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## Bonus Taxes and International Competition for Bank Managers

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# Bonus Taxes and International Competition for Bank Managers

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## **Abstract**

This paper analyzes the competition in bonus taxation when banks compensate their managers by means of incentive pay and bankers are internationally mobile. Bonus taxes make incentive pay more costly for national banks and lead to an outflow of managers, lower effort and less risk-taking in equilibrium. The international competition in bonus taxes may feature a ‘race to the bottom’, or a ‘race to the top’, depending on whether bankers exert a positive or a negative fiscal value on their home government. The latter can arise when governments bail out banks in the case of default, and bankers take excessive risks as a result of incentive pay.

**Keywords:** Bonus taxes, international tax competition, migration

**JEL classification:** H20, H87, G28

# 1 Introduction

Bank managers' bonuses have been the cause of much debate, and resentment, in recent years. Steep incentive schemes for bank managers have been identified as one of the root causes for the global financial crisis, as bonuses are supposed to have caused excessive risk-taking in the banking sector (see e.g. DeYoung et al., 2013 or Bhagat and Bolton, 2014). First empirical evidence confirms that incentive pay has been positively correlated with risk-taking in the pre-crisis period 2003-2007 (Efung et al., 2015). In addition, bankers' bonuses play a significant role in the rising inequality of incomes in many developed countries. Bell and Van Reenen (2014) estimate, for example, that rising bonuses paid to bankers account for two-thirds of the increase in the share of the top 1% of the income distribution in the United Kingdom since 1999. For the United States, Phillippon and Reshef (2012) find that, from the mid-1990s to 2006, chief executive officers (CEOs) in the finance industry have earned a 250% premium relative to CEOs in other sectors of the economy.

In response to these developments, several countries have introduced bonus taxes. For instance, in 2009, the US House of Representatives approved a 90% withholding tax on sufficiently large bonuses for companies that held at least 5 billion in bailout money. The UK introduced a one-off 50% withholding tax on banker bonuses that exceeded GBP 25,000 and were paid between 9 December 2009 and 5 April 2010. In 2015, the Labour party is again in favor of introducing a bank bonus tax in order to finance a compulsory job guarantee for young people (Labour Party, 2015).

Given the massive side effects of bankers' bonuses and the strong public sentiment that banker bonuses are set too high<sup>1</sup> it is surprising, however, that the taxation of bankers' bonuses has not become more common, or more persistent. One critical argument for why bankers' bonuses are not taxed more is that top bankers might leave a country that taxes their bonuses severely, and work instead for a bank abroad. Indeed, there is ample evidence that bank managers are mobile across countries. The largest German bank, the Deutsche Bank, for example, has been consecutively governed by three non-

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<sup>1</sup>This sentiment is nicely captured by a comment of Barack Obama in 2009: "I did not run for office to be helping out a bunch of fat cat bankers on Wall Street. [...] They're still puzzled why is it that people are mad at the banks. Well, let's see. You guys are drawing down 10, 20 million dollar bonuses after America went through the worst economic year that it's gone through in decades, and you guys caused the problem." (Obama, 2009).

German CEOs since 2002.<sup>2</sup> More generally, there is a substantial literature indicating that the international mobility of top managers has grown substantially over the past two decades (see e.g. Van Veen and Marsmann, 2008; Greve et al., 2014). Focusing specifically on the finance industry, Greve et al. (2009) investigate the nationality of board executives in 41 large European firms in the banking and insurance industry. They find that 59% of the companies in that sector have at least one foreign-born executive and 26% of all executives in the sample are non-nationals. Similarly, Staples (2008) investigates 48 of the largest commercial banks in the world and finds that 68.8% of them have at least one non-national board member.

Despite the conclusive evidence for the international mobility of bank managers, almost all theoretical papers investigating the impact of banker bonus taxes use a closed-economy framework (see our literature review below). In this paper we want to partly fill this gap by analyzing the non-cooperative setting of bonus taxes in a two-country model with one bank in each country and mobility of bankers between the two banks. In our model governments, banks, and bank managers all behave optimally, given their incentives. The model has four stages. In the first stage, the two symmetric countries non-cooperatively set bonus taxes that maximize national welfare, which we model as the expected revenue from bonus taxation less the expected costs to taxpayers of bailing out the bank in the case of default. In the second stage, the two banks set their profit-maximizing bonuses. The bonuses set in stage 2 determine where managers choose to work in stage 3, where each manager opens up a new division in the bank for which he works. Finally, in stage 4, bank managers take simultaneous effort and risk-taking decisions in the country in which they work.

At the core of our analysis are two principal-agent problems. First, there is a principal-agent problem between a bank's shareholders and its managers. Managers have private effort costs and thus do not exert as much effort as would be optimal for shareholders. Second, there is a principal-agent problem between shareholders and the government, if shareholders anticipate that their bank is, at least sometimes, bailed out by the government. Then, shareholders want to incentivize their managers to take on "excessive" risk (relative to what would be optimal for the country as a whole), in order to

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<sup>2</sup>Josef Ackermann (Switzerland) chaired the Deutsche Bank from 2002 to 2012. From 2012 until 2015, Anshuman Jain (UK) and the German Juergen Fitschen governed the Deutsche Bank as Co-CEOs, but commentators agreed that it was Jain who took the main decisions. Since 2015, John Cryan (UK) and Juergen Fitschen are the Deutsche Bank's chief executives, but again with Cryan being perceived as the top representative.

shift losses to the government. Shareholders use bonuses to affect these two principal-agent problems. More precisely, a higher bonus increases both effort and risk-taking of all managers in the bank, and it also leads to an inflow of bank managers from abroad that increases the number of divisions and hence the size of the domestic bank. Hence the bank trades off the higher salaries associated with a higher bonus against its higher gross profits. Governments can affect this trade-off by a bonus tax, which makes bonuses a more costly instrument from the bank's perspective.

Our main result is that there can be either a 'race to the bottom' or a 'race to the top' with respect to the bonus taxes chosen in the non-cooperative tax equilibrium. This depends on the fiscal value per manager, which equals the expected bonus tax income minus the expected bailout costs for the government. If the fiscal value of a manager is positive, then bonus taxes will be set inefficiently low in equilibrium. This case arises when a low investment return is unlikely and the investment returns in different bank divisions are largely uncorrelated. In contrast, a negative fiscal value per manager implies that governments set bonus taxes higher than is globally optimal. In this case each government tries to induce bank managers to move abroad and reduce the number of divisions in the domestic banking sector. This case occurs in equilibrium when the probability of a low investment is high, and when the returns in different divisions of the bank are highly correlated.

