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Discussion Paper No. 318

February 14, 2022

Collaborative Research Center Transregio 190 | www.rationality-and-competition.de
Ludwig-Maximilians-Universität München | Humboldt-Universität zu Berlin
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Taxing mobile and overconfident top earners*

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Revised version, February 2022

Abstract

We set up a simple model of tax competition for mobile, highly-skilled and overconfident managers. Firms endogenously choose the compensation scheme for managers, which consists of a fixed wage and a bonus payment in the high state. Managers are overconfident about the probability of the high state and hence of receiving the bonus, whereas firms and governments are not. When governments maximize tax revenues, we show that overconfidence unambiguously reduces the bonus tax rate that governments set in the non-cooperative tax equilibrium, while increasing tax revenues. When the government objective incorporates the welfare of resident managers, however, bonus taxes also serve a corrective role and may rise in equilibrium when overconfidence is increased.

Keywords: Overconfidence, bonus taxes, tax competition, migration
JEL classification: H20, H87, G28

*We are grateful to the editor, Ron Davies, and three referees for their constructive and detailed comments. This paper was presented at the Belgian-Japanese Public Finance Workshop in Louvain-la-Neuve and at the 2020 online conference of the IIPF. We thank David Agrawal, Traviss Cassidy, Daniel Gietl, Bernhard Kassner, Mohammed Mardan and Pierre Pestieau for helpful comment and Susanna Hassinen for excellent research assistance. For financial support we thank the German Research Foundation through CRC TRR 190 (Haufler) and MEXT/JSPS KAKENHI JP18H00866 (Nishimura). The paper was started when Yukihiro Nishimura visited the University of Munich. He wishes to thank the members of CES for their hospitality.

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1 Introduction

During the last decades, top income earners have been able to increase their share in total national income in most countries.[1] An important contributor to this increased income concentration is the prevalence of bonus payments and other forms of incentive pay. For example, Bell and Van Reenen (2014) show that the top percentile of income earners in the United Kingdom received 35% of their total pay as bonus income in 2008, and the bonus share was even 44% in the financial sector. Similarly, Lemieux et al. (2009) find for the United States that performance pay accounts for most of the increase in wage inequality above the 80th percentile during the period 1976-1998.[2]

At the same time, top income tax rates have been reduced in many countries. Egger et al. (2019) have shown for the OECD countries that income tax systems have become less progressive since the mid-1990s. They explain this development with the increasing international mobility of high income earners. Moreover, several countries specifically try to attract international top earners by means of tax cuts that are only available to foreign residents (Kleven et al., 2020). There is a substantial literature indicating that the international mobility of top managers has grown substantially over the past two decades (e.g. Staples, 2007; Greve et al., 2015).[3] Theoretical work has shown that the international mobility of top income earners reduces the optimal progressivity of income tax schedules in the countries competing for the high-skilled, mobile population (Simula and Trannoy, 2010; Lehmann et al., 2014). These effects are confirmed in empirical studies demonstrating that foreign residents respond to tax incentives with an elasticity that is far larger than the response of domestic residents (Kleven et al., 2013; Kleven et al., 2014; Akcigit et al., 2016).

In this paper we introduce overconfidence as a behavioral trait of mobile top earners and ask how this affects the tax competition for them. Specifically we focus on overestima-

[1]See Atkinson et al. (2011) for an international comparison and Piketty et al. (2018) for a detailed study of income distribution in the United States, based on national accounts data.

[2]More generally, Bryson et al. (2012, Figures 1 and 2) show that the share of private sector employees with an incentive pay contract has risen substantially over time in most OECD countries, and is highest in the Scandinavian countries (around 30%) and in the U.S. (over 40%).

[3]Staples (2007) investigates 70 of the world's largest transnational corporations and finds that the percentage of firms with at least one non-national board member rose from 36% in 1993 to 75% in 2005. Greve et al. (2015) show that the internationalization of management boards is positively associated with the globalization strategies of firms.

tion as the most common form of overconfidence.[4] The psychology literature has shown that many individuals overestimate their own abilities and talents, as well as the probabilities of advantageous events (Taylor and Brown, 1988). This behavioral pattern is particularly pronounced among high-income individuals, who have experienced success in their previous career and attribute this success largely, or even exclusively, to their own abilities (Gervais and Odean, 2001). Empirical research has convincingly shown that company CEOs and top managers exhibit systematic and persistent patterns of overconfident behavior.[5] Thus Malmendier and Tate (2005) show that overconfident CEOs make excessive investments when their liquidity is high, and Malmendier and Tate (2008) show that overconfident CEOs engage in value-destroying mergers. Ho et al. (2016) demonstrate that banks with overconfident CEOs weakened lending standards prior to the 2007-2009 financial crisis, and performed worse in the crisis. Finally, Humphery-Jenner et al. (2016) show empirically that firms 'exploit' this overconfidence by adjusting their compensation structure and increasing the share of incentive pay.

There are some well-known examples of top income earners that are both internationally mobile and overconfident. Perhaps the most obvious case is Elon Musk, a South African native who migrated to the United States. As the current CEO of Tesla, a large share of his wealth is invested in Tesla stock, a clear signal of overconfident beliefs in his firm (cf. footnote 5). Another example is Josef Ackermann, a Swiss national who chaired the Deutsche Bank from 2002-2012 and in 2003 famously declared a 25% rate of return to equity as his target. A third example is Masayoshi Son, the Korean-born CEO of the Japanese SoftBank, who bought the US real estate company We-Work for USD 47 billion in 2019, and revised its value to USD 2.9 billion just one year later.[6] More generally, the psychology literature has shown that migration decisions are empirically linked to personality traits such as openness and extraversion (Jokela, 2009;

[4]Moore and Healy (2008) distinguish three notions of overconfidence: overestimation, overplacement (relating to comparisons with others) and overprecision. While overprecision relates to the margin of error in stochastic decisions, overestimation relates to the probability with which (typically positive) outcomes occur.

[5]In these studies, the dominant approach to empirically identify managerial overconfidence is the failure of top managers to diversify their personal investment portfolio. Specifically, managers are classified as 'overconfident' when they do not sell stock options in their own firm that are "in the money" (Malmendier and Tate, 2005).

[6]See https://www.cnbc.com/2020/05/18/softbank-ceo-calls-wework-investment-foolish-valuation-falls-to-2point9-billion.html

Canache et al., 2013).[7] Just these personality traits have in turn been shown to be positively associated with overconfidence (Schaefer et al., 2004; Dessi and Zhao, 2018).

Against this background, the present paper studies tax competition for managers that are both mobile and overconfident. We cast our analysis in a framework where managers hold an incentive contract and receive a compensation that consists of both a fixed wage and a bonus in case of success. Governments levy a bonus tax, but this tax can also be seen more generally as a higher tax rate (or surtax) on top incomes.[8] In our benchmark model we assume that governments maximize tax revenues and use the receipts from bonus taxation for redistributive purposes. In this setting we analyze how overconfidence of top managers affects both the compensation structure of the firms employing them, and the bonus tax rate that governments competing for the mobile high-skilled levy in the non-cooperative tax equilibrium.

Our first main finding is that overconfidence increases the share of the bonus component in total manager compensation, relative to the fixed wage rate. This higher prevalence of bonuses makes the ex-post distribution of incomes more unequal and it increases the tax base for the bonus tax. Nevertheless, we find that higher levels of overconfidence *reduce* revenue-maximizing bonus tax rates in the symmetric Nash equilibrium.

The intuition for this result is that overconfident managers overestimate the likelihood that they will receive the bonus, and hence pay the bonus tax. This increases their migration elasticity, and rational governments have to factor in this behavioral response. Since the true likelihood that the bonus is paid and the bonus tax is indeed collected is lower than anticipated by managers, overconfidence makes the bonus tax a less attractive instrument from the perspective of governments. Hence, in addition to the international mobility of top earners, their overconfidence may also contribute to explaining both the increased reliance of firms on bonuses and other forms of incentive pay, and the fall in top income tax rates faced by highly skilled migrants.

The falling tax rate on bonus incomes does not imply, however, that overconfidence is detrimental for the government's tax revenue collections. In fact, our second main

[7] The important role of personality traits is also mirrored in the economics literature. Borjas et al. (2018) find, using Danish data, that more than half of the difference between the expected earnings of migrants and non-migrants is due to differences in unobserved characteristics ('personality').

[8] Many countries incorporate bonuses in the tax base for the general income tax. The United States is an exception as it taxes bonuses as 'supplementary income' under a separate tax schedule. This schedule has fewer tax brackets than the general income tax schedule, but the top tax rates are aligned.

result shows that managerial overconfidence raises bonus tax revenues in equilibrium, despite the falling bonus tax rate. This is because overconfidence shifts the manager's compensation towards the taxed bonus component of his pay, and this increase in the bonus tax base dominates the effects of a lower tax rate. In fact, governments can "exploit" the overconfidence of managers in equilibrium, in the sense that the rewards to the overly high effort caused by the manager's overconfidence partly accrue to the government as tax revenue.

We then consider two modifications of our benchmark model. First, we assume that governments incorporate the utility of resident managers in their objective function, in addition to tax revenues. This gives the bonus tax a corrective component, as governments use bonus taxes to limit the managers' excessive work effort that follows from the misperceived success probability. Therefore, equilibrium tax rates may now be rising in the managers' overconfidence level, if this corrective component is sufficiently strong.

In a second extension, we show that our results for revenue-maximizing governments are robust to introducing a two-tier income tax where the fixed wage income is taxed at a positive rate and bonus income is subject to an additional tax – or, alternatively, to a higher marginal tax rate. In this setting it remains true that, whenever the extra tax on bonus income is positive in equilibrium, it is reduced by overconfidence, and tax progressivity accordingly falls.

Our paper contributes to the literature on the optimal taxation of mobile high-income individuals (Hamilton and Pestieau, 2005; Simula and Trannoy, 2010; Bierbrauer et al., 2013; Lehmann et al., 2014; Blumkin et al., 2015; Lipatov and Weichenrieder, 2015; Wilson, 2015). Most of this literature considers non-linear income taxation and focuses on marginal migration costs as a determinant of optimal marginal tax rates.[9] This literature shows that marginal tax rates generally fall as a consequence of international mobility, and that marginal tax rates on top earners may even become negative. We simplify the tax schedule by focusing on (piecewise) linear income taxation and show that adding overly optimistic beliefs will increase the elasticity with which high-income migrants respond to taxation, and hence further reduce optimal tax rates.

