have taken the withholding taxes to apply to all financial returns. These assumptions can be qualified to take account of crediting arrangements as they actually exist among many countries. Also, a relatively large class of international investors – institutional investors – are subject to rather different tax treatments than individual investors. Often they are (close to) exempt from home-country taxation. At the same time, there is close surveillance by domestic authorities. For portfolio diversification reasons, institutional investors wish to allocate some funds abroad, but they are loath to pay sizeable foreign withholding taxes. In addition, withholding taxes, as currently in force, are limited to simple financial transactions like bank deposits, and they are very difficult to extend to derivative financial instruments (see below). Finally, political considerations might preclude the application of withholding taxes to certain financial instruments such as government bonds and Eurobonds.

There have been few analytical studies of a minimum withholding tax in Europe. Janeba and Peters (1996), however, investigate the proposal in their model of interest taxation in two (almost) symmetrical EU countries. The two countries have Leviathan governments, and they both tax an immobile base and compete for a mobile one. Focusing on the possible non-existence of non-cooperative tax equilibria in their paper, they also stress the desirability of tax discrimination between domestic and foreign depositors (such a distinction is irrelevant in our asymmetric model). Janeba and Peters ignore any outside tax havens, though.

Evaluating the minimum withholding tax proposal

The analysis in sections 3-5 above casts a mildly positive light on the proposal to install a minimum withholding tax in the EU. Typical EU countries seem to be able to gain from it, while inside tax haven countries in most cases stand to lose. However, the former should be able to compensate the latter.

¹³In the more general model referred to in fn. 6, banks in country A (more correctly, their debtors) do bear part of the incidence of withholding taxes.

In order to advocate an EU-wide minimum withholding tax it would, though, be necessary to overcome two lines of criticism. First, some argue that such a minimum withholding tax is very difficult to enforce properly in practice. Second, others argue that the minimum withholding tax, while seemingly beneficial, is not the most appropriate solution to interest tax evasion and distortions.

The enforcement problems mainly have to do with significant exemptions from the withholding tax and with difficulties associated with applying the tax to new financial instruments. As seen in the presentation of the Commission proposal in section 2, there would likely be a series of tax exemptions. In particular, the exemption of residents from third countries (giving an impetus to 'triangular arbitrage'), and the non-application of the tax to interest from international loans (Eurobonds) can conceivably dilute the tax (see Frank (1991)).

Equally seriously, a host of new derivative financial instruments (DFIs) do not lend themselves well to withholding taxation. The tax presupposes an outgoing income payment, but for the DFIs income may materialize in other ways, or there may be a series of in- as well as outgoing payments associated with the instrument. Often a financial instrument can be imitated by a combination of other instruments. Only very carefully constructed capital gains and foreign exchange gains taxes can then ensure the necessary tax neutrality. See Alworth (1996) for an illuminating, if distressing, exposition of these problems. Alworth concludes by stating "Simplistic approaches to international capital mobility such as those calling for a uniform gross basis withholding tax at source are doomed to failure under the inevitably complex and burdensome procedures which would need to be implemented in order to guarantee a minimally correct treatment of passive income flows." (p. 23)¹⁴

As to the second line of criticism, some propose a 'reporting system' similar to the one in use in five EU countries (Denmark, the Netherlands, Spain, France and Sweden), to be extended to operate in the entire EU. The reporting system entails that domestic banks and other financial institutions automatically report to tax authorities (in Denmark partially through a central register for securities) the amount of interest that has been paid out, and to whom. If this system were to cover the entire EU, then information on all intra-EU interest payments could be recorded and exchanged between national tax authorities in EU.

As far as we know, the reporting systems function well in the above-mentioned four EU countries, ensuring a high degree of coverage in the tax system of interest earned

¹⁴At the same time, however, he acknowledges that movement toward a truly effective residence tax on individuals is not presently feasible in EU.

domestically. It is an entirely different matter, though, to introduce such a system on an EU-wide basis, since this runs counter to the bank secrecy and blocking laws prevailing in many EU countries, not the least in tax havens. It requires considerable political will to remove these administrative and legal obstacles to the automatic exchange of information on interest payments in a comprehensive reporting system. In fact, at this stage the requirement of unanimity in EU tax policy decisions suffices to prevent the reporting system from being adopted. The inside tax havens currently have very little incentive to remove any obstacles to information exchange; indeed, Bacchetta and Espinoza (1995) stress that in circumstances of asymmetry between countries there are strong disincentives to transmit information on capital income to other countries.