Our analysis is related to two strands in the literature. A first strand analyzes the effects of public policies towards bonus schemes.<sup>3</sup> Besley and Ghatak (2013) analyze the optimal bonus taxation of managers when bankers can choose both effort and risk-taking. Hakenes and Schnabel (2014) study how bailout expectations affect both the optimal bonus contract offered by the bank, and the imposition of bonus caps by welfare-maximizing governments. Both of these studies analyze policies towards bonus pay in a closed economy setting. We are aware of only paper which studies bonus taxation in an open economy, Radulescu (2012). She employs a setting where a single bank is able to relocate managers between two symmetric countries. She finds that a bonus tax is harmful for the taxing country, while it may benefit the other country. Radulescu's analysis does not incorporate risk-taking decisions by bank managers, however, and bonus taxes are exogenous in her model.

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<sup>3</sup>The incentive effects of bonus schemes are themselves the subject of a large literature. See e.g. Bannier et al. (2013) for a recent analysis of bonus pay in the competition for managerial talent, and for further references.

A second relevant strand in the literature analyzes income tax competition in the presence of internationally mobile individuals. A summary of the early work in this area is given in Wilson (1999). More recently, the mobility of high income earners has been incorporated into models of non-linear income tax competition; see Lehmann et al. (2014) for a theoretical analysis and Kleven et al. (2014) for an application to high income earning immigrants in Denmark. The general prediction in these models is that international tax competition reduces tax rates in comparison to a setting where income earners are not mobile internationally. However, the mobile rich take no risks in these models, and they are always a source of positive tax revenue for the competing governments.<sup>4</sup> As we show in this paper, the direction of tax competition may change when the competition is for bank managers, who may inflict fiscal losses on their home governments through overly risky investment choices.

This paper is structured as follows. Section 2 introduces the model. The general analysis of the model follows in Section 3. Section 4 investigates and interprets the fiscal externalities of bonus taxes. Several extensions are carried in Section 5. Finally, Section 6 concludes.

## 2 The model

To analyze optimal bonus taxes when managers are mobile across countries, we set up a four-stage model with three kinds of players (countries, banks and managers). In Stage 1, there are two symmetric countries  $i \in (1, 2)$  that each set a bonus tax  $t_i$  in order to maximize their net tax revenue, which is a function of bonus tax income and bailout costs. There is one bank in each country. The size of each bank is given by the number of managers employed, which determine the number of divisions within the bank. In Stage 2, the bank in each country maximizes its expected after tax profits by choosing the size of the net bonus  $z_i$ . Stage 3 analyzes the migration decision of managers. Each manager chooses in which country to work based on the net bonus and his individual attachment to one of the two countries. Finally, in Stage 4 managers maximize their utility by choosing the level of effort and risk-taking in their division. The model is solved through backwards induction, implying that countries take into account the effects of the bonus tax on domestic bonus payments, the migration decision

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<sup>4</sup>See Sinn (1997) for a discussion of the general principles underlying tax competition in this type of models.

of managers, and the effort- and risk-taking decisions of domestic managers.

**Managers:** There is a total of  $2N$  managers in our model, which are imperfectly mobile across the two countries. All managers are employed in one of the two countries in equilibrium. Managers are risk-neutral and differ only in their individual attachment to the two countries. The managers' decisions where to work (Stage 3) and how much effort and risk to take (Stage 4) are influenced by the bonuses paid by the banks. We will show that the higher the bonus payment of a bank, the larger is the number of managers that work for this bank, and the more effort and risk these managers take.

**Banks:** There is one bank in each of the two countries  $i \in (1, 2)$ , which is run by a risk-neutral shareholder. Each bank sets the bonus  $z_i$  that maximizes its expected after-tax profits. These after-tax profits are a positive function of the *size of the bank* and of the *expected profit per division*. The *size of a bank* is determined by its number of divisions. A bank employs exactly one manager per division so that the number of managers a bank hires equals the number of its divisions.

The *expected profit per division* is determined by the division's exogenous financing structure, the endogenous investment decision and the endogenous gross bonus. Each division is financed through both equity and savings deposits. The repayment of savings deposits and the payment of interest are guaranteed by the government. Hence insured depositors face no risk and receive a risk-free fixed return of  $R$ .

Each division has a total amount of fixed assets of 1 and each of them invests in one risky portfolio with the same three exogenous returns ( $Y^h$ ,  $Y^m$  and  $Y^l$ ). The divisions execute their investments on the world market. The portfolio realizes a high return  $Y^h$  with probability  $p^h > 0$ , a medium return  $Y^m < Y^h$  with probability  $p^m > 0$  and a low return  $Y^l = 0$  with probability  $p^l = 1 - p^h - p^m > 0$ . We assume that the medium return  $Y^m$  is already sufficient for the division to fully pay back  $R$  to all its insured depositors. If, however,  $Y^l$  occurs, the division itself cannot repay the depositors. In this case, depositors can still be paid back by the bank as a whole, if other divisions make positive profits that outweigh the losses of the failed division. But it is also possible that the bank as a whole defaults and the government has to step in to repay the depositors. This is discussed in more detail in subsection 3.3.

While the portfolio returns are exogenous and observable, the corresponding probabilities are endogenously determined by the unobservable decisions of managers to exert effort  $e$  and take risk  $r$ . Specifically, we assume that the probabilities for the different

returns are linear functions of the manager's effort and risk-taking choices:

$$\begin{aligned} p^h &= \alpha e + \beta r \\ p^m &= p_0^m - r \\ p^l &= p_0^l - \alpha e + (1 - \beta)r \end{aligned} \tag{1}$$

where  $p^h + p^m + p^l = p_0^m + p_0^l \equiv 1$ . Hence a high return  $Y^h$  can only be obtained when managers either exert effort, or take risk. More generally, taking effort  $e$  shifts probability mass from  $p^l$  to  $p^h$  and therefore increases the mean return of the portfolio. Risk-taking  $r$  instead shifts probability mass from  $p^m$  to  $p^l$  and  $p^h$ , while leaving the mean return of the portfolio unaffected.<sup>5</sup>

Taking effort and risk involves private, nonmonetary costs for the manager. For analytical tractability, we assume that these cost functions are quadratic. The private effort and risk-taking costs of a manager are given by

$$c^e(e) = \eta e^2/2, \quad \text{and} \quad c^r(r) = \mu r^2/2. \tag{2}$$

These private costs, along with non-observable effort and risk-taking choices by the managers, cause moral hazard problems between the manager and the bank. Specifically, the manager will neither exert enough effort nor take enough risk from the point of view of the bank. In our model, this principal agent problem can be mitigated by the bank in country  $i$  through the bonus payment  $z_i$ , which incentivizes the manager to take more effort and risk.