We also contribute to the recent literature on optimal income taxation with behavioral agents (Bernheim and Taubinsky, 2018; Farhi and Gabaix, 2020; Moore and Slemrod,

[9]The empirical literature on tax-induced mobility confirms that high-income earners respond to higher taxes by relocating to other regions or countries (Schmidheiny and Slotwinski, 2018; Agrawal and Foremny, 2019).

2021). Much of this literature focuses on issues of tax salience and individual misperceptions of tax schedules. One exception is Gerritsen (2016), who derives optimal corrective tax policies when heterogeneous individuals work too much or too little. By incorporating overconfidence, we introduce individual misperceptions of their own *abilities*, which is a major theme in behavioral finance (Malmendier and Tate, 2015). Moreover we take the behavioral public economics literature to an international setting where countries compete in attracting mobile and overconfident managers.[10]

Our analysis of bonus payments and their taxation draws on the framework of Besley and Ghatak (2013). Gietl and Haufler (2018) have extended this setting to analyze international competition in bonus taxes when governments bail out failing banks. Gietl and Kassner (2020) introduce overconfidence, but analyze bonus taxation in a closed economy. In this paper, we use a simpler framework without default risks and governments bailouts, which is therefore not specific to the banking sector. We combine, however, the international mobility of managers with their overconfidence.

In the following, Section 2 describes our model, analyzing in turn the effort and migration decisions of high-skilled managers and the firm's choice of the managerial compensation structure. Section 3 addresses international competition in bonus taxes when governments maximize tax revenues. Section 4 analyzes the case where governments maximize national welfare, including managers' utility. Section 5 extends the analysis of revenue maximizing governments by considering a two-tier income tax in which all incomes are taxed at a positive, exogenous rate and an endogenous surcharge is levied on bonus income. Section 6 concludes.

2 The model

2.1 The basic setup

We structure our analysis as a sequential four-stage game. In the first stage, governments non-cooperatively choose their bonus taxes, anticipating the responses of both firms and their managers to these taxes. In the second stage, firms choose their profit-maximizing remuneration scheme, consisting of a fixed wage and a bonus payment, and

[10] See Kotakorpi (2009) for one of the few existing analyses of tax competition in a framework with non-rational agents. Her focus is very different from ours, however, and analyzes Pigouvian taxation in a setting where consumers have self-control problems.

taking as given the bonus taxes that governments have set in the first stage. In the third stage, managers decide in which country to work, on the basis of the remuneration schemes offered to them by firms, as well as the taxes levied by their potential country of residence. Finally, in the fourth stage, managers choose their level of effort provision in the country (and hence firm) of their choice. We thus model a strict hierarchy of decisions where optimizing governments behave as first movers towards firms, whereas firms behave as first movers vis-à-vis managers.

The framework of our analysis is a region of two symmetric open economies $i \in \{1, 2\}$, which are small in the world market. In each of the two countries, there is a representative firm of variable size, where firm size corresponds to the number of identical divisions within the firm. Running a division requires the specific knowledge of a firm manager, which is the limiting resource in our model. Each firm employs exactly one manager per division and the number of managers a firm hires equals the number of its divisions. Hence each firm tries to attract internationally mobile managers in order to increase the number of its divisions, and hence profits.

Each division of a firm in country i has a total amount of fixed assets equal to one, which is lent in the world market. Lending operations are risky. We assume that there are two possible returns for each of the identical divisions of a firm, which can be high (h) or low (l). The division realizes a high return Y^h with probability $p^h > 0$ and a low return $Y^l < Y^h$ with probability $p^l = 1 - p^h$. Even the low return Y^l is sufficient for the firm to pay all its obligations, and to avoid default. Returns are fixed from the firm's perspective, as outputs are sold in a large world market. Hence, the representative firms in both countries produce with constant returns to scale.

We employ a standard principal-agent problem between the firms' shareholders and their managers. Managers have private effort costs and thus choose lower effort than would be optimal from the perspective of shareholders. Bonuses thus serve as a second-best instrument for the firm to solve this principal-agent problem.[11]

In each country i, managers choose an effort level e_i and all managers behave in identical ways with respect to their effort choice. We assume that the probability that the firm

[11] There is an active discussion of whether existing incentive contracts are compatible with modern shareholder value theories (Edmans and Gabaix, 2016), or reflect "rent extraction" by CEOs (Piketty et al., 2014). Our discussion restricts attention to the productivity enhancing effects of incentive contracts.

receives the high return Y^h is a linear function of each manager's effort level:[12]

$$p_i^h = \beta e_i, \qquad p_i^l = 1 - \beta e_i, \qquad \beta, p_i^h, p_i^l > 0. \tag{1}$$

In our model, firm managers overestimate their skills and thus overestimate the return to their effort. We denote parameters as perceived by an overconfident manager with a hat ($\hat{}$). The probabilities of the high and the low state, as perceived by managers, are then given by

$$\hat{p}_i^h = (1+\theta)\beta e_i, \qquad \hat{p}_i^l = 1 - (1+\theta)\beta e_i. \tag{2}$$

The parameter $\theta > 0$ in eq. (2) measures the degree of managers' overconfidence. Overconfidence thus leads each manager to overestimate the likelihood of the high state, $\hat{p}^h > p^h$, and hence to overestimate the expected reward to his effort. We confine the level of overconfidence to the range $0 \leq \theta < 1$.[13] In the following, changes in θ will be at the heart of our analysis of how overconfidence affects the firms' compensation schemes for their managers, as well as the governments' optimal bonus taxes.

2.2 Managers' effort choice

We proceed by backward induction to obtain the subgame perfect Nash equilibrium. In Stage 4, risk-neutral managers choose their effort levels. For analytical tractability, we assume that the cost of effort provision is quadratic and given by $c(e) = \eta e^2/2$. Due to these private costs, managers will not exert enough effort from the point of view of firm owners. Effort decisions are not observable. However, firm owners can mitigate the principal agent problem by a bonus payment z_i in the high return state, which occurs with a higher probability $p^h(e)$ when the manager's effort level e is increased.

Managers located in country i maximize their *perceived* location-specific utility $\hat{u}_i$, which is the excess of expected bonus payments and the fixed wage w_i over the private costs of effort.[14] Using (2) gives

$$\hat{u}_i = \hat{p}_i{}^h z_i + w_i - c(e_i) = (1+\theta)\beta e_i z_i + w_i - \frac{\eta e_i^2}{2}. \tag{3}$$

[12] Since managers are identical, manager-specific indices are omitted from all variables.

[13] The upper bound placed on θ is needed to ensure that the firms' optimal bonus choice is well-defined; see Section 2.4 below. The constraint that $\hat{p}^h < 1$ must hold in (2) will then be met by placing an upper bound on the parameter β.

[14] The perceived utility is also labelled *decision utility* in the behavioral economics literature. In contrast, the utility evaluated at the true success probability p_i^h is known as *experience utility* (e.g. Farhi and Gabaix, 2020).

Maximizing (3) with respect to the managers' choice variable e_i yields

$$e_i = \frac{(1+\theta)\beta z_i}{\eta} \,. \tag{4}$$

Hence each manager's effort level e_i increases in the bonus payment z_i and in his level of overconfidence θ. The latter occurs because an overconfident manager overestimates the likelihood that the high state will occur, and hence the expected return to his effort. In contrast, the fixed wage w_i does not affect managers' optimal effort.

Substituting the managers' effort decision (4) into (1), we can derive the *true* equilibrium probabilities of the states h and l:

$$p_i^{h*} = \beta e_i = (1+\theta)\left[\frac{\beta^2}{\eta}\right] z_i \equiv (1+\theta)\gamma z_i, \tag{5a}$$

$$p_i^{l*} = 1 - \beta e_i = 1 - (1+\theta)\gamma z_i. \tag{5b}$$

In eq. (5a), we have introduced the parameter $\gamma > 0$ to summarize the marginal effect of the bonus payment on the probability of a high return. This effect is multiplied by the overconfidence factor $(1+\theta)$. Therefore, the *true* success probability is rising in the overconfidence of managers, because of the higher effort level that is induced by the bonus when managers overestimate their return to effort.

The managers' *perceived* success probability is then $\hat{p}_i^h = (1+\theta)p_i^{h*} = (1+\theta)^2\gamma z_i$. Substituting this along with (4) and (5a) into (3) gives the location-specific *perceived* utility of a manager working in country i. This perceived utility is increased by both a higher bonus and a higher fixed wage:

$$\hat{u}_i^* = (1+\theta)^2 \frac{\gamma z_i^2}{2} + w_i. \tag{6}$$

Again, an overconfident manager ($\theta > 0$) overvalues the influence of the bonus payment z_i on his utility in country i, as he overestimates his success probability.

2.3 Managers' migration decision

In Stage 3 managers take the bonuses z_i and fixed wages w_i as given and choose whether to work in country 1 or in country 2. Managers maximize their gross utility, which consists of the location-specific utility in (6), and the non-monetary attachment to a particular country. We normalize the total number of managers in the region to 2.

All managers are employed in one of the two countries. Hence $N_1 + N_2 = 2$, where N_i is the (continuously divisible) number of managers working in country i in equilibrium.

Managers differ in their country preferences. More precisely, managers are of type m, where m is the relative attachment to country 1 and we assume that m is distributed uniformly along $[-1, +1]$. Other things equal, all managers with $m > 0$ prefer to work in country 1, whereas managers with $m < 0$ prefer to work in country 2.

The utility weight of the location preference parameter m is given by the constant $a > 0$. The gross utility U_i of a manager of type m in country i is then

$$U_1(z_1, w_1, m) = \hat{u}_1^*(z_1, w_1) + am, \qquad U_2(z_2, w_2) = \hat{u}_2^*(z_2, w_2). \tag{7}$$

All managers choose to work in the country that gives them the higher gross utility. We characterize the manager that is just indifferent between working in country 1 or in country 2 by the critical location preference m^c. Equating U_1 and U_2 in (7) and using (6), we derive m^c as a function of differences in bonus payments and fixed wages between the two countries:

$$m^c = \frac{1}{a}\left[\frac{\gamma}{2}(1+\theta)^2(z_2^2 - z_1^2) + (w_2 - w_1)\right]. \tag{8}$$

Managers with $m \in [m^c, 1]$ work in country 1 and managers with $m \in [-1, m^c]$ work in country 2. Using (8) then determines the number of managers in country i as a function of the differences in bonus payments and wages:

$$N_i = 1 + \frac{1}{a}\left[\frac{\gamma}{2}(1+\theta)^2(z_i^2 - z_j^2) + (w_i - w_j)\right] \qquad \forall\, i, j \in \{1, 2\},\ i \neq j. \tag{9}$$

The larger is the bonus of country i, relative to that of country j, the more managers will work in country i in equilibrium. The same holds for the fixed wage. As managers value the bonus payment z_i in each country by their *perceived* probability of the high state $\hat{p}^h$, the effect of bonuses (z_1, z_2) on the location decision of managers is increased by managers' overconfidence, whereas the effect of the fixed wage is not.