An EU-wide reporting system would allow member countries to continue to adhere to the residence principle in the taxation of interest. The reporting system is, therefore, strongly supported by many economists, including Frank (1991) – who, however, would like to see it coupled with a minimum withholding tax – Giovannini (1989), and others.

Mayer (1989, p. 379) goes one step further and suggests an extension of the tax credit system, in which effectively "taxes are collected at source in the overseas country and a tax credit given for overseas taxes paid. The incentive to overtax is avoided by allowing the domestic country to claim tax credits from the overseas tax authority. The overseas tax authority is then merely acting as a tax collecting agent and deriving no tax revenue. This is exactly analogous to a local office of a national tax system." Thus, withholding of taxes on interest would be coupled with transfer of the associated tax revenue to the home country of the investor. Of course, the system presupposes that the foreign tax authority not only collects taxes, but also is willing to transfer the revenue abroad in case of foreign investors; the incentives to undertake these functions would not be strong.¹⁵

Other suggestions are possible. A large part of the bank and enterprise gross capital income providing the basis for the payment of interest on deposits, company bonds etc. in principle can be taxed more directly, namely at the level of production instead of the saver. This points in the direction of the Comprehensive Business Income Tax (CBIT) (see Cnossen (1996)). The CBIT includes the remuneration of firms' debt on the same basis as remuneration of equity in the tax on business income. Instead of deducting interest on debt, firms simply also pay a tax on interest on debt; conversely, such interest would no longer be subject to tax at the personal level, so that the personal income tax on capital income becomes superfluous.

The transition to a CBIT, if chosen, would not be an easy one. Firms might legitimately

¹⁵This is also the reason why have we ignored such transfers in our model of the minimum withholding tax above.

fear that the compulsory taxation of interest on debt at the level of the firm will lead to an increase in the cost of debt finance (in that the before tax interest rate would not decline by enough). Further, opting for a CBIT is difficult in those countries where the marginal personal income tax rate applicable to interest is considerably higher than the corporate income tax rate (Cnossen (1996)). Finally, however, the potential evasion and circumvention problems associated with a CBIT would probably be mitigated, if a CBIT were adopted in the entire EU.

The main reason for considering a minimum withholding tax is the evasion of interest taxation. However, there seems to be no definitive evidence of the extent of such evasion in Europe. 'Episodic' evidence, related to the German tax experiments with "Quellensteuer" in 1991 and "Zinsabschlagsteuer" since 1993, is discussed in Janeba and Peters (1996), and Alworth (1996). Kazemier (1991) and Frank (1991) estimate figures for the evasion of interest taxation occurring in the Netherlands prior to that country's introduction of a general reporting system. And Weichenrieder (1996) gives an account of Germany's fight against avoidance of various capital income taxes. The common message of these and other studies seems to be that evasion phenomena in the area of capital income taxation are sufficiently important to constitute a major problem for tax authorities in industrialized countries.

Unfortunately, this is not the only difficulty in the area of capital income taxation these days; the predominant asymmetric treatment of debtors and creditors (often institutional investors) also reduces the revenue from such taxation. In view of these and other problems in taxing capital income, Gordon (1996) proposes to abolish the capital income tax completely. Instead, he favors installing a comprehensive labor income tax in the form of a cash flow tax on business, coupled with a personal tax on wages (and royalties etc.).

The EU has not yet taken any significant action against the evasion of interest taxation in Member States. The Commission, though, remains worried about the erosion of the more mobile tax bases stemming from tax competition between members, and from the development of a parallel economy (through the relocation of tax bases towards the black economy). Therefore, it is "looking into the question of whether a minimum rate of effective taxation throughout the Union, which should be set at a level that would not be liable to drive businesses or wealth out of the EU, would help to achieve the necessary stabilization of revenue from the different types of taxation." (European Commission (1996, press release pp. 1-2)) Accordingly, the minimum withholding tax idea may be given a new lease on life.

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Appendix: Stackelberg equilibrium in the model

As an alternative to the Nash withholding tax equilibrium we can consider a Stackelberg withholding tax equilibrium, with the typical EU country, A, as the leader and the inside tax haven, B, as the follower. This Stackelberg equilibrium is arguably just as sensible as the Nash equilibrium.