**Bonus contracts:** The net bonus  $z_i$  of a bank in country  $i$  is set at the bank level and is the same for all managers of the bank. The payment of the bonus, however, depends on the realized return of a division's portfolio. More precisely, a manager receives a bonus if and only if his division's portfolio realizes a return of  $Y^h$ .<sup>6</sup> Bonuses are the only instrument of banks in our model and we will show that banks use them to increase bank size and to influence the effort and risk-taking choices of its managers.

Bonuses are taxed by the two symmetric countries  $i \in (1, 2)$  where the tax rate  $t_i$  in each country is chosen to maximize net domestic tax revenue. We define net tax revenue as the total expected bonus tax revenue minus the expected bailout costs. Hence governments use the bonus tax not only to raise tax revenue, but also to correct

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<sup>5</sup>See Hakenes and Schnabel (2014) for a similar specification.

<sup>6</sup>We can also assume that both banks in our model pay the same fixed, exogenous wage without changing the results of the paper.



managers' effort and risk-taking choices when the latter are not aligned with the government's net revenue objective. In particular, domestic banks do not fully take into account the downside of their investments because, in case the low return  $Y^l = 0$  is obtained, the bank will generally not be able to pay back all investors and therefore has to be bailed out by the government. The bonus tax then serves as an instrument to reduce the probability that a government bailout is necessary.

### 3 Analyzing the four-stage game

The analysis of our paper proceeds by backward induction. In Section 3.1, we study the managers' effort- and risk-taking choices in Stage 4. Section 3.2 analyzes the managers' migration decisions in Stage 3. Section 3.3 turns to Stage 2 and derives the banks' optimal bonus schemes. Finally, in Section 3.4 we turn to the government's non-cooperative choice of bonus taxes in Stage 1.

#### 3.1 Stage 4: Effort and risk-taking choices of managers

In Stage 4, the two countries have set their bonus taxes  $t_i$ , the two banks have set their bonus payments  $z_i$  and all managers have already decided where to work. Therefore, the attachment of managers to the countries does not matter in this stage and all managers respond in the same way to a given bonus scheme. Managers located in country  $i$  maximize the utility  $U_i$ , which is the excess of net bonus payments over the private costs of effort and risk-taking, with respect to their choice variables  $e_i$  and  $r_i$ . Using (1) and (2) gives

$$u_i = p_i^h z_i - c^e(e_i) - c^r(r_i) = (\alpha e_i + \beta r_i) z_i - \frac{\mu r_i^2}{2} - \frac{\eta e_i^2}{2}. \quad (3)$$

Maximizing (3) with respect to  $e_i$  and  $r_i$ , respectively, yields

$$e_i = \frac{\alpha z_i}{\eta}, \quad (4)$$

$$r_i = \frac{\beta z_i}{\mu}. \quad (5)$$

Hence the managers' effort level  $e_i$  depends positively on the bonus payment  $z_i$ , and negatively on the nonmonetary effort cost parameter  $\eta$ . Analogously, the risk  $r_i$  chosen

by managers in country  $i$  is increasing in the bonus payment  $z_i$  and it is falling in the risk cost parameter  $\mu$ .

Using (4) and (5) in (1), we can derive the equilibrium probabilities of the different investment returns:

$$p_i^{h*} = \alpha e_i + \beta r_i = \left[ \frac{\alpha^2}{\eta} + \frac{\beta^2}{\mu} \right] z_i \equiv \gamma z_i \quad (6)$$

$$p_i^{m*} = p_0^m - \frac{\beta}{\mu} z_i \quad (7)$$

$$p_i^{l*} = p_0^l + \left[ \frac{(1-\beta)\beta}{\mu} - \frac{\alpha^2}{\eta} \right] z_i \equiv p_0^l + \delta z_i. \quad (8)$$

In (6),  $\gamma$  is the marginal effect of the bonus payment on the probability  $p^h$ , which consists of two effects. A higher bonus leads to more effort and to more risk-taking, which both increase  $p^h$ . Similarly, in (8) the parameter  $\delta$  summarizes the marginal effect of the bonus on  $p^l$ . The sign of  $\delta$  is ambiguous, in general. On the one hand, a higher bonus leads to more risk-taking, which increases  $p^l$ . On the other hand, a higher bonus induces more effort and this reduces  $p^l$ . In what follows we will generally assume that  $\delta > 0$ , implying that the risk effect of bonuses on  $p^l$  dominates the effect on effort. Finally, the effect of the bonus on the medium return in (7) is unambiguously negative, as the bonus shifts probability mass away from the medium probability to incentivize risk-taking.

Finally, substituting (4) and (5) in (3) gives us the net utilities of managers in each country:

$$u_i^* = \left[ \frac{\alpha^2}{\eta} + \frac{\beta^2}{\mu} \right] \frac{z_i^2}{2} \equiv \frac{\gamma z_i^2}{2}. \quad (9)$$

This shows that a higher bonus in country  $i$  increases the net utility of managers working in this country.

### 3.2 Stage 3: Managers' migration decision

In Stage 3 managers take the bonuses  $z_i$  as given and choose whether to work in country 1 or 2. Managers maximize their gross utility, which consists of the consumption utility in (9) and the non-monetary attachment to the different countries. There is a total of  $2N$  managers in the economy, which are all employed in one of the two countries in equilibrium:

$$N_1 + N_2 = 2N. \quad (10)$$

Managers differ only in their country preferences. More precisely, managers are of type  $k$  where  $k$  is the relative attachment to country 1 and we assume that  $k$  is distributed uniformly along  $[-N, +N]$ . Other things equal, all managers with  $k > 0$  prefer to work in country 1, whereas managers with  $k < 0$  prefer to work in country 2.<sup>7</sup> We scale the parameter  $k$  by the constant  $a$ , where a large measure  $a$  increases the attachment to home for all managers. The parameter  $a$  can be interpreted as the cultural, institutional and geographical distances between two countries, where a large  $a$  stands for large differences.<sup>8</sup> The gross utility  $U_i$  of a manager of type  $k$  in country  $i$  is then

$$U_1(z_1, k) = u_1^*(z_1) + ak, \quad (11)$$

$$U_2(z_2) = u_2^*(z_2). \quad (12)$$

All managers choose to work in the country that gives them the higher gross utility. We denote the manager that is just indifferent between working in country 1 or in country 2 by  $\tilde{k}$ . Setting (11) equal to (12) and using (9), we derive  $\tilde{k}$  as a function of the bonus payment in the two countries:

$$\tilde{k} = \frac{\gamma}{2a}[z_2^2 - z_1^2]. \quad (13)$$

All managers with  $k \in [\tilde{k}; N]$  work in country 1 and all other managers  $[-N; \tilde{k}]$  work in country 2. Given the uniform distribution of  $k$ , we have  $N - \tilde{k}$  managers working in country 1 and  $N + \tilde{k}$  managers working in country 2. Using (13) then determines the number of managers in country  $i$  as a function of the difference in bonus payments:

$$N_i = N + \frac{\gamma}{2a}[z_i^2 - z_j^2] \quad \forall i, j, i \neq j. \quad (14)$$