2.4 Firms' compensation choices

In Stage 2, we turn to the remuneration decisions made by the owners of the representative, scalable firm in each country. The representative firm in country i sets the bonus $z_i \geq 0$ and the fixed wage $w_i \geq 0$ to maximize its expected after-tax profits. Both bonuses and fixed wage payments are constrained to be non-negative. Since all divisions are equal, total profits Π_i are obtained by multiplying the profits of a representative division, π_i^D, with the number of divisions, which equals the number of managers N_i. Firms assess their expected division profits using the true probabilities of the high and the low state (p_i^{h*}, p_i^{l*}). The bonus is paid only in state h, and its gross costs to the firm are increased by the bonus tax t_i. Therefore, total after-tax expected profits are

$$\Pi_i = N_i \pi_i^D = N_i \left\{ p_i^{h*}[Y^h - z_i(1+t_i)] + p_i^{l*} Y^l - w_i \right\}. \tag{10}$$

The firm maximizes its profits in (10) with respect to the bonus z_i, taking account of the managers' migration decision (9) and their equilibrium effort levels, which determine probabilities by (5a)–(5b). This gives

$$\frac{\partial \Pi_i}{\partial z_i} = (1+\theta)^2 \frac{\gamma z_i}{a} \, \pi_i^D + N_i (1+\theta)\gamma \left[(Y^h - Y^l) - 2z_i(1+t_i) \right] = 0. \tag{11}$$

The first effect in eq. (11) gives the effect of the bonus on the number of firm divisions. This effect is unambiguously positive. As we discussed in (9) above, it incorporates the managers' migration decision that is based on their *perceived* success probability $\hat{p}^{h*} = (1+\theta)^2 \gamma z_i$. The second effect in eq. (11), which describes the marginal effect of the bonus on the profits of a representative division, must therefore be negative in the firm's optimum. For this second effect, the *true* success probability $p^{h*} = (1+\theta)\gamma z_i$ is relevant, as this determines the probability with which the bonus is actually paid.

Maximizing firm profits in (10) with respect to the fixed wage gives

$$\frac{\partial \Pi_i}{\partial w_i} = \frac{\pi_i^D}{a} - N_i \leq 0 \quad \forall\, i. \tag{12}$$

The first-order condition (12) holds with equality, if and only if the fixed wage is positive in the firm's optimum; otherwise the fixed wage is zero. In line with existing manager compensation schemes, we assume that $w_i > 0$ holds in the firm's optimum. This implies $\pi_i^D / a = N_i$. Substituting this into (11) we can simplify the first-order condition for the optimal bonus payment. The optimal bonus can then be expressed as:[15]

$$z_i^* = \frac{\Omega}{1 - \theta + 2t_i} \quad \forall\, i, \qquad \Omega \equiv Y^h - Y^l. \tag{13}$$

[15] To ensure positive bonuses, the denominator in eq. (13) must be positive. This will be guaranteed if $\theta < 1$ and $t_i \geq 0$. This is the reason for placing an upper bound on θ (cf. footnote 13). The second-order condition for the firm's optimization problem with respect to z_i and w_i will also hold if $\theta < 1$. The proof is available from the authors upon request.

Hence the equilibrium bonus is rising in the output gap between the high and the low state, Ω, and it is falling in the bonus tax rate t_i. Moreover, for a given tax rate t_i, the bonus payment is unambiguously increasing in the managers' degree of overconfidence θ. Intuitively, since managers overestimate the probability of the good state h, they also overestimate the probability of receiving the bonus. This makes the bonus an attractive form of compensation from the perspective of the firm, which holds rational expectations about the likelihood of the high state.[16]

In Appendix A.1, we use equations (12) and (13) for both countries to derive the optimal fixed wage, as a function of both countries' tax rates. This is given by

$$w_i^* = Y^l - a + \frac{\gamma(1+\theta)\Omega^2}{6}\left[\frac{1}{(1+2t_j-\theta)} + \frac{4t_i - 5\theta - 1}{(1+2t_i-\theta)^2}\right]. \tag{14}$$

The second term in (14) shows that an increase in manager mobility (a decrease in a) increases the fixed wage. In contrast, the parameter a does not appear in the optimal bonus equation (13). This shows that the fixed wage is the firms' marginal instrument to attract mobile workers in our analysis, whereas the bonus payment is used to incentivize effort. The overall effects of the overconfidence parameter θ on the fixed wage will be analyzed once we have solved for the equilibrium bonus tax rate t_i.

3 Bonus tax competition with revenue maximizing governments

3.1 Cooperative tax setting

We now turn to the effects that the mobility of overconfident managers has on tax competition between the two symmetric countries. In this section we assume that governments aim to maximize tax revenues R_i. This assumption corresponds to maximizing the transfer to the local resident population, and hence local welfare, while assuming that governments do not include footloose managers in their welfare objective. Revenue maximization is also an attractive government objective for reasons of analytical tractability, and it allows us to derive closed-form solutions for optimal tax rates under both coordinated and non-coordinated tax setting.

[16] Humphery-Jenner et al. (2016) provide empirical evidence for this effect by showing that firms 'exploit' overconfident CEOs and other executives by tailoring their compensation structure towards incentive pay.

Like firms, governments form an unbiased expectation about the probabilities of the different states. Hence they maximize:

$$R_i = t_i p_i^{h*} z_i N_i \quad \forall \quad i \in \{1, 2\}. \tag{15}$$

We first study the efficient benchmark case when countries coordinate their tax policies. In our symmetric model this corresponds to joint-revenue maximization $R_i + R_j = t_i p_i^{h*} z_i N_i + t_j p_j^{h*} z_j N_j$. The optimal coordinated tax rate is then implicitly defined by

$$\frac{\partial(R_i + R_j)}{\partial t_i} = p_i^{h*} z_i N_i + t_i \frac{\partial(p_i^{h*} z_i)}{\partial t_i} N_i + t_i p_i^{h*} z_i \frac{\partial N_i}{\partial t_i} + t_j p_j^{h*} z_j \frac{\partial N_j}{\partial t_i} = 0. \tag{16}$$

Since the total number of managers in our model is fixed, $N_i + N_j = 2$, symmetry implies that the last two terms on the left-hand side of (16) sum to zero. Using (5a) and (13) and noting that p_j^{h*} and z_j do not depend on t_i the first-order condition for the cooperative, revenue-maximizing tax rate (superscripts C, R) simplifies to

$$\frac{\partial(R_i + R_j)}{\partial t_i} = z_i^2 \gamma (1 + \theta) N_i \left\{ 1 - \frac{4t_i}{1 - \theta + 2t_i} \right\} = 0 \quad \Longrightarrow \quad t_i^{C,R} = \frac{1}{2}(1 - \theta). \tag{17}$$

Eq. (17) yields a very simple expression for the coordinated tax rate, which is falling in the degree of overconfidence. Intuitively, overconfident managers overestimate the likelihood of receiving a bonus, and hence they also overestimate the negative effect of the bonus tax on their utility. This reduces the optimal coordinated tax, relative to a setting where managers behave fully rationally.

Substituting (5a), (13), and the cooperative tax rate from (17) into the revenue expression (15) yields

$$R_i^{C,R} = \frac{(1 + \theta)\gamma \Omega^2}{8(1 - \theta)}, \tag{18}$$

which is unambiguously rising in θ. Higher overconfidence of managers increases both their effort and the bonus payment as an incentive device. Together, these increases in the bonus tax base more than compensate for the lower bonus tax rate so that coordinated tax revenue increases in the overconfidence level θ.

3.2 Non-cooperative tax setting

We now turn to the non-coordinated tax equilibrium where each country chooses its optimal bonus taxes t_i in isolation. In the first step, we determine the response of the equilibrium number of managers in country i when this country raises its bonus tax. Differentiating (9) with respect to t_i and taking account of (13) and (14) leads to

$$\frac{\partial N_i}{\partial t_i} = \frac{1}{a}\left[\frac{\gamma(1+\theta)^2}{2}\frac{\partial(z_i^2)}{\partial t_i} + \frac{\partial w_i}{\partial t_i} - \frac{\partial w_j}{\partial t_i}\right] = \frac{-\gamma(1+\theta)\Omega^2}{3a(1-\theta+2t_i)^2} < 0. \tag{19}$$

From (19) we see that the outflow of managers in response to a higher bonus tax unambiguously rises in the managers' overconfidence level θ. This is because the managers' migration decision is based on their overly high expectation of receiving the bonus, combined with their correct anticipation that the tax will reduce the bonus payment.

In the second step we maximize tax revenue in (15) with respect to t_i, using the migration response (19), along with the effects of the tax on the success probability p_i^{h*} in (5a) and on the bonus payment z_i in (13). This gives

$$\frac{\partial R_i}{\partial t_i} = \frac{z_i^2\gamma(1+\theta)}{a}\left[aN_i\left\{1 - \frac{4t_i}{1-\theta+2t_i}\right\} - \frac{t_i\gamma(1+\theta)\Omega^2}{3(1-\theta+2t_i)^2}\right]. \tag{20}$$

In eq. (20), the first term in the squared bracket gives the change in tax revenues for a given number of managers. This term is in turn composed of the mechanical effect of a tax increase at an unchanged tax base, and the fall in the expected tax base induced by the higher bonus tax (resulting from both the lower bonus payment and the reduced success probability of the project). The negative second term in the squared bracket gives the loss in the tax base that results from the outmigration of managers in response to the tax.

Evaluated at $t_i = 0$, the derivative $\partial R_i/\partial t_i$ is positive in eq. (20). Also, continuity of $R_i(t_i, t_j)$ is guaranteed in our setting because all the relevant functions are continuous in t_i and t_j. Finally, Appendix A.2 derives the second-order condition for the governments' optimal choice of bonus taxes, and shows that this is fulfilled. Hence, a Nash equilibrium with positive bonus tax rates in both countries must exist in our model.