Country B's tax rate, as before, is given by the reaction function (15), given country A's tax rate. Country A sets its tax rate taking due account of how the inside tax haven responds to A's withholding tax. The surplus in country A as before is given by (16). Substituting for t_B from (15), we proceed to solve for country A's optimal tax rate, t_A , as follows

$$t_A = [\rho_B (4\rho_A (\gamma + \beta) - \gamma - 3\beta)]^{-1} [4\rho_B \gamma \beta (\rho_A - 1) - (\delta_A - \delta^*) \rho_B (2\rho_A (\gamma + \beta) + (\gamma - \beta)) - \delta^* (\gamma (2\rho_A - 1) + 2\rho_B (\beta + \gamma))] \quad (1A)$$

The qualitative properties of the optimal tax in A are as before (cfr. (19)). High values of the MCPFs in the two countries, and low values of the profit margins, point in the direction of a positive and sizeable tax, and vice versa.

Next, expressions (15) and (1A) together yield the optimal tax, t_B , for country B

$$t_B = [\rho_B (4\rho_A (\gamma + \beta) - \gamma - 3\beta) \gamma]^{-1} [2\beta \rho_B \gamma (\gamma - \beta) (\rho_A - 1) + (\delta_A - \delta^*) \rho_B (\rho_A - 1) (\gamma^2 - \beta^2) - \delta^* (\gamma^2 (3\rho_A - 1) + \rho_B (\gamma^2 - \beta^2) + \beta \gamma (\rho_A - 1))] \quad (2A)$$

Again, this equation is qualitatively similar to the Nash tax formula (18) for B. A high profit margin of banks in tax havens specifically points in the direction of a low (or negative) withholding tax in B, and vice versa.

The Nash tax formulas (18) and (19) and the Stackelberg tax formulas (1A) and (2A) are sufficiently complex to prevent any clear insight as to the relative size of tax rates in a given country in the two equilibria. We therefore present some numerical simulations performed with the same parameter values as in section 5 above, i.e. with $\beta = .04$, $\gamma = .10$, $\delta_A = .002$, $\delta^* = .001$, $\rho_A = 1.5$, $\rho_B = 1.4$, and $\eta = .02$. Table A1 gives the ensuing Stackelberg withholding tax rates, the extent of cross-border financial transactions and national surpluses in countries A and B.

The withholding taxes in both countries are seen to be somewhat higher in the Stackelberg equilibrium than in the Nash equilibrium in section 5. Further, table A1 shows the consequences for national surpluses in the two countries when B is forced to raise its withholding tax, while country A optimally responds to this. Letting country B raise its tax rate above the Stackelberg value destroys the rationale for the initial Stackelberg behavior

on the part of country A. In response, country A reverts to its Nash reaction function as given in (17). Overall, a similar pattern of welfare deterioration in the tax haven and welfare improvement in the typical EU country emerges as in section 5. Indeed, with positive slope of reaction functions and higher withholding tax rates in the Stackelberg equilibrium than in the Nash outcome, country A strictly prefers jumping back to its reaction function at an unchanged or higher withholding tax rate in country B, as compared to the Stackelberg equilibrium.