The larger is the bonus of country  $i$ , relative to that of country  $j$ , the more managers will work in country  $i$  in equilibrium. Note also that strong attachments to a particular country (i.e., a large parameter  $a$ ), imply that managers responds less elastically to differences in bonus payments across countries. On the other hand, a large marginal effect of bonuses on the probability of a high return ( $\gamma$ ) increases the mobility of managers for any given level of attachment to their home country.

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<sup>7</sup>A common interpretation is that country 1 is the home country for all managers with  $k > 0$ , whereas country 2 is the home country for all managers with  $k < 0$ .

<sup>8</sup>See van Veen et al. (2014) for empirical evidence confirming this assumption. The authors show that a higher cultural, institutional and geographical distance between a manager's nationality and a company's country-of-origin makes it less likely that the manager of that nationality is employed by the company.

### 3.3 Stage 2: Banks' bonus decision

In Stage 2, we turn to the bonus decision made by the single bank in each country. The bank in country  $i$  sets the bonus  $z_i$  to maximize its expected after-tax profits (which accrue to its shareholders). While banks compete in the regional market for managers, they deliver their services in a large world market. The latter implies that the returns  $Y^h$ ,  $Y^m$  and  $Y^l$  are exogenously given from the perspective of the two banks in the region. Moreover, symmetry between the two countries and banks implies that if bonuses are the same in countries 1 and 2, so are the equilibrium probabilities in (6)–(8).

The expected after-tax profit of the bank in country  $i$  is

$$\Pi_i = N_i \pi_i^D \quad (15)$$

where the number of divisions, or managers, is given in (14) and the profit of each division is

$$\pi_i^D = p_i^{h*} [Y^h - R - z_i(1 + t_i)] + p_i^{m*} [Y^m - R] - p_i^{l*} \phi^i R. \quad (16)$$

Eq. (16) gives the profits and losses that a division causes for the bank in each portfolio state ( $h$ ,  $m$  and  $l$ ), weighted by the respective probabilities in equilibrium. If a representative division of the bank in country  $i$  realizes  $Y^h$ , it pays  $R$  to its depositors, the net bonus  $z_i$  to its manager, and the proportional bonus tax  $t_i z_i$  to country  $i$ 's government. In state  $m$ , the division receives a portfolio return of  $Y^m$  and pays back  $R$  to its depositors. Bonuses are not paid in this state. If a division's portfolio return is  $Y^l = 0$  then the division itself is unable to pay back  $R$  to its depositors. The insured depositors are then paid either by the returns of the other divisions of the bank in country  $i$ , or by country  $i$ 's government via a bailout.

We characterize the probability that other divisions of the bank in country  $i$  can offset the loss made by one of its divisions by  $\phi_i$ . For reasons of simplicity, we treat  $\phi_i \in \{0, 1\}$  as an exogenous parameter. Effectively,  $\phi_i$  measures the correlation between the investment returns of the various divisions of bank  $i$ . At one extreme,  $\phi_i = 0$  implies that the returns of the various divisions of a bank are perfectly correlated. Therefore, if one division defaults so will all the others and the bank as a whole is unable to repay its creditors. On the other hand,  $\phi_i \rightarrow 1$  implies that the bank as a whole will surely come up for the losses of a single division. This will be the case if the returns of the different divisions are uncorrelated and if the number of divisions, as well as their average profitability, is sufficiently high.

Maximizing the bank's after-tax profits with respect to the bonus  $z_i$  and using (6)–(7) gives

$$\frac{\gamma z_i}{a} \pi_i^D + N_i \left\{ \gamma [Y^h - R - z_i(1 + t_i)] - p_i^{h*}(1 + t_i) - \frac{\beta}{\mu} (Y^m - R) - \delta \phi_i R \right\} = 0. \quad (17)$$

Equation (17) shows the trade-off that a bank faces in the interior equilibrium. On the one hand, a higher bonus  $z_i$  enables the bank to attract more managers and thereby run more divisions, which increases bank profits for a given expected profit per division. On the other hand, there are several effects of the bonus on expected profits per division, which are negative in the aggregate.<sup>9</sup> An increase in the bonus raises the probability of a high investment return, but it also adds direct costs of the bonus and its taxes. Moreover the bonus reduces the probability of a medium return while increasing the likelihood of a low return when the risk-taking incentives dominate the effects of the bonus on effort ( $\delta$  is positive).

Note that in our international model with an exogenous number of managers and full employment, bonuses are set higher than they would be in a closed economy, as modeled by Hakenes and Schnabel (2014) and Besley and Ghatak (2013). In our international setting, the effect of bonuses on the number of managers is strictly positive [the positive first term in (17)], while it would be zero in autarky. The international competition for managers thus increases the marginal benefit of bonuses, other things being equal, and therefore drives up bonuses. This effect is the stronger the lower is the strength of the country preferences, as measured by the parameter  $a$ . The higher bonuses due to international competition for managers imply that, for given bonus tax rates, managers will exert both more risk and more effort than in autarky. The effect of an increase in the mobility of managers across countries (i.e. a lower  $a$ ) on the bailout probability then depend on whether the effort- or the risk-taking effect of bonuses with respect to the bailout probability dominates. We summarize these findings in the following proposition.

**Proposition 1** *For a given bonus tax, the default probability of a bank increases in the mobility of bank managers (i.e. it decreases in  $a$ ), if the risk effect of bonuses on the default probability of a branch dominates the effect of effort on the default probability of a branch (i.e. if  $\delta > 0$ ).*

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<sup>9</sup>Since the first term in (17) is positive, the second term must be negative in an interior optimum. This implies that a higher bonus payment reduces profits per division.