In the following, we focus on a symmetric Nash equilibrium. Setting (20) equal to zero at $t_i = t_j$, which in turn implies $N_i = 1$, yields a quadratic equation in t. Solving gives an explicit expression for the non-cooperative, revenue maximizing tax rate in both countries (superscripts N, R):

$$t_i^{N,R} = -\frac{\gamma\,\Omega^2\,(1+\theta)}{24a} + \sqrt{\left(\frac{\gamma\Omega^2\,(1+\theta)}{24a}\right)^2 + \frac{1}{4}\,(1-\theta)^2} > 0. \tag{21}$$

Comparing the non-cooperative tax rate in (21) to the cooperative tax rate in (17) yields $t_i^{N,R} < t^{C,R}$. Hence, as in models with mobile, but fully rational individuals

(Lehmann et al., 2014; Lipatov and Weichenrieder, 2015), the competition for mobile managers reduces optimal bonus tax rates below their cooperative levels. In turn, the lower non-cooperative tax than under cooperation leads to higher bonus payments and lower fixed wages.

It is also straightforward to establish that a higher degree of international mobility (a lower attachment-to-home parameter a) reduces the non-cooperative bonus tax rates in equilibrium:

$$\frac{\partial t_i^{N,R}}{\partial a} = \frac{\gamma\,\Omega^2\,(1+\theta)}{24a^2}\left[1 - \frac{\gamma\,\Omega^2\,(1+\theta)}{24a}\left(\sqrt{\left(\frac{\gamma\Omega^2\,(1+\theta)}{24a}\right)^2 + \frac{1}{4}\,(1-\theta)^2}\right)^{-1}\right] > 0. \tag{22}$$

This result is in line with the literature on the optimal taxation of mobile individuals that face relocation costs (e.g. Simula and Trannoy, 2010).

The simple structure of (21) further allows us to unambiguously sign the derivative of the Nash equilibrium tax rate with respect to the overconfidence parameter θ:

$$\frac{\partial t_i^{N,R}}{\partial \theta} = \frac{1}{24a}\left(-\Omega^2\gamma + \frac{\gamma^2\Omega^4(1+\theta) - 144(1-\theta)a^2}{\sqrt{\gamma^2\Omega^4(1+\theta)^2 + 144(1-\theta)^2 a^2}}\right) < 0. \tag{23}$$

Equation (23) shows that overconfidence of mobile managers reduces the optimal tax rate that both governments choose in the Nash equilibrium. Note that this result occurs even though the bonus tax base is increasing in the overconfidence level θ for any given tax rate t_i [eq. (13)]. However, this effect is overcompensated by a twofold increase in the elasticity with which the bonus tax base responds to taxation. First, even in the absence of manager migration, firm's bonus payments respond more elastically to the bonus tax when θ increases. This is seen from the positive first effect in the squared bracket of the first-order condition (20), whose negative component is rising in θ. Moreover, a higher level of overconfidence leads to a larger migration response of managers to the bonus tax rate, as is seen from the negative second effect in the squared bracket of (20).

Intuitively, the negative effect of overconfidence on the governments' optimal bonus tax rate arises because revenue-maximizing governments have to incorporate the higher migration elasticity with which overconfident managers respond to the bonus tax. At the same time, a rational government will calculate the expected bonus tax revenue only on the basis of the true success probability. Therefore, a higher overconfidence level raises the *elasticity* of the bonus tax base more quickly than it raises the bonus tax base itself. This makes the bonus tax a less attractive instrument from the government's perspective.

Given that the optimal bonus tax rate is falling in the overconfidence level θ, we can now determine how the firms' compensation schemes for managers change as a result of overconfidence. Inserting this result in the bonus payment (13) shows that the positive direct effect that an increase in θ has on the equilibrium bonus payment z_i increases further due to the indirect effect that results from the reduced bonus tax rate. Therefore, equilibrium bonus payments unambiguously increase when managers become more overconfident.

Next we derive the equilibrium change in the fixed wage payment of firms that results from overconfidence. Evaluating the fixed wage expression (14) at the common Nash equilibrium tax rate $t_i^{N,R} = t_j^{N,R}$ in (21) and differentiating gives

$$\frac{\partial w_i^*}{\partial \theta} = \gamma \Omega^2 \frac{(2t_i - 3\theta - 1)}{(1 + 2t_i - \theta)^3} \left[1 + t_i - (1+\theta) \frac{\partial t_i^{N,R}}{\partial \theta} \right] < 0. \tag{24}$$

This is negative because $2t_i^{N,R} - 3\theta - 1 < 2t_i^{N,R} - 2t_i^{C,R} < 0$ holds in the Nash equilibrium. Also, the squared bracket is unambiguously positive since $\partial t_i^{N,R} / \partial \theta < 0$ from (23). Therefore the fixed wage declines when managers become more overconfident, and the compensation structure unambiguously shifts towards more incentive pay.

We can also determine how managerial overconfidence affects each government's equilibrium level of tax revenues. Overconfidence has counteracting effects on total tax collections, because it increases the bonus tax base, but reduces the equilibrium tax rate under tax competition, as given in (23). The total effect of θ on tax revenues is derived in Appendix A.3 and given by

$$\frac{\partial R_i^*}{\partial \theta} = \frac{8 t_i^2 \gamma \Omega^2}{(1 - \theta + 2t_i)^2 [(1-\theta)^2 + 4t_i^2]} > 0. \tag{25}$$

Hence, in the Nash equilibrium, the enlarged tax base dominates the effects of more aggressive tax rate competition between countries. To understand this result, recall that there are offsetting effects on the equilibrium bonus tax rate that follow from the higher tax base and the higher elasticity of the tax base. Combined with the unambiguous increase in the tax base, this leads to higher tax revenue collections in each of the two competing countries as a result of higher managerial overconfidence.

With non-cooperative tax setting, overconfidence thus lowers the bonus tax rate, but raises equilibrium tax revenue. The same qualitative results have also been shown under cooperative tax setting; cf. eqs. (17) and (18). It is then natural to ask how the level of overconfidence θ affects the revenue losses that arise from tax competition. From (18) and (A.8) an the appendix, we get:

$$\frac{1}{R_i^{C,R}}\frac{\partial R_i^{C,R}}{\partial \theta} - \frac{1}{R_i^*}\frac{\partial R_i^*}{\partial \theta} = \frac{2(2t_i + \theta - 1)^2}{(1+\theta)[(1-\theta)^2 + 4t_i^2]} > 0, \tag{26}$$

which shows that higher managerial overconfidence *aggravates* the revenue losses arising from tax competition for mobile managers. This is a direct consequence of the result that higher levels of overconfidence increase the migration response of managers, and therefore make tax competition more aggressive.

Our results in this section are summarized in:

Proposition 1 *When governments maximize tax revenues, increased overconfidence of mobile managers (a rise in θ) leads to:*
(i) firms choosing a compensation structure with higher bonus payments and lower fixed wages;
(ii) governments choosing lower bonus taxes in the non-cooperative equilibrium, despite the increased bonus tax base;
(iii) equilibrium tax revenues rising for all initial levels of θ.
(iv) a larger shortfall of tax revenues, in comparison to the cooperative allocation.

Note that Proposition 1(*iii*) implies a redistributive effect from the manager to the government in equilibrium. This redistributive effect arises because the manager's overconfidence leads to a higher reliance on the taxed bonus component of his pay, whereas the untaxed fixed wage component is reduced. In this sense the manager's overconfidence is "exploited" by the government in our model. This differs from the existing literature in closed economies, where a higher bonus share allows the firm to meet the participation constraint of an overconfident manager at a lower expected total salary (Gervais et al., 2011; De la Rosa, 2011). In our model firms' profits are fixed in equilibrium, however, by the international competition for scarce and mobile managers.[17] As a result, the gains from the managers' misconception are passed on to governments in the form of higher tax revenue.

[17]This is seen from (12) when the fixed wage is part of the compensation package and (12) thus holds with equality. The firms' competition for mobile managers will, in equilibrium, fix division profits π_i^D at a level that depends only on the managers' international mobility, as measured by the parameter a. Total profits in equilibrium are then fixed by $\Pi_i^* = \pi_i^D = a$.

We conclude this section by emphasizing that employing an overconfident manager does not have any negative effects on the level of firm profits in our benchmark model. In Appendix A.4 we analyze an extended setting that incorporates such a negative effect of overconfidence. Specifically, we assume that overconfidence leads managers to take fewer precautions, leading to higher costs for the firm in the case of adverse events. We model this as a loss to the firm arising in the low state that is proportional to the manager's degree of overconfidence. Hence, in the low state, the return to the firm is given by $Y^l - \kappa\theta$, where $\kappa \geq 0$. We show that this additional effect *increases* the firm's optimal bonus payment in equilibrium, and also that it strengthens the downward effect on the equilibrium tax rate. On net, the increase in the bonus tax base dominates and tax revenues rise further under this model extension. In other words, all our results in Proposition 1 are *strengthened* when we incorporate a loss from overconfident managerial behavior that arises in the low state.

The intuition for these results is straightforward. The loss that overconfidence creates in the low state makes the firm even more willing to incentivize the manager's effort, in order to increase the likelihood that the high state with Y^h occurs. Hence managerial pay will be directed even more towards higher bonuses and lower fixed wages, as compared to our benchmark model. These changes simultaneously raise the bonus tax base and increase the elasticity with which managers respond to the bonus tax rate, hence amplifying all effects that overconfidence has in our benchmark model.

4 Welfare maximizing governments

In this section we ask how our above results are changed when governments, in addition to caring about transfers to the local population, also include the *actual* utility of mobile managers into their objective function. Hence we adopt a paternalistic perspective where governments see through the behavioral bias of managers and aim at correcting this bias via bonus taxation. We assume, however, that governments do not incorporate firms' profits in their objective function, for example because these profits accrue entirely to non-residents.[18]

[18] While firm profits are fixed in equilibrium in our model (see footnote 17), profits are still *perceived* as endogenous by non-cooperatively behaving governments. This is why we need an explicit assumption that competing governments place a weight of zero on firm profits. We are grateful to an anonymous referee for pointing out this complication to us.