Figure 1: The destination of deposits by country A households

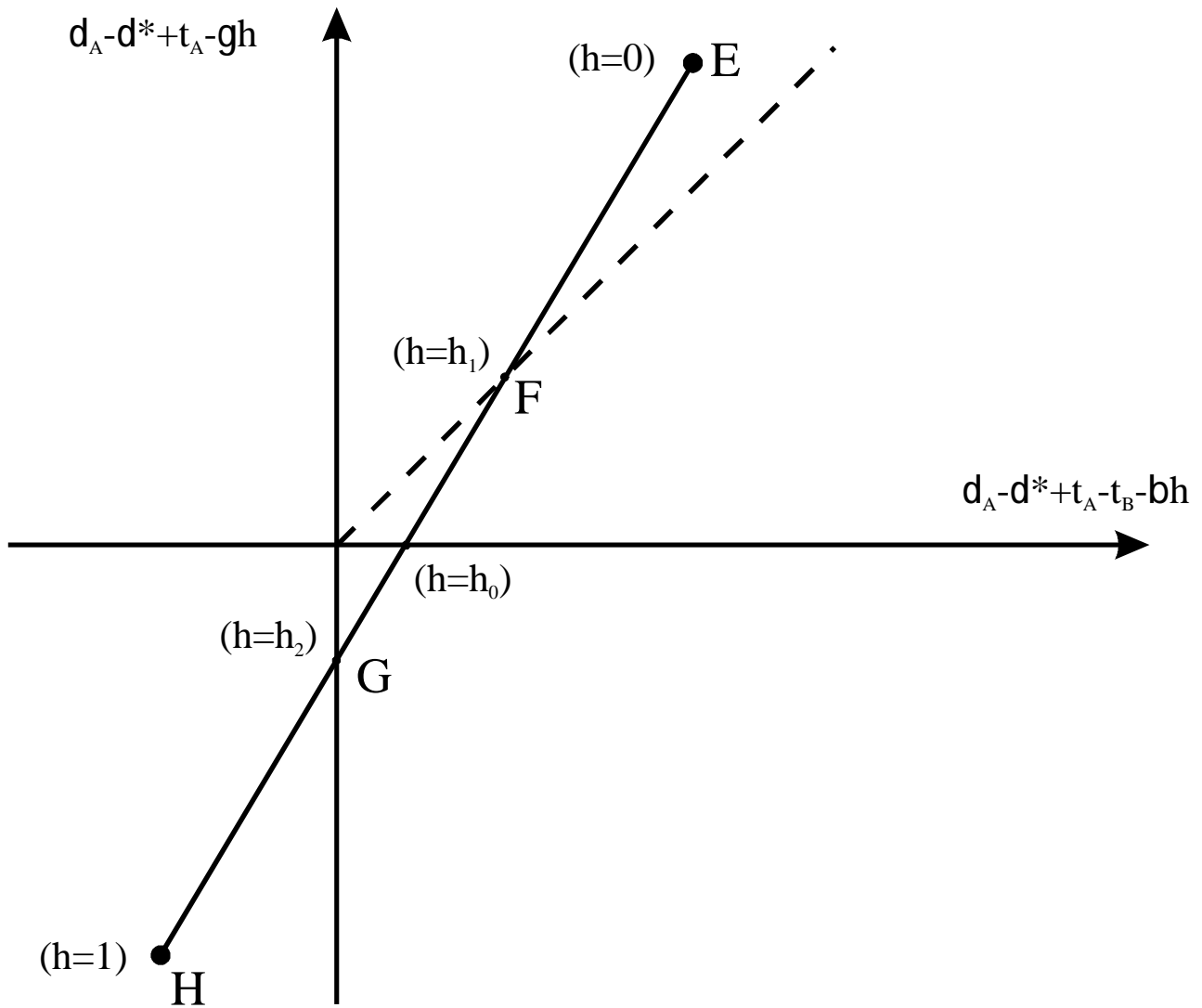


Figure 2: Net interest earnings of households and the parameter h

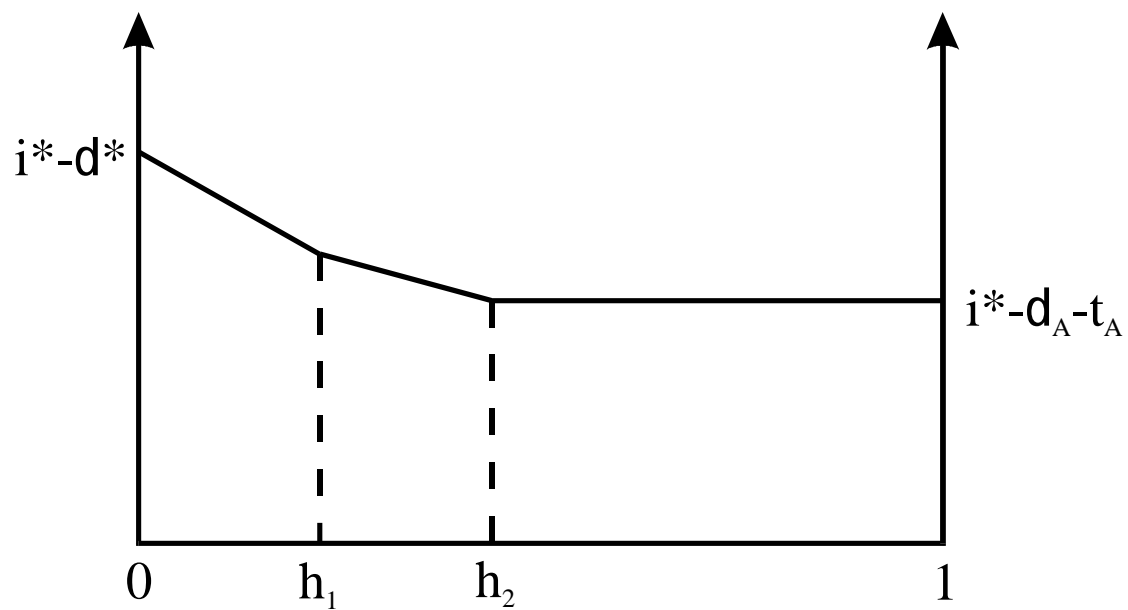


Figure 3: Total borrowing costs of firms and the parameter f

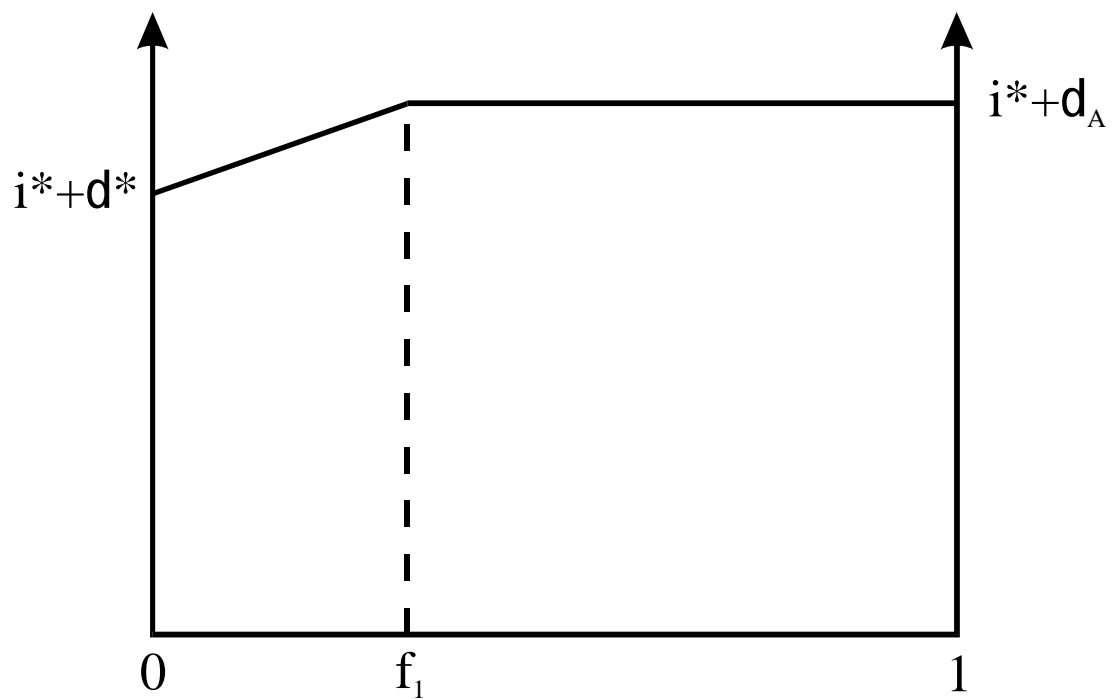


Figure 4: The Nash withholding tax equilibrium

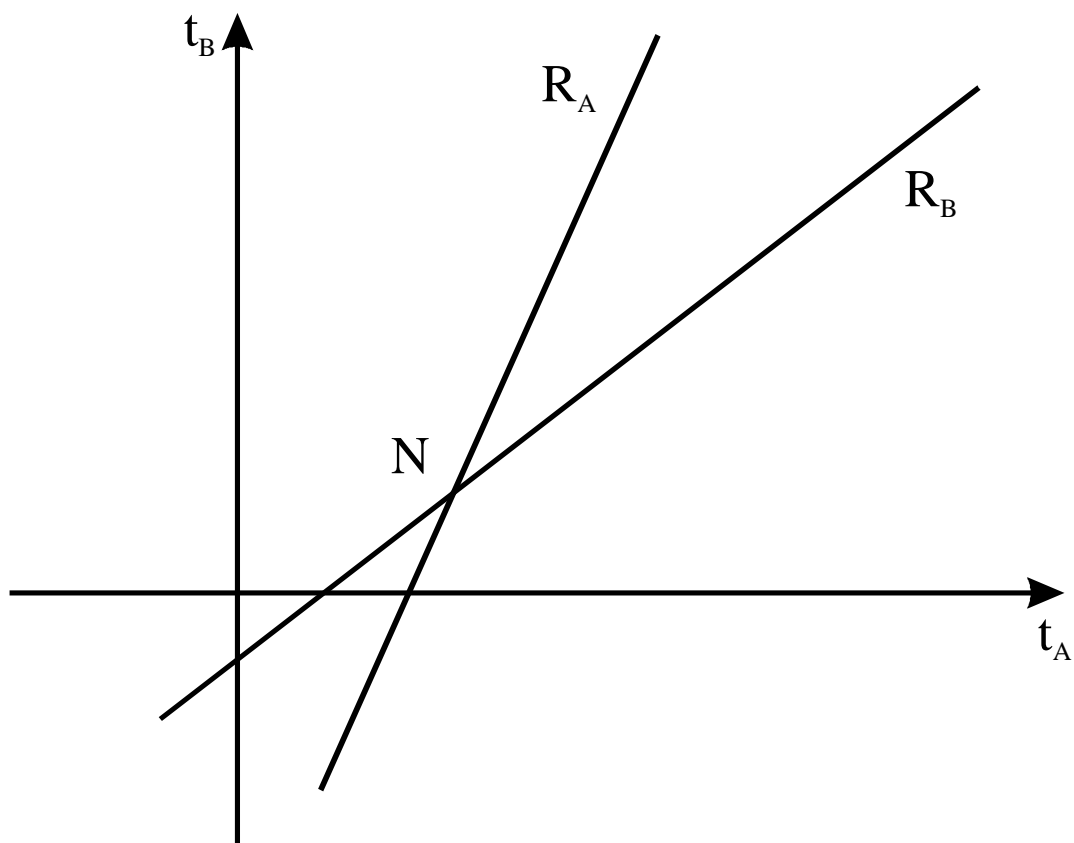


Figure 5: Non-cooperative tax equilibrium and the contract curve

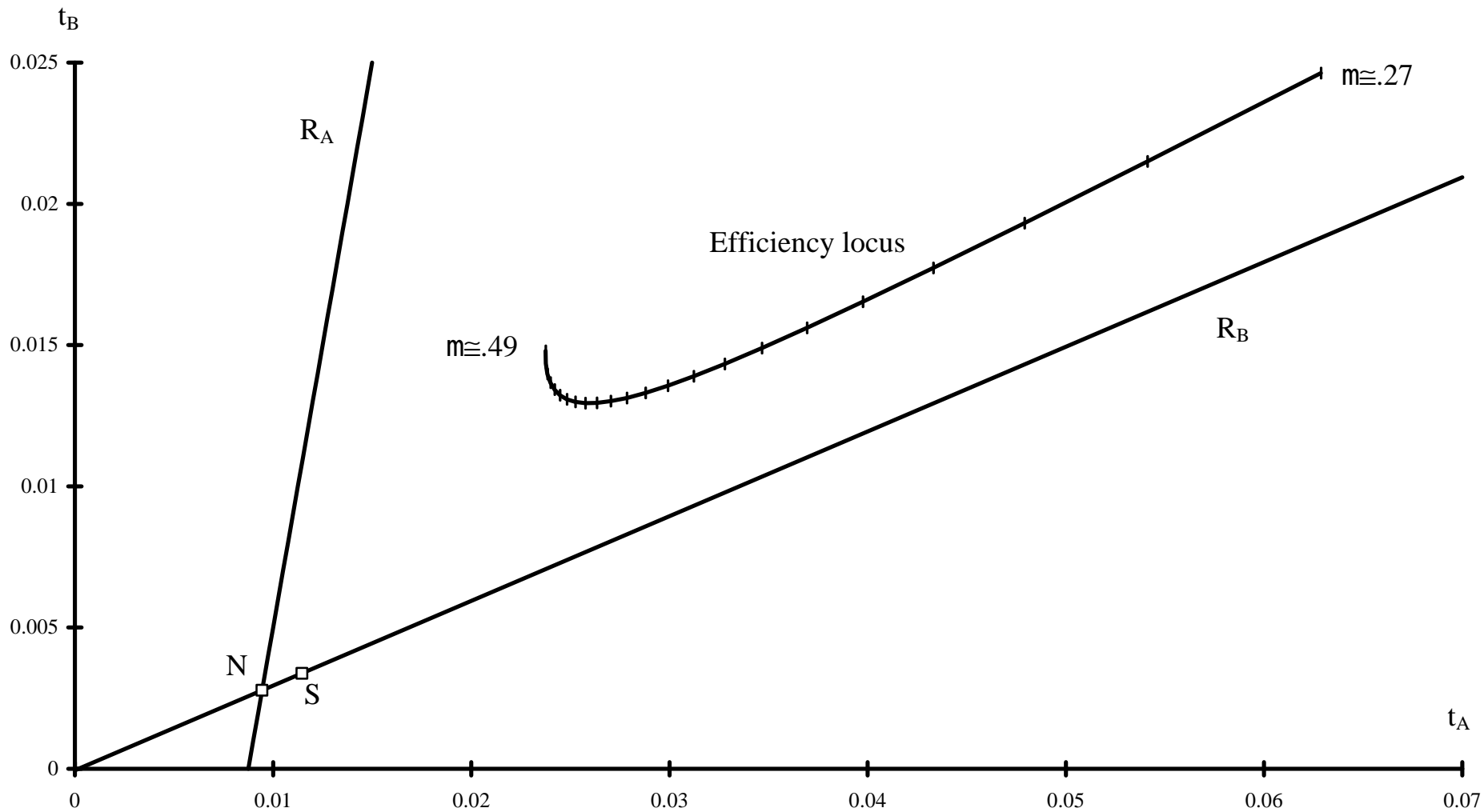


Table 1: The effects of forced increases in t_b from Nash equilibrium