If bonus taxes remain constant, the recent trend of increasing manager mobility<sup>10</sup> will have an effect on the stability of the financial sector.

Using (17) for countries 1 and 2 and solving the system of two equations, Appendix 1 derives the effects of changes in the bonus tax rates of both countries on the optimal domestic bonus  $z_i$ . This leads to:

$$\frac{\partial z_i}{\partial t_i} < 0, \quad \frac{\partial z_i}{\partial t_j} < 0. \quad (18)$$

As one would expect, a higher domestic bonus tax  $t_i$  reduces the optimal bonus  $z_i$  paid by the domestic bank. This is due to the fact that taxes make bonuses more expensive. More surprisingly, a higher foreign bonus tax  $t_i$  will also reduce the optimal bonus in the home country. A rise in  $t_j$  reduces the bonuses  $z_j$  paid in the foreign country. This reduces the attractiveness of working in the foreign country  $j$  and more managers work in the domestic country  $i$  for any given bonus  $z_i$ . This implies that there are more divisions in the bank of country  $i$ . Thus, an increase in  $z_i$  now has a negative effect on profits in more divisions, whereas the beneficial effect of  $z_i$  on attracting additional divisions is unaffected. On net, therefore, bonuses also become more costly for domestic banks when the other country raises its bonus tax.

### 3.4 Stage 1: Countries' bonus tax decision

In Stage 1, governments set the bonus tax  $t_i$  that maximizes net domestic tax revenue  $W_i$ . In our model, net tax revenues are given by the expected bonus tax revenues minus expected bailout costs. Expected bonus tax revenue is collected from  $N_i$  managers in the domestic bank multiplied by the expected bonus tax revenue per manager  $p_i^h t_i z_i$ . Expected bailout costs are obtained by multiplying the number of divisions  $N_i$  of the domestic bank with the expected bailout costs per division  $p_i^l (1 - \phi_i) R$ . As the number of managers equals the number of divisions, net tax revenue is then given by

$$W_i = N_i F_i, \quad F_i \equiv [p_i^h t_i z_i - p_i^l (1 - \phi_i) R], \quad (19)$$

where  $N_i$  is given in (14) and we have introduced  $F_i$  as the net fiscal value of a manager in country  $i$ , which equals expected tax income minus the expected bailout costs per manager.

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<sup>10</sup>See Van Venn and Marsmann (2008) and Greve et al. (2014) as well as references therein.

Importantly for our analysis, the fiscal value of a manager can be positive or negative. It is positive if, in the government's tax optimum, the revenue from taxing the manager's bonus exceeds the expected bailout costs for the government when the manager's division fails. This is more likely when a high level of  $p^h$  can be induced by bonuses, when the default probability  $p^l$  is low, and when the correlation between the profitability of divisions is low ( $\phi$  is high). It is equally possible, however, that the fiscal value of a manager is negative, even when the government chooses the bonus tax optimally. In this case the expected net domestic tax revenue of the government is then also negative in the government's optimum. We assume that the government will still solve its tax optimization problem in this case, rather than shutting down the domestic banking sector entirely. Effectively we assume that there are unmodelled and fixed benefits for the economy from having a domestic sector which will make the government accept negative net tax revenues from the banking sector if conditions are unfavorable.

Maximizing net tax revenue as given in (19) with respect to  $t_i$  gives

$$\frac{\partial W_i}{\partial t_i} = N_i \left\{ z_i^2 \gamma + [2\gamma z_i t_i - \delta(1 - \phi_i)R] \frac{\partial z_i}{\partial t_i} \right\} + F_i \frac{\gamma}{a} \left( z_i \frac{\partial z_i}{\partial t_i} - z_j \frac{\partial z_j}{\partial t_i} \right) = 0. \quad (20)$$

The first term in (20) gives the change in net tax revenue for a representative division. This is composed of the positive direct effect of a tax increase and the net effect on tax revenue of the induced fall in the bonus. For  $\delta > 0$  this net effect is ambiguous as both bonus tax revenue and the expected bailout payments fall when the bonus is reduced in response to the higher tax. The second term in (20) has the same sign as  $F_i$ , since the bracketed expression in this term is always positive in a symmetric equilibrium where  $z_i = z_j$  and  $|\partial z_i / \partial t_i| > |\partial z_j / \partial t_i|$  follows from the stability of the Nash equilibrium. This net effect describes the equilibrium decrease in the number of managers working in country  $i$  when country  $i$  increases its tax rate and the bonus paid by country  $i$ 's bank falls by more than the bonus paid in country  $j$ .

If the fiscal value of a manager,  $F_i$ , is positive in (19), then the outmigration of managers caused by the tax creates a welfare loss and a negative second term in (20). In this case the first term must therefore be positive in an interior equilibrium, implying a net revenue increase per manager. In the opposite case where  $F_i < 0$ , the falling number of managers and bank divisions creates a net revenue gain for the taxing government. In this case the bonus tax must therefore reduce the net revenue obtained from each division in an interior tax optimum.

To summarize, we have analyzed a four stage game in which the bonus taxes set by

governments discourage the use of bonus payments by both banks in the region. The effect is larger in the taxing country, however, so that a higher bonus tax causes an outmigration of managers to the neighboring country. Moreover, the reduced bonus implies that managers will take less risk and reduce their effort. These behavioral adjustments reduce the expected revenue from the bonus tax, but they also reduce the expected bailout costs for the government when the risk-taking effect is sufficiently strong ( $\delta$  is positive). Therefore, in addition to raising tax revenue, a bonus tax is also able, in principle, to reduce the need for governments to bail out their resident banks.

## 4 Fiscal externalities of bonus taxes

In this section we analyze the fiscal externalities associated with bonus taxation when countries compete for internationally mobile managers. We assume an interior, symmetric equilibrium where  $\partial W_i / \partial t_i = 0 \forall i$ . Then the effect of a marginal increase in the foreign tax rate  $t_j$  on domestic welfare  $W_i$  equals the effect on total welfare in the region. Differentiating (19) with respect to the foreign tax rate and using (6) gives

$$\frac{\partial W_i}{\partial t_j} = [2t_i\gamma z_i - \delta(1 - \phi)R] N_i \frac{\partial z_i}{\partial t_j} + F_i \frac{\gamma}{\alpha} \left[ z_i \frac{\partial z_i}{\partial t_j} - z_j \frac{\partial z_j}{\partial t_j} \right]. \quad (21)$$

Equation (21) shows that there are two main externalities of bonus taxes in our model. The first term in (21) stems from the fall in the domestic bonus payment  $z_i$  that is induced by the foreign tax increase [see eq. (18)]. The falling bonus in  $i$  is associated with lower bonus tax revenues, but also with lower expected bailout cost. Hence this effect is ambiguous, in general. The second effect in (21) is driven by the migration decision of managers. The bracketed expression in this term is unambiguously positive from the stability of the symmetric Nash equilibrium [cf. our discussion of eq. (20)]. This implies that an increase in  $t_j$  raises the number of managers in country  $i$ , and hence the size of country  $i$ 's bank.