Specifically, we assume that governments maximize a weighted sum of tax revenues and the welfare of a representative manager in their jurisdiction, where the welfare weight of the representative manager is exogenously given by $\lambda > 0$. This objective function is in line with other models where the government's objective includes the welfare of mobile individuals (Mansoorian and Myers, 1993; Hindriks and Myles, 2006, Chapter 18). Evaluating the representative manager's net utility in (3) at the *actual* probability of receiving the bonus, p_i^h, the welfare function is given by

$$W_i = R_i(t_i, t_j) + \lambda u_i^* = t_i p_i^h z_i N_i + \lambda \left(p_i^h z_i + w_i - \frac{\eta e_i^2}{2} \right) \quad \forall i. \tag{27}$$

4.1 Cooperative tax policy

We start again with the cooperative case. The cooperative tax rate of welfare-maximizing governments is derived from a global welfare function $W = R_i + R_j + \lambda(u_i + u_j),\ i \neq j$. The effect of a change in t_i on joint tax revenue $R_i + R_j$ is given in (16) above. For the utility of the representative manager in country i, we substitute (4), (5a) and (13) in (27). This yields:

$$u_i^* = \gamma\, z_i^2 \left[1 + \theta - \frac{(1+\theta)^2}{2} \right] + w_i, \tag{28}$$

where $w_i(t_i, t_j)$ is given in (14). To derive the tax rate that maximizes the joint welfare of the representative managers in both countries, we make use of symmetry, which implies $\partial u_j / \partial t_i = \partial u_i / \partial t_j$. Differentiating (28) and (14) with respect to t_i *and* t_j, the cooperative tax rate that maximizes the manager's utility, $t^{C,u}$, is given by

$$t^{C,u} = \frac{5\theta - 1}{2}. \tag{29}$$

Equation (29) shows that the cooperative tax rate $t^{C,u}$ is increasing in the manager's behavioral bias θ. Intuitively, overconfidence distorts the manager's effort decision in the direction of 'excessive' effort, when evaluated at the actual success probability. A higher bonus tax changes the managers' compensation package, increasing the fixed wage and reducing the bonus, thus reducing the incentive to provide excessive effort. This corrective effect of the tax will benefit managers, and it can even dominate the negative income effect of the tax when θ is sufficiently high.

The optimal cooperative tax rate of welfare-maximizing governments is derived by differentiating W with respect to t_i. This yields the first-order condition

$$\frac{\partial W}{\partial t_i} = \frac{\gamma(1+\theta)\Omega^2}{(1-\theta+2t_i)^3} \left[(1-\theta-2t_i) + \lambda(5\theta - 1 - 2t_i) \right] = 0, \tag{30}$$

which can in turn be written as a weighted average of the revenue-maximizing tax rate derived in the last section [eq. (17)] and the tax rate that maximizes managerial utility in (29). Denoting this cooperative tax rate by $t^{C,W}$ gives:

$$t^{C,W} = \frac{1}{(1+\lambda)}\, t^{C,R} + \frac{\lambda}{(1+\lambda)}\, t^{C,u} \,. \tag{31}$$

Equation (31) shows that the overconfidence parameter θ has counteracting effects on the cooperative, welfare-maximizing tax rate, since $t^{C,R}$ is falling in θ from (17), but $t^{C,u}$ is rising in θ from (29). If the welfare weight λ of a representative manager is large enough, then the cooperative, welfare-maximizing tax rate may indeed be rising in θ, in contrast to our result for tax revenue maximizing governments.

The result that optimal taxes should be corrected upwards when individuals provide excessive work effort has been studied by Gerritsen (2016) in a closed-economy setting, and for a non-linear income tax. Gerritsen also empirically estimates, using British life satisfaction data, that high-income individuals do indeed tend to work "too much". His empirical findings are therefore in line with the setup of our analysis.

4.2 Non-cooperative tax policies

When bonus taxes are set non-cooperatively, the effect of a tax increase in country i on its tax revenues R_i is given in (20). The effect of an isolated tax increase in country i on the welfare of a representative manager in this country differs from the cooperative case analyzed above. Differentiating (28) and $w_i(t_i, t_j)$ in (14) with respect to t_i, while holding t_j constant, and denoting the non-cooperative tax rate that maximizes the manager's utility by $t_i^{N,u}$ gives

$$t_i^{N,u} = \frac{7\theta - 1}{2} \,. \tag{32}$$

Comparing (32) to (29) shows that, when looking at the isolated maximization of managerial utility, the non-cooperative tax rate rises more steeply in θ than the cooperative tax rate. Intuitively, an isolated increase in the bonus tax puts firms in country i under competitive pressure and induces them to change the managers' compensation package more strongly in the direction of higher fixed wages and lower bonuses than is true under a coordinated tax increase. This is because the fixed wage is the marginal instrument for each country to attract mobile managers; cf. our discussion of eq. (14). In sum, therefore, an insolated tax increase in country i is a more potent instrument to correct the distortion arising from managerial overconfidence than is a coordinated increase in t_i and t_j.

To derive the non-cooperative tax rate of welfare maximizing governments, we differentiate (27) with respect to t_i. This yields

$$\frac{\partial W_i}{\partial t_i} = \frac{\gamma(1+\theta)\Omega^2}{(1-\theta+2t_i)^3}\left[(1-\theta-2t_i) - \frac{t_i\gamma(1+\theta)\Omega^2}{3a(1-\theta+2t_i)} + \frac{2\lambda}{3}(7\theta-1-2t_i)\right] = 0. \quad (33)$$

Comparing (33) to the first-order condition in the cooperative case [eq. (30)] shows that the first terms in the squared bracket are identical. In (33) there is, however, a negative second effect that derives from tax competition and is not present in (30). On the other hand, the isolated last term in the squared bracket of (33) implies a higher tax rate than the last term in (30), corresponding to the higher level of $t_i^{N,u}$ in (32), as compared to $t_i^{C,u}$ in (29). Therefore, non-cooperative tax rates can even be higher than cooperative tax rates for welfare-maximizing governments, if the manager's welfare weight λ is sufficiently high.[19]

The effects of higher overconfidence levels θ on the optimal non-cooperative tax rates will generally be ambiguous when governments maximize national welfare. We know from our analysis of Section 3 that the effect of θ on non-cooperative, revenue-maximizing tax rates $t_i^{N,R}$ is negative [see eq. (23)], whereas the effect of a higher θ on the tax rate that maximizes the managers' utility is positive [eq. (32)]. Appendix B.2 shows that a sufficient condition for the net effect of θ on $t_i^{N,W}$ to be negative is that the welfare weight of the manager is $\lambda < 3/14$. Conversely, $t_i^{N,W}$ will be rising in the overconfidence level θ when the managerial welfare weight λ is sufficiently high.

Taking these tax changes into account, we can then ask how overconfidence affects the equilibrium utility level of a representative manager. Differentiating (28) with respect to θ and incorporating the endogeneity of $t_i^{N,W}$ and $t_j^{N,W}$ symmetrically gives

$$\frac{\partial u_i^*}{\partial \theta} = \frac{\gamma\Omega^2(2t_i^2+t_i-5t_i\theta-4\theta)}{(1-\theta+2t_i)^3} + \Delta\,\frac{\partial t_i^{N,W}}{\partial \theta}; \qquad \Delta \equiv \frac{\gamma\Omega^2(1+\theta)(5\theta-1-2t_i)}{(1-\theta+2t_i)^3}. \quad (34)$$

The first term in (34) shows that managers' utility is generally hump-shaped in their overconfidence level θ. For $\theta = 0$, managers' utility is rising in θ if $t_i > 0$.[20] Intuitively, for low levels of overconfidence, the extra effort supplied by the manager has

[19]The argument comparing implicit optimal tax rates in (30) and (33) relies in the second-order condition of the optimal tax problem $W_i(t_i)$ to hold. Appendix B.1 shows that the second-order condition is satisfied for any $\lambda > 0$, if θ is sufficiently low ($\theta \leq 0.25$).

[20]In Appendix B.2, we show that $t_i^{N,R} > 0$ when $\lambda \leq 1.5$.

a first-order effect on relaxing the moral hazard constraint and increasing the aggregate surplus from employing the manager. Therefore, higher total earnings more than compensate the manager for his increased effort. At the same time, the distortion of the manager's effort level through his behavioral bias is only of second order when the initial level of overconfidence is very low. For high levels of θ, however, the distortion of the manager's effort decision arising from overconfidence will cause a first-order welfare loss when measured by his actual utility. Therefore, high levels of overconfidence reduce the manager's true utility.

These effects are modified by the changes in the bonus tax rate that are induced by increased overconfidence. For low levels of overconfidence we have $\Delta < 0$. In this case the second term in (34) is positive when the bonus tax rate *falls* in response to higher overconfidence, as is the case when revenue considerations dominate in governments' optimal tax choices. For high levels of overconfidence and sufficiently low level of λ, the term Δ is instead positive. In this case, the second term is positive when the corrective motive dominates in the setting of bonus tax rates and $\partial t_i^{N,W}/\partial\theta > 0$.

Finally, we derive the aggregate welfare changes resulting from overconfidence. Appendix B.2 derives sufficient conditions for tax revenue to rise in response to changes in overconfidence, $\partial R_i^*/\partial\theta > 0$, as in the case of revenue maximizing governments. When these conditions are met, a sufficient condition for W_i^* to be rising in θ is that $\partial u_i^*/\partial\theta$ in (34) is also positive. As we have discussed above, this will unambiguously be the case when the overconfidence level is low in the initial equilibrium (so that the first effect in (34) is positive and $\Delta < 0$), and when the bonus tax rate is *decreased* by a rise in θ. Interestingly, the latter will occur when governments value the managers' utility only moderately ($\lambda < 3/14$), and hence reduce the tax rate in response to an increase in managerial overconfidence. Intuitively, in this case the governments' dominant concern about tax revenues will lead them to reduce the bonus tax rate, and the resulting increase in their net income benefits managers when their initial level of overconfidence is sufficiently low. Conversely, aggregate welfare may be falling in θ when the initial level of managerial overconfidence is high, and when the welfare weight of managers in the governments' objective function is so high that this negative effect dominates the positive effect that higher levels of θ have on equilibrium tax revenue.

We summarize the conditions under which our results from the previous section extend to the case of welfare-maximizing governments as follows:

Proposition 2 *When governments maximize national welfare, but the managerial wel-*

fare weight is sufficiently low ($\lambda < 3/14$), higher overconfidence θ of mobile managers leads to: (i) falling optimal tax rates; and (ii) rising equilibrium tax revenues.