	Initial Nash equilibrium	Increase in t_b with no response in t_a				Increase in t_b with reaction in t_a :			
		20%	40%	60%	80%	20%	40%	60%	80%
t_A	0.009444	0.009444	0.009444	0.009444	0.009444	0.009583	0.009722	0.009860	0.009999
t_B	0.002776	0.003331	0.003886	0.004442	0.004997	0.003331	0.003886	0.004442	0.004997
h_1	0.046268	0.055521	0.064775	0.074028	0.083282	0.055521	0.064775	0.074028	0.083282
h_2	0.191699	0.177819	0.163938	0.150058	0.136178	0.181289	0.170878	0.160468	0.150058
h_0	0.104440	0.104440	0.104440	0.104440	0.104440	0.105828	0.107216	0.108604	0.109992
f_1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
P_A	0.003517	0.003544	0.003572	0.003600	0.003628	0.003537	0.003558	0.003579	0.003600
P_B	0.000145	0.000122	0.000099	0.000076	0.000053	0.000126	0.000106	0.000086	0.000067
P_C	0.000046	0.000056	0.000065	0.000074	0.000083	0.000056	0.000065	0.000074	0.000083
S_A	0.002347	0.002497	0.002660	0.002836	0.003025	0.002498	0.002662	0.002840	0.003032
S_B	0.000711	0.000693	0.000639	0.000549	0.000423	0.000712	0.000683	0.000624	0.000534
dS_A/dt_B	0.258719	-	-	-	-	-	-	-	-

Note: $b=0.04, g=0.10, d_A=0.002, d=0.001, r_A=1.5, r_B=1.4, h=0.02$

Table A1: The effects of forced increases in t_B from Stackelberg equilibrium

	Initial Stackelberg equilibrium	Increase in t_B with reaction in t_A :			
		20%	40%	60%	80%
t_A	0.011447	0.009763	0.009932	0.010101	0.010270
t_B	0.003377	0.004052	0.004728	0.005403	0.006079
h_1	0.056283	0.067539	0.078796	0.090052	0.101309
h_2	0.226751	0.167768	0.155105	0.142441	0.129778
h_0	0.124470	0.107631	0.109319	0.111008	0.112696
f_1	0.05	0.05	0.05	0.05	0.05
P_A	0.003447	0.003564	0.003590	0.003615	0.003640
P_B	0.000170	0.000100	0.000076	0.000052	0.000028
P_C	0.000056	0.000068	0.000079	0.000090	0.000101
S_A	0.002425	0.002714	0.002937	0.003181	0.003446
S_B	0.000976	0.000669	0.000581	0.000449	0.000271
dS_A/dt_B	0.216156	-	-	-	-

Note: $b=0.04$, $g=0.1$, $d_A=0.002$, $d=0.001$, $r_A=1.5$, $r_B=1.4$, $h=0.02$