The overall sign of the second term thus hinges critically on the sign of  $F_i$ , the fiscal value of a manager. If this term is positive, a bonus tax increase in country  $j$  will benefit country  $i$  through the immigration of managers, who are net contributors to tax revenues. In this case the net fiscal externality is likely to be positive, implying that bonus taxes set in the non-cooperative equilibrium are lower than the bonus taxes that would be chosen under policy coordination. This is the conventional case of a ‘race-to-the-bottom’ in the setting of bonus taxes. From (19) this scenario will be the more



likely, the lower is the exogenous probability of a low return [see eq. (8)], which causes losses to a typical division, and the lower is the correlation between the investment returns of different divisions (the higher is  $\phi$ ).

Conversely, if the expected bailout costs for governments dominate the expected revenue from a bonus tax so that  $F_i < 0$ , then the second effect in (21) is negative. In this case non-cooperatively set bonus taxes are likely to be higher than those in the coordinated equilibrium and there is thus a ‘race to the top’ in bonus taxation. Intuitively, managers are unwanted by governments in this case, as their risk-taking decisions increase the probability of failure in the division, and in the the entire bank and this effect dominates the revenue potential from bonus taxation. Hence driving managers to the other country by means of a high bonus tax is an attractive policy option in this setting. This case is more likely, if a low investment return is likely ( $p_0^l$  is large), and if the correlation between the returns of different divisions is high ( $\phi$  is low).

In Appendix 2 we show that  $F_i < 0$  is indeed a sufficient condition for the net externality of bonus taxation to be negative, when each country’s first-order condition for the optimal tax rate [eq. (20)] is met with equality. We summarize these results in:

**Proposition 2** *When non-coordinated bonus taxation leads to a symmetric, interior tax equilibrium, the following holds:*

(i) *A positive fiscal value of a manager ( $F_i > 0$ ) is a necessary, but not a sufficient condition for a ‘race to the bottom’ in bonus taxation. This case is more likely when probability of a low investment return is low and the investment returns in different divisions are largely uncorrelated.*

(ii) *A negative fiscal value of a manager ( $F_i < 0$ ) is a sufficient, but not a necessary condition for a ‘race to the top’ in bonus taxation. This case is more likely when the probability of a low investment return is high and the investment returns in different divisions are highly correlated.*

Proposition 2 shows that the direction of the fiscal externalities caused by bonus taxation in the presence of internationally mobile managers is ambiguous a priori. The ambiguity arises from the fact that managers may take excessive risks and thus represent a potential source of revenue losses to the country in which they operate. In this case each country tries to discourage bank managers from working in their jurisdiction by setting a high bonus tax rate. This in turn prevents the bank in country  $i$  from offering large bonuses to its managers.

## 5 Extending the government's objective

In this section we extend the governments' welfare functions. In section 5.1 we introduce domestic bank profits into the welfare functions of governments. Section 5.2 then analyzes the fiscal externalities when the two symmetric countries internalize a share of each other's bailout costs.

### 5.1 Bank profits

So far the welfare functions have only included bonus tax revenue and bailout costs. In this section the governments additionally take into account a share  $\Delta$  of the domestic bank profits  $\Pi_i$ .

$$\hat{W}_i = \left[ N + \frac{\gamma}{2a}(z_i^2 - z_j^2) \right] [p_i^{h*} t_i z_i - p_i^{l*} (1 - \phi_i) R] + \Delta N_i \pi_i^D \equiv N_i F_i + \Delta \Pi_i. \quad (22)$$

The share  $\Delta$  can represent different factors. Most directly, we can assume that the government takes into account the income that domestic capital owners derive from the profits of the domestic banking sector. In this interpretation,  $\Delta$  jointly reflects the share of the domestic banking sector that is owned by domestic residents, and the relative valuation of profit income in the government's objective. Alternatively, we can assume that the government levies profit taxes on the domestic banking sector; in this case  $\Delta$  is simply the exogenously given profit tax rate. In order to investigate fiscal externalities, we derive the extended welfare function with respect to the foreign bonus tax. Using the envelope theorem from the bank's first-order condition for the optimal bonus  $z_i$  [eq. (17)], we get

$$\frac{\partial \hat{W}_i}{\partial t_j} = [F_i + \pi_i^D N_i] \frac{\partial N_i}{\partial t_j} + N_i [2\gamma t_i z_i - \rho(1 - \phi) R \rho] \frac{\partial z_i}{\partial t_j}. \quad (23)$$

The marginal effect of  $\Delta$  on  $\frac{\partial \hat{W}_i}{\partial t_j}$  is thus simply

$$\frac{d \frac{\partial \hat{W}_i}{\partial t_j}}{d \Delta} = \pi_i^D N_i \frac{\partial N_i}{\partial t_j}. \quad (24)$$

Equation (24) shows that the higher is the share of domestic bank profits that are internalized by the domestic government, the stronger is the race to the bottom. This is because the domestic government does not internalize the effect of the domestic bonus tax on the foreign bank profits through the number of managers working abroad. This negative externality is larger (in absolute terms), the more the foreign government values the profits of its banking sector (i.e. the higher is  $\Delta$ ).

## 5.2 Joint liability of bailout costs

Another relevant extension of our benchmark model is to incorporate joint liability in a union of countries for the probability of individual bank failures. In the Euro area, such a scheme is the so-called ‘Single Resolution Mechanism’ within the EU’s banking union.<sup>11</sup> In a first-best setting, such a scheme would collect a levy from all banks within the Euro area that is sufficient to fully finance the expected costs of all bank failures. The contribution of each national banking sector would thus be proportional to its size. Let  $\tau$  be the rate of this bank levy, which is set at the supranational level. Then  $\tau\pi_i^D N_i = p_i^l(1 - \phi)RN_i$  is the condition for the fund to finance the bailout costs in expected value terms in each country, demonstrating that the required level of  $\tau$  is independent of the equilibrium size of the banking sector. Using this budget balance condition to substitute out for the expected bailout costs, the objective function of each country’s government becomes

$$\hat{W}_i = N_i [p_i^h t_i z_i + \Delta(1 - \tau)\pi_i^D]. \quad (25)$$

It is immediately seen from (25) that the bailout term, which has given rise to negative externalities in our previous analysis, is now subsumed in the net expected bank profits, which are always positive. Therefore, the fiscal value of a manager,  $F_i$ , will now always be positive, and Proposition 2(i) will always hold in equilibrium. Effectively, taxpayers in each country are fully insured against the failure of an individual bank in their country through the EU-wide bailout mechanism. The competition for mobile managers will thus lead to a ‘race to the bottom’ in bonus taxes, if the sufficient condition holds.