Proof: See Appendix B.2.

The results summarized in Proposition 2 are illustrated in Figure 1. The panels on the left-hand side of Figure 1 [case (a)] assume a low welfare weight of managers ($\lambda = 0.1$), satisfying the condition $\lambda < 3/14$.[21] All panels compare cooperative tax setting (black line with diamonds) and non-cooperative tax setting (blue line with filled circles). The upper panel of case (a) shows that both cooperative and non-cooperative tax rates are falling in the level of overconfidence θ. The middle panel of case (a) shows that tax revenues are rising in θ under both cooperative and non-cooperative tax setting, but the gap between cooperative and non-cooperative tax revenues widens as θ is increased. In the lower panel of case (a), aggregate welfare is monotonously rising in θ under cooperative tax policies, but it is hump-shaped in θ when taxes are set cooperatively. This is because true managerial welfare drops steeply when θ becomes large, and tax rates under tax competition are too low to correct this distortion substantially.

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********* Figure 1 about here **********

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The right-hand panels of Figure 1 [case (b)] assume instead that the government values managerial welfare higher ($\lambda = 0.5$), thus violating the condition $\lambda < 3/14$ in Proposition 2. In the upper panel of case (b), cooperative tax rates are now rising in θ, whereas non-cooperatively tax rates are largely flat. As θ increases, the downward pressure on tax rates due to the more intense competition for mobile managers is roughly compensated by the upward effect on tax rates that arises from the motive to correct the manager's distorted beliefs. Tax revenues continue to rise in θ for both cooperative and non-cooperative tax setting, and Proposition 2(ii) continues to hold for this higher level of overconfidence. Finally, as in case (a), aggregate welfare levels under cooperative and non-cooperative tax setting diverge as θ increases, implying that the welfare costs of tax competition become more severe, the higher is managerial overconfidence. Hence, our finding for revenue-maximizing governments [Proposition 1(iv)] carries over to the more general welfare function in this section.

[21] Exogenous parameters in the numerical examples are set at $Y^l = 1$, $\Omega = 8$, $\gamma = 0.02$; $a = 0.1$.

5 Two-tier income taxation

Our benchmark model in Section 3 has considered only a tax on bonus payments, but has left untaxed the fixed salary earned by managers in each country. This has direct implications for tax revenue when firms change the mix of bonus versus fixed wage compensation. In this section we show that qualitatively the same results are obtained when we allow both the fixed wage and the bonus to be taxed, but the bonus is taxed at a higher rate under a general and progressive income tax. To keep the complexity of the resulting framework manageable, we revert to the simpler case of tax revenue maximizing governments.

We thus analyze a two-tier tax system where all income is taxed at a flat rate τ_i, but an additional surtax t_i is levied on bonuses. Since all managers receive the same compensation package in our model, this is equivalent to a directly progressive two-tier income tax system where the fixed wage falls in the lower ('general') income tax bracket with a tax rate of τ_i, and the bonus payment in case of success falls in the higher bracket with tax rate $(\tau_i + t_i)$. Moreover, while managers are identical ex ante, their incomes differ ex post due to the stochastic environment of our model. In such a setting we ask how an optimal progressive tax is determined from the perspective of tax revenue maximization.

It is well-known from the optimal income tax literature that replicating the directly progressive tax schedules that exist in most countries through a two-tier income tax with two endogenously chosen tax rates is extremely difficult, even if redistributive motives between individuals are explicitly accounted for.[22] In the following, we therefore follow a two-step procedure. In the first step we provide analytical results for the case where the general income tax rate τ_i is exogenously fixed, and only the bonus tax t_i is endogenized. We derive the optimal bonus tax in this extended setting, and ask how it is affected by overconfidence for any given level of the lower-bracket tax rate τ_i. In a second step we treat both tax rates τ_i and t_i as endogenous and solve the model numerically for this case.

With two-tier taxation of the manager's remuneration, the after-tax profits of the firm

[22]Slemrod et al. (1994) have shown that no directly progressive income tax schedule will result in settings where standard assumptions are made with respect to social welfare functions and the distribution of abilities. Conversely, Apps et al. (2014) study the conditions under which two-tier income tax systems are directly progressive, but these schemes are not easily tractable analytically.

[eq. (10)] change to

$$\tilde{\Pi}_i = \tilde{N}_i \left\{ \tilde{p}_i^{h*}[Y^h - \tilde{z}_i(1 + \tilde{t}_i + \tau_i)] + \tilde{p}_i^{l*} Y^l - \tilde{w}_i(1 + \tau_i) \right\}, \tag{35}$$

where the tilde symbol ($\tilde{}$) is used for endogenous variables in this extension.

Maximizing (35) with respect to the firm's compensation variables w_i and z_i gives

$$\frac{\partial \tilde{\Pi}_i}{\partial \tilde{w}_i} = \frac{\tilde{\pi}_i^D}{a} - \tilde{N}_i(1 + \tau_i) = 0, \qquad \tilde{z}_i^* = \frac{\Omega}{(1-\theta)(1+\tau_i) + 2\tilde{t}_i} \quad \forall\, i, \tag{36}$$

where the second expression in (36) assumes again that the fixed wage is positive in equilibrium. In comparison to the benchmark case [eqs. (12) and (13)], the equilibrium level of division profits $\tilde{\pi}_i^D$ is now larger, because the fixed wage is taxed in equilibrium. Also, the larger denominator in the expression for $\tilde{z}_i^*$ reflects the additional taxation of the bonus by the general income tax τ_i. The optimal fixed wage in this setting is given in Appendix C.1 [eq. (C.3)].

Tax revenue for government i is now

$$\tilde{W}_i = \tilde{N}_i[\tilde{p}_i^{h*}(\tilde{t}_i + \tau_i)\tilde{z}_i + \tau_i \tilde{w}_i] \qquad \forall\, i. \tag{37}$$

Appendix C.2 derives the optimal bonus tax $\tilde{t}_i^{N,R}$ when the income tax rate τ_i is exogenous. This gives:

$$\tilde{t}_i^{N,R} = \frac{B + \sqrt{B^2 - AC}}{A}, \tag{38}$$

$$\begin{aligned}
A &= 8\left[3 + \tau_i\left(7 + 4\tau_i + Y_a^l\right)\right] > 0,\\
B &= -4\tau_i(1-\theta)(1+\tau_i)\left[4(1+\tau_i) + Y_a^l\right] - (1+\theta)(1+2\tau_i)\gamma\Omega_a^2 < 0,\\
C &= 2(1+\tau_i)(1-\theta)\left\{(1-\theta)(1+\tau_i)(Y_a^l\tau_i + 4\tau_i^2 + \tau_i - 3) + \tau_i\,(1+\theta)\gamma\Omega_a^2\right\},
\end{aligned}$$

where $Y_a^l \equiv Y^l/a$ and $\Omega_a^2 \equiv \Omega^2/a$.

We can infer from the structure of (38), together with $A > 0$ and $B < 0$ for all $\theta \in (0,1)$, that the bonus tax will be positive if and only if the term C is negative. In this case it will thus be optimal to tax bonus income at a higher rate than income from the fixed wage. Inspection of the term C shows that this will unambiguously be the case when $\tau_i = 0$, in which case we return to our benchmark setting.[23] As τ_i is continuously raised, this tends to reduce the optimal bonus tax $\tilde{t}_i^{N,R}$. Therefore, $\tilde{t}_i^{N,R}$

[23] This can easily be checked by setting $\tau_i = 0$ in expressions A–C. In this case the optimal tax in (38) collapses to eq. (21) in Section 3.

will be lower than the corresponding bonus tax rate in the benchmark case, $t_i^{N,R}$, for all $\tau_i > 0$ and $\theta \in [0,1]$. At some point the general income tax rate will reach a critical level, denoted by τ_i^{crit}, at which the term C turns positive and hence $\tilde{t}_i^{N,R} < 0$. Our following analysis focuses on the parameter range $\tau_i \in [0, \tau_i^{crit}]$ for which the bonus surtax $\tilde{t}_i^{N,R}$ is positive, and generates additional tax revenue.

Our main interest is in the question of how an increase in the overconfidence level of managers affects the optimal bonus tax under this extension. This is summarized in:

Proposition 3 *When all incomes are taxed at an exogenous rate $\tau_i \in [0, \tau_i^{crit}]$, and the optimal bonus tax rate $\tilde{t}_i^{N,R}$ is positive in the symmetric, non-cooperative equilibrium, then increased overconfidence of mobile managers (a rise in θ) leads to:*
(i) higher bonus payments and lower fixed wages by firms;
(ii) managers responding more elastically to bonus taxation;
(iii) lower optimal bonus taxes $\tilde{t}_i^{N,R}$ in both countries.

Proof: See Appendix C.3.

Proposition 3 states that our results for revenue-maximizing governments (Proposition 1) carry over to an extended setting with a positive general rate of income taxation, whenever the endogenous bonus surtax is positive in the optimum. In this case the intuition from our benchmark model carries over as well. The higher bonus payments by firms will increase the bonus tax base. However, the higher overconfidence of managers simultaneously increases their migration response, making the bonus tax base respond more elastically to a higher bonus tax rate. In equilibrium, the effect of the higher tax base elasticity dominates, and the optimal bonus tax must fall. To put it differently, a directly progressive income tax system will become less progressive in the government's optimum, when the overconfidence level of mobile managers increases.

In the next step, we endogenize the general income tax rate τ. In our setting, the analysis of tax competition with two endogenous variables is too complex, however, to yield tractable analytical results. Therefore we solve the model numerically. Figure 2 summarizes our results for different values of the parameter a, which inversely measures the international mobility of managers.[24]

****

[24] The numerical analysis in Figure 2 is based on the following parameter values: $Y^l = 0.75$, $\Omega = 0.5$, $\gamma = 0.5$ (which differ from the values used in Figure 1).