In reality, however, it is not very likely that the European banking sector will indeed pay ex ante for the full costs of individual bank failures. The EU resolution fund will be built up only gradually and with a moderate target volume of 1% of the covered deposits of banks in member states (around 55 billion Euro, based on the volume of deposits in 2010). If national experiences are any guide, the actual accumulation of funds can be expected to proceed even slower.<sup>12</sup> We thus consider the opposite

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<sup>11</sup>See [http://ec.europa.eu/finance/general-policy/banking-union/index\\_en.htm](http://ec.europa.eu/finance/general-policy/banking-union/index_en.htm)

<sup>12</sup>Several countries, such as Germany, have built up special funds financed by compulsory bank levies, in order to make the banking sector participate in the costs of bank restructuring. The size of these insurance funds remained small, however. In Germany, for example, the volume of this ‘restructuring fund’ was only around 2 billion Euro in 2015 after four years of collecting bank levies, far below its target value. From 2016 onwards, these national restructuring funds will be transferred to the EU-wide resolution fund.

extreme to the case studied above and assume that, while the costs of bank failures are collectivized, it is exclusively taxpayers who come up for the losses. We thus revert to a government objective function that includes only the governments' net tax revenues. Taking  $\rho \in (0.5, 1)$  to be the share that taxpayers in country  $i$  pay for the expected losses of bank failures in country  $i$ , whereas  $(1 - \rho)$  is the share of losses paid by the taxpayers of country  $j$ , joint liability of bailout costs implies

$$\begin{aligned} \tilde{W}_i &= N_i [T_i - \rho B_i] - (1 - \rho) N_j B_j \quad \forall i \neq j, \\ \text{with } T_i &\equiv p_i^{h*} t_i z_i, \quad B_i \equiv p_i^{l*} (1 - \phi_i) R, \end{aligned} \quad (26)$$

where  $T_i$  is the tax revenue per manager and  $B_i$  is the bailout cost per manager in country  $i$ .

We analyze the fiscal externalities associated with bonus taxation in this setting. We again assume an interior, symmetric equilibrium where  $\partial \tilde{W}_i / \partial t_i = 0 \forall i$ . Then the effect of a marginal increase in the tax rate  $t_j$  on welfare in country  $i$  equals the effect on total welfare in the region. Differentiating (26) with respect to  $t_j$  gives

$$\frac{\partial \tilde{W}_i}{\partial t_j} = \frac{\partial N_i}{\partial t_j} [T_i - \rho B_i] + N_i \frac{\partial [T_i - \rho B_i]}{\partial t_j} - (1 - \rho) B_j \frac{\partial N_j}{\partial t_j} - N_j (1 - \rho) \frac{\partial B_j}{\partial t_j}. \quad (27)$$

In order to see how the fiscal externalities change with respect to the collectivization of bailout costs, we differentiate (27) with respect to  $\rho$ . This gives, after summarizing terms

$$\frac{d \frac{\partial \tilde{W}_i}{\partial t_j}}{d \rho} = -2 p_i^l (1 - \phi_i) R \frac{\partial N_i}{\partial t_j} - N_i \delta (1 - \phi_i) R \left[ \frac{\partial z_i}{\partial t_j} - \frac{\partial z_j}{\partial t_j} \right]. \quad (28)$$

The first term in (28) is always negative. This implies that if the collectivization of bailout costs increases (i.e.  $\rho$  decreases), the negative externality that arises from shifting the bailout costs via manager migration abroad is reduced. The second term in (28) is also negative when  $\delta > 0$ . This effect arises because the increase in  $t_j$  reduces the bonus in both countries, thus reducing risk taking and hence the expected losses from the banking sector. Since the reduction in the bonus is stronger in country  $j$  (the term in squared brackets is positive), a higher degree of sharing in the bailout costs (a fall in  $\rho$ ) will further reduce the negative externality that arises from risk-shifting. In sum, the effects in (28) are thus unambiguously negative, implying that a higher degree of joint liability in the bailout costs (a reduction in  $\rho$ ) will unambiguously increase the value of the net externality  $\partial \tilde{W}_i / \partial t_j$  and thus make a 'race to the bottom' more likely. We summarize our results in this section in:

**Proposition 3** *A ‘race to the bottom’ in bonus taxes becomes more likely, if*

- (i) domestic bank profits receive a higher weight in the welfare function of governments ( $\Delta$  is increased), or if*
- (ii) bailout costs are more strongly collectivized between countries ( $\rho$  falls).*

Proposition 3 has straightforward policy implications. If countries set up a common bailout scheme for failing banks then tax competition for mobile managers is more likely to lead to a mutual undercutting of bonus taxes. The setting of a lower bound on bonus taxes then becomes more likely to be a desirable complementary coordination measure. Similarly, a minimum rate of bonus taxation is more likely to be an optimal coordination measure when bank profits are high, and countries value these profits (or taxes thereon) highly.

## 6 Conclusion

In this paper we have incorporated international mobility of bank managers into a principal-agent model of manager compensation. In such a setting non-cooperative levels of bonus taxes can generally be above or below the level that would be optimal under policy coordination. Therefore there can be a ‘race to the bottom’ or a ‘race to the top’ in bonus taxes. The latter scenario can arise because bank managers operating in one country inflict (expected) losses on the taxpayers of the jurisdiction in which they work, and these may exceed the tax revenues from the taxation of their bonuses. In such a setting bank managers have a negative ‘fiscal value’ for governments, which may therefore set bonus taxes above the coordinated level in order to reduce the size of their national banking sector.

The possibility of a ‘race to the top’ on bonus taxation is reduced in a banking union where the costs of failure of an individual bank are collectivized at a supranational level. If the banking sector in a union of countries collectively pays for the entire expected costs of individual bank failures, then the competition for mobile managers will always lead to a ‘race to the bottom’ in bonus taxation. In this case, a coordinated minimum level of bonus taxes is thus a desirable complementary policy measure. The results are somewhat less clear-cut, but go in a similar direction when we assume, perhaps more realistically, that bailout costs are collectivized but the costs are at least partly borne by taxpayers in the different countries.