********* Figure 2 about here **********

****

In Figure 2, the bonus tax rate $\tilde{t}_i^{N,R}$ is higher, for any given level of θ, in the low-mobility case shown in panel (a), as compared to the intermediate mobility case in panel (b). This corresponds to our results for the benchmark model [eq. (22)]. However, the qualitative response of both taxes to changes in the overconfidence parameter θ is the same in both panels. The bonus tax rate (upper-tier tax rate) is monotonously falling in θ, as in Propositions 1 and 3. The new insight from the numerical analysis is that the general income tax rate (lower-tier tax rate) is instead rising in θ. The reason for this is seen from the firm's optimal compensation structure in (36): a higher overconfidence level θ *reduces* the effect that a higher income tax rate τ_i has on equilibrium bonus payments $\tilde{z}_i^*$, and hence on the bonus tax base. This in turn results from the fact that a higher income tax must increase division profits in equilibrium, from the firm's first-order condition for the fixed wage [the first expression in (36)].

In both panels of Figure 2 it is also true that the total tax rate on managers' bonus income, $(\tau_i + t_i)$, is falling in the overconfidence level θ. Hence the downward effect that overconfidence has on the isolated bonus tax rate t_i dominates the upward effect on the general wage tax τ_i. This implies that the negative effect of overconfidence that we derived in our benchmark analysis for an isolated tax on bonus income carries over to a two-tier income tax system in which the fixed wage is also taxed optimally.[25]

Finally, there is a third case, not shown in Figure 2, in which the mobility of managers is high ($a = 0.4$). In this case the bonus tax rate t_i is negative for higher levels of θ and the overall tax schedule thus turns regressive. This case is familiar from the analysis of two-tier taxes (Slemrod et al., 1994) and from the non-linear income taxation for mobile top earners (Simula and Trannoy, 2010; Lehmann et al., 2014). In our setting, the negative effect of managers' international mobility on the bonus tax rate [eq. (22)] becomes so strong that governments choose a bonus subsidy and thus a regressive tax structure. In this case, higher levels of overconfidence will reduce the equilibrium bonus

[25] Note that the total taxation of bonus income $(t_i + \tau_i)$ in panel (b) exceeds that in panel (a) for all given levels of θ. This result is surprising at first glance, as the international mobility of managers is higher in case (b). The reason is that higher manager mobility (a fall on a) induces the firms to increase total manager compensation by increasing both the bonus and the fixed wage payment. This is seen from the fact that the firm's division profits fall in equilibrium when the parameter a is reduced [the first expression in (36)]. For the government this implies that the total tax base is increased, and this effect dominates the tighter tax competition between governments.

subsidy, and thus *increase* t_i. Intuitively, overconfident managers now overestimate the expected bonus *subsidy* that they receive in a given location, and this misperception makes them less mobile internationally.

To summarize, our analysis in this section has shown that the negative effect of overconfidence on the bonus tax rate t_i carries over to a two-tier tax system, whenever the upper-tier bonus tax rate is positive, and the tax system is therefore progressive. This result can be established theoretically for the case where the general income tax rate is held fixed (Proposition 3), and it carries over to our numerical analyses, where the entire tax structure is optimized.

6 Conclusion

Our analysis has shown that overconfidence as a behavioral trait of high-skilled managers can contribute to explaining several important developments that have been observed over the past decades. On the one hand, it offers an additional rationalization for the increased use of incentive pay contracts in most OECD countries. Higher shares of incentive pay are in turn an obvious driver of wage income inequality. On the other hand, overconfidence in connection with incentive pay provides a mechanism that increases the migration elasticity of the mobile highly skilled. This adds to the explanation for the rather high migration elasticities that have been found empirically for this segment of the labor market (Kleven et al., 2020). When governments focus on tax revenue maximization, the higher migration elasticities in turn offer a rationale for the fall in top income tax rates that has been observed since the mid-1990s (Egger et al., 2019). A counteracting effect arises, however, when governments incorporate the true utility of overconfident managers in their objective function and use bonus taxes to correct the managers' distorted incentives.

Our theoretical results have been derived in a simplified setting where general wage income remained either untaxed, or it was taxed at an exogenously given tax rate. A first extension of our analysis would therefore be to study the effects of (potentially heterogeneous) overconfidence under a more general system of optimal non-linear income taxation. A further extension would be to study optimal contracts by firms when only some part of their managers are overconfident, and this is private information. We leave these and other extensions to future research.

Appendix

A. Appendix to Section 3

A.1 Derivation of equation (14)

Firm i chooses the bonus z_i and the fixed wage w_i, which depends on z_j and w_j. Hence the system of first-order conditions in (12) is interdependent, and given by

$$\begin{aligned}
\frac{\partial \Pi_i}{\partial w_i} &= \frac{1}{a}\left\{p_i^{h*}[Y^h - z_i(1+t_i)] + p_i^{l*}Y^l - w_i\right\} \\
&\quad - 1 - \frac{1}{a}\left[\frac{\gamma}{2}(1+\theta)^2(z_i^2 - z_j^2) + w_i - w_j\right] = 0, \qquad \text{(A.1)} \\
\frac{\partial \Pi_j}{\partial w_j} &= \frac{1}{a}\left\{p_j^{h*}[Y^h - z_j(1+t_j)] + p_i^{l*}Y^l - w_j\right\} \\
&\quad - 1 - \frac{1}{a}\left[\frac{\gamma}{2}(1+\theta)^2(z_j^2 - z_i^2) + w_j - w_i\right] = 0. \qquad \text{(A.2)}
\end{aligned}$$

Substituting in the equilibrium bonuses z_i and z_j from (13) and the equilibrium probabilities from (5a)–(5b) yields

$$\begin{aligned}
w_i &= \begin{pmatrix} \frac{2}{3} & \frac{1}{3} \end{pmatrix} \begin{pmatrix} p_i^{h*}(\Omega - z_i(1+t_i)) + Y^l - a - \frac{\gamma}{2}(1+\theta)^2(z_i^2 - z_j^2) \\ p_j^{h*}(\Omega - z_j(1+t_j)) + Y^l - a - \frac{\gamma}{2}(1+\theta)^2(z_j^2 - z_i^2) \end{pmatrix} \\
&= Y^l - a + \frac{1}{3}\frac{\gamma(1+\theta)\Omega^2}{(1+2t_j-\theta)}\left(1 - \frac{1+t_j}{1+2t_j-\theta}\right) + \frac{2}{3}\frac{\gamma(1+\theta)\Omega^2}{(1+2t_i-\theta)}\left(1 - \frac{1+t_i}{1+2t_i-\theta}\right) \\
&\quad + \frac{\gamma(1+\theta)^2\Omega^2}{6}\left(\frac{1}{(1+2t_j-\theta)^2} - \frac{1}{(1+2t_i-\theta)^2}\right). \qquad \text{(A.3)}
\end{aligned}$$

Simplifying (A.3) leads to eq. (14) in the main text.

A.2 Second-order condition for optimal bonus taxes

Differentiating the first-order condition for bonus taxes (20) with respect to t_i gives

$$\begin{aligned}
\frac{\partial^2 R_i}{\partial t_i^2} &= \frac{\partial z_i^2}{\partial t_i}\frac{\gamma(1+\theta)}{a}\left[aN_i\left\{1 - \frac{4t_i}{1-\theta+2t_i}\right\} - \frac{t_i\gamma(1+\theta)\Omega^2}{3(1-\theta+2t_i)^2}\right] \\
&\quad + \frac{z_i^2\gamma(1+\theta)}{a}\Bigg[-a\frac{\gamma(1+\theta)\Omega^2}{3a(1-\theta+2t_i)^2}\left\{1 - t_i\frac{4}{1-\theta+2t_i}\right\} - aN_i\frac{4(1-\theta)}{(1-\theta+2t_i)^2} \\
&\quad - \frac{\gamma(1+\theta)\Omega^2}{3(1-\theta+2t_i)^2} + \frac{4t_i\gamma(1+\theta)\Omega^2}{3(1-\theta+2t_i)^3}\Bigg]. \qquad \text{(A.4)}
\end{aligned}$$

At $t_i = t_i^{N,R}$ [eq. (21)], the first term on the right-hand side is zero. The remaining terms are rearranged to yield:

$$\frac{\partial^2 R_i}{\partial t_i^2} = \frac{z_i^2 \gamma(1+\theta)}{a}\Big[-aN_i\frac{4(1-\theta)}{(1-\theta+2t_i)^2} + \frac{\Omega^2(-1+2t_i+\theta)2\gamma(1+\theta)}{3(1-\theta+2t_i)^3}\Big]. \qquad \text{(A.5)}$$

A sufficient condition for (A.5) to be negative is $-1+\theta+2t_i < 0$, which is true since $(1-\theta)/2 = t_i^{C,R} > t_i^{N,R}$. Hence the second-order condition for an optimum is fulfilled. $\square$.

A.3 Derivation of eq. (25)

All derivatives include $\partial t_i/\partial\theta$. Evaluating this at the equilibrium tax rate $t_i = t_i^{N,R}$ yields

$$\left.\frac{\partial t_i}{\partial \theta}\right|_{t_i=t_i^{N,R}} = \frac{-t_i[2(1+\theta)(1-\theta)+(1-\theta)^2-4t_i^2]}{(1+\theta)[(1-\theta)^2+4t_i^2]}\ . \qquad \text{(A.6)}$$

From (5a) and (13), tax revenue is $R_i^* = p_i^{h*} t_i z_i N_i = t_i(1+\theta)\gamma z_i^2 = \dfrac{t_i\,(1+\theta)\,\gamma\Omega^2}{(1-\theta+2\,t_i)^2}N_i$. Differentiating and dividing by R_i^* gives

$$\frac{1}{R_i^*}\frac{\partial R_i^*}{\partial\theta} = \frac{3+\theta+2t_i}{(1+\theta)(1-\theta+2t_i)} + \frac{1-\theta-2\,t_i}{t_i(1-\theta+2t_i)}\frac{\partial t_i^{N,R}}{\partial\theta}\ . \qquad \text{(A.7)}$$

Substituting (A.6) in (A.7) and simplifying terms gives

$$\frac{1}{R_i^*}\frac{\partial R_i^*}{\partial\theta} = \frac{8t_i}{(1+\theta)[(1-\theta)^2+4t_i^2]} > 0. \qquad \text{(A.8)}$$

Multiplying (A.8) by R_i^* gives (25) in the main text.

A.4 Loss in the low state caused by overconfidence

We extend our benchmark model by assuming that, in the low state, the return to the firm is given by $Y^l - \kappa\theta$, where $\kappa \geq 0$. The firm's after-tax expected profits are then

$$\Pi_i = N_i \pi_i^D = N_i\left\{p_i^{h*}[Y^h - z_i(1+t_i)] + p_i^{l*}(Y^l-\kappa\theta) - w_i\right\}. \qquad \text{(A.9)}$$

Differentiating with respect to z_i and assuming that (12) holds with equality yields

$$z_i^* = \frac{\hat\Omega}{1-\theta+2t_i} \quad \forall\ i, \qquad \hat\Omega \equiv Y^h - (Y^l-\kappa\theta), \qquad \text{(A.10)}$$

which is *higher* than the optimal bonus in the benchmark model [eq. (13)]. Hence part (i) of Proposition 1 is strengthened by this extension.

The structure of the optimal tax rate in (21) is unchanged by this extension, but Ω is replaced by $\hat{\Omega}$ in (A.10). Therefore, the derivative with respect to θ changes to

$$\frac{\partial t_i^{N,R}}{\partial \theta} = \frac{1}{24a}\left\{-\hat{\Omega}\gamma[\hat{\Omega}+2(1+\theta)\kappa] + \frac{\gamma^2\hat{\Omega}^3(1+\theta)[\hat{\Omega}+2(1+\theta)\kappa] - 144(1-\theta)a^2}{\sqrt{\gamma^2\hat{\Omega}^4(1+\theta)^2+144(1-\theta)^2a^2}}\right\} < 0. \tag{A.11}$$

The sum of the terms added by the parameter κ in (A.11) is negative. Hence, a given increase in overconfidence lowers the equilibrium tax rate by more when overconfidence causes a loss to the firm in the low state. Hence Proposition 1(ii) is also strengthened when overconfidence causes a loss in the low state.

Finally, we turn to tax revenue collections. With losses in the low state, we get

$$\frac{\partial \hat{R}_i^*}{\partial \theta} \equiv \frac{\partial R_i^*}{\partial \theta} + \frac{\partial R_i^*}{\partial \hat{\Omega}}\kappa \tag{A.12}$$

where the first term on the right-hand side is positive from (A.8). Evaluating the second term on the RHS of (A.12), accounting for the endogeneity of $t_i^{N,R}$ with respect to $\hat{\Omega}$ and introducing $\delta \equiv \gamma/(a)$ gives:

$$\begin{aligned}\frac{1}{(1+\theta)\gamma}\frac{\partial R_i^*}{\partial \hat{\Omega}} &= \frac{\partial}{\partial \hat{\Omega}}\left(\frac{t_i\hat{\Omega}^2}{(1-\theta+2\,t_i)^2}\right)|_{t_i=\bar{t}_i} + \frac{\partial}{\partial t_i}\left(\frac{t_i\hat{\Omega}^2}{(1-\theta+2\,t_i)^2}\right)\frac{\partial t_i}{\partial \hat{\Omega}} \\ &= \frac{2\kappa t_i\,(\kappa\,\theta+\hat{\Omega})}{(1-\theta+2\,t_i)^2} + \frac{2\kappa(\kappa\,\theta+\hat{\Omega})^3(1-\theta-2\,t_i)}{24\,(1-\theta+2\,t_i)^3}\left[\frac{\delta^2(\kappa\,\theta+\hat{\Omega})^2(1+\theta)^2}{\chi} - \delta(1+\theta)\right],\end{aligned}$$

where $\chi \equiv \sqrt{\delta^2\left(\kappa\,\theta+\hat{\Omega}\right)^4(1+\theta)^2 + 144\,(\theta-1)^2}$.

Dividing this expression by $2\kappa(\kappa\theta+\hat{\Omega})/(24(1-\theta+2t_i)^2)$ gives:

$$\begin{aligned}\frac{1}{(1+\theta)\gamma}\frac{\partial R_i^*}{\partial \hat{\Omega}}\frac{24(1-\theta+2t_i)^2}{2\kappa(\kappa\theta+\hat{\Omega})} &= -\frac{\delta\,\left(k\theta+\hat{\Omega}\right)^2(1+\theta)\,(2-2\,\theta)}{1-\theta+2\,t_i} \\ &+ \frac{1}{\chi}\left[\frac{\delta^2\left(\kappa\,\theta+\hat{\Omega}\right)^4(1+\theta)^2\,(2-2\,\theta)}{1-\theta+2\,t_i} + 144\,(\theta-1)^2\right].\end{aligned}$$

Multiplying the last formula by χ and noting that $-\delta(\kappa\theta+\hat{\Omega})^2(1+\theta)+\chi = 24t_i$, we finally obtain:

$$
\begin{aligned}
\frac{1}{(1+\theta)\gamma}\frac{\partial R_i^*}{\partial \hat{\Omega}}\frac{24(1-\theta+2t_i)^2}{2\kappa(\kappa\theta+\hat{\Omega})}\chi &= -\frac{\delta\left(\kappa\,\theta+\hat{\Omega}\right)^2(1+\theta)\,(2-2\,\theta)\,24t_i}{1-\theta+2\,t_i} \\
&+ \left[24\,t_i+\delta\left(\kappa\,\theta+\hat{\Omega}\right)^2(1+\theta)\right]^2-\delta^2(\kappa\theta+\hat{\Omega})^4(1+\theta)^2 \\
&= (24t_i)^2+\frac{96t_i^2\delta(\kappa\theta+\hat{\Omega})^2(1+\theta)}{1-\theta+2\,t_i}>0. \qquad \text{(A.13)}
\end{aligned}
$$

Hence Proposition 1(*iii*) also carries over to the case where overconfidence leads to an extra loss κ in the low state.

B. Appendix to Section 4

B.1 Second-order condition for optimal bonus taxes

Differentiating the first-order condition for bonus taxes (33) with respect to t_i gives

$$
\begin{aligned}
\frac{\partial^2 W_i}{\partial t_i^2} = \quad & \frac{1}{1+\lambda}\frac{\partial z_i^2}{\partial t_i}\gamma(1+\theta)\left[\frac{1-\theta-2t_i}{1-\theta+2t_i}-\frac{t_i\gamma(1+\theta)\Omega^2}{3a(1-\theta+2t_i)^2}+\frac{2\lambda}{3}\frac{(7\theta-1-2t_i)}{(1-\theta+2t_i)}\right] \\
& -\frac{1}{1+\lambda}z_i^2\gamma(1+\theta)\frac{8\lambda\theta}{(1-\theta+2t_i)^2} \\
& +\frac{1}{1+\lambda}\frac{z_i^2\gamma(1+\theta)}{a}\Big[-aN_i\frac{4(1-\theta)}{(1-\theta+2t_i)^2}-\frac{\Omega^2(1-\theta-2t_i)2\gamma(1+\theta)}{3(1-\theta+2t_i)^3}\Big]
\end{aligned}
$$

At $t_i = t_i^{N,W}$, the first term on the right-hand side is zero. The second term is negative. Note that $1-\theta+2t_i^{N,W} > 0$, since $t_i^{N,R} > 0$ and $t^{N,u}+(1-\theta)/2 = (7\theta-1)/2+(1-\theta)/2 > 0$. Finally, the third term on the right-hand side is negative when $(1-\theta)/2 \geq t_i^{N,W}$, or from (33), when $(1-\theta)/2 \geq \max\{t_i^{N,R}, t^{N,u}\}$. From Section 3, we know that $(1-\theta)/2 = t_i^{C,R} > t_i^{N,R}$. Also, $t^{N,u} - (1-\theta)/2 = (7\theta-1)/2-(1-\theta)/2 = 4\theta-1$. Therefore, a sufficient (but not a necessary) condition for the second-order condition to be fulfilled is that $\theta \leq 0.25$.

B.2 Proof of Proposition 2

We differentiate (33) with respect to θ to get

$$
\text{sign}\frac{\partial t_i^{N,W}}{\partial\theta} = \text{sign}\frac{\partial^2 W_i}{\partial t_i\partial\theta} \propto \frac{\gamma(1+\theta)\Omega^2}{(1+\lambda)(1-\theta+2t_i)^2}\left[\frac{14\lambda}{3}-1-\frac{2t_i(1+t_i)\gamma\Omega^2}{3a(1-\theta+2t_i)^2}\right]. \quad \text{(B.1)}
$$

Since the third term in the squared bracket is unambiguously negative, a sufficient (but not a necessary) condition for the sum of all terms to be negative is that $\lambda < 3/14$.

Part (i) of Proposition 2 follows immediately from (B.1). For part (ii), differentiating R_i^* with respect to θ gives

$$\frac{1}{R_i^*}\frac{\partial R_i^*}{\partial \theta} = \frac{3+\theta+2t_i}{(1+\theta)(1-\theta+2t_i)} + \frac{(1-\theta-2\,t_i)}{t_i(1-\theta+2t_i)}\frac{\partial t_i^{N,W}}{\partial \theta}\ . \tag{B.2}$$

where the only difference to (A.7) lies in the different equilibrium tax rate. Evaluating (33) at $t_i = 0$ gives $\partial W_i/\partial t_i|_{t_i=0} > 0$ for all $\lambda > 0$ and $\theta \geq 1/7$. For $\theta < 1/7$, $\partial W_i/\partial t_i|_{t_i=0} > 0$ follows if $\lambda \leq 1.5$. Therefore, $t_i^{N,W} > 0$ must hold when $\lambda \leq 1.5$. When $\lambda < 3/14$ we have $0 > \partial t_i^{N,W}/\partial\theta > \partial t_i^{N,R}/\partial\theta$. Therefore, if $(1-\theta-2t_i) < 0$ in the second term of (A.7), the second term is positive and $\partial R_i^*/\partial\theta > 0$ is unambiguous. If $(1-\theta-2t_i) > 0$ a sufficient condition for $\partial R_i^*/\partial\theta$ to be larger under $t_i^{N,W}$ than under $t_i^{N,R}$ is that $t_i^{N,W} \approx t_i^{N,R}$. But this is met when λ is sufficiently low. Since $\partial R_i^*/\partial\theta > 0$ holds for $t_i^{N,R}$ from (A.8), it must then also hold for $t_i^{N,W}$. For part (iii), we can directly infer from (34) that $\partial u_i^*/\partial\theta > 0$ when $\theta \to 0$ initially and $\partial t_i^{N,W}/\partial\theta < 0$ from part (i). Together with part (ii), aggregate welfare must then rise as well. $\square$

C. Appendix to Section 5

C.1 Derivation of the fixed wage

Differentiating (35) with respect to fixed wages gives

$$\begin{aligned}
\frac{\partial\tilde{\Pi}