# Appendix 1

We define  $H_i$  as follows:

$$H_i \equiv \frac{\pi_i^D \gamma z_i}{a} + N_i(z_i, z_j) \left\{ \frac{\partial p_i^h}{\partial z} [Y^h - R - z_i(1 + t_i)] - p_i^{h*}(1 + t_i) + \right. \quad (\text{A.1}) \\ \left. + \frac{\partial p_i^m}{\partial z} (Y^m - R) - \delta \phi_i R \right\} = 0$$

This corresponds to a set of equations ( $H_i, H_j$ ) with  $t_i$  as an exogenous shifter.

$$H_i(z_i, z_j, t_i) = 0, \quad H_j(z_i, z_j, 0) = 0, \quad (\text{A.2})$$

where  $z_i$  and  $z_j$  are the endogenous variables in Stage 2.

Totally differentiating and employing matrix notation we get

$$\underbrace{\begin{bmatrix} \frac{\partial H_i}{\partial z_i} & \frac{\partial H_i}{\partial z_j} \\ \frac{\partial H_j}{\partial z_i} & \frac{\partial H_j}{\partial z_j} \end{bmatrix}}_A \underbrace{\begin{bmatrix} dz_i \\ dz_j \end{bmatrix}}_X = \underbrace{\begin{bmatrix} -(\frac{\partial H_i}{\partial t_i}) dt_i \\ 0 \end{bmatrix}}_b \quad (\text{A.3})$$

Solving for  $\frac{dz_i}{dt_i}$  and  $\frac{dz_j}{dt_i}$  gives

$$\frac{dz_i}{dt_i} = \frac{1}{|A|} \begin{bmatrix} \frac{\partial H_i}{\partial t_i} & \frac{\partial H_i}{\partial z_j} \\ 0 & \frac{\partial H_j}{\partial z_j} \end{bmatrix} = -\frac{1}{|A|} \frac{\partial H_j}{\partial z_j} \frac{\partial H_i}{\partial t_i} \quad (\text{A.4})$$

$$\frac{dz_j}{dt_i} = \frac{1}{|A|} \begin{bmatrix} \frac{\partial H_i}{\partial z_i} & -\frac{\partial H_i}{\partial t_i} \\ \frac{\partial H_j}{\partial z_i} & 0 \end{bmatrix} = \frac{1}{|A|} \frac{\partial H_j}{\partial z_i} \frac{\partial H_i}{\partial t_i} \quad (\text{A.5})$$

Replacing  $\pi_i^D$  and  $N_i$  in (A.2) we get

$$H_i = \left\{ p_i^{h*} [Y^h - R - z_i(1 + t_i)] + p_i^{m*} [Y^m - R] + p_i^{l*} [-R\phi^i] \right\} \frac{1}{a} \gamma z_i + \\ + \left\{ N + \frac{\gamma}{2a} [(z_i)^2 - (z_j)^2] \right\} \\ \left\{ \frac{\partial p_i^h}{\partial z} [Y^h - R - z_i(1 + t_i)] - p_i^{h*}(1 + t_i) + \frac{\partial p_i^m}{\partial z} (Y^m - R) - \delta \phi_i R \right\} = 0 \quad (\text{A.6})$$

Assuming that the second-order condition for an optimal choice of  $z_i$  holds, we have

$$\frac{\partial H_i}{\partial z_i} < 0 \quad (\text{A.7})$$

From (A.6), we obtain the following two equations:

$$\frac{\partial H_i}{\partial z_j} = \frac{-\gamma}{a} z_j \frac{\partial \pi_i^D}{\partial z_i} > 0 \quad (\text{A.8})$$

$$\frac{\partial H_i}{\partial t_i} = -p_i^{h^*} z_i \frac{\gamma}{a} z_i < 0 \quad (\text{A.9})$$

Using (A.7), (A.8) and (A.9), we can thus sign  $\frac{dz_i}{dt_i}$  and  $\frac{dz_j}{dt_i}$ .

$$\frac{dz_i}{dt_i} = - \underbrace{\frac{1}{|A|}}_+ \underbrace{\frac{\partial H_j}{\partial z_j}}_+ \underbrace{\frac{\partial H_i}{\partial t_i}}_- < 0 \quad (\text{A.10})$$

$$\frac{dz_j}{dt_i} = \underbrace{\frac{1}{|A|}}_+ \underbrace{\frac{\partial H_j}{\partial z_i}}_+ \underbrace{\frac{\partial H_i}{\partial t_i}}_- < 0 \quad (\text{A.11})$$

This shows that a rise in  $t_i$  makes the use of bonuses in both countries  $i$  and  $j$  more costly and therefore lower bonuses are used in the optimum.

## Appendix 2

Rearranging the countries' first-order condition for the optimal bonus tax (20), multiplying through by  $(\partial z_i / \partial t_j) / (\partial z_i / \partial t_i)$  and using symmetry gives

$$[2\gamma z_i t_i - \delta(1 - \phi_i)R] N_i \frac{\partial z_i}{\partial t_j} = -N_i z_i^2 \gamma \frac{\partial z_i / \partial t_j}{\partial z_i / \partial t_i} - F_i \frac{\gamma z_i}{a} \left(1 - \frac{\partial z_i / \partial t_j}{\partial z_i / \partial t_i}\right). \quad (\text{A.12})$$

Substituting (A.12) in (21) gives, after cancelling terms

$$\frac{\partial W_i}{\partial t_j} = F_i \frac{\gamma z_i}{a} \frac{\partial z_i}{\partial t_j} \left( \frac{\partial z_i / \partial t_j}{\partial z_i / \partial t_i} - \frac{\partial z_i / \partial t_i}{\partial z_i / \partial t_j} \right) - N_i z_i^2 \gamma \frac{\partial z_i / \partial t_j}{\partial z_i / \partial t_i}. \quad (\text{A.13})$$

Since  $dz_i/dt_i$  and  $dz_i/dt_j$  are both negative and since  $|dz_i/dt_i| > |dz_i/dt_j|$  follows from the stability of the Nash equilibrium, the first term in (A.13) has the same sign as  $F_i$ , whereas the second term in (A.13) is always negative. Hence  $F_i < 0$  is a sufficient condition for  $dW_i/dt_j < 0$ , as stated in Proposition 1.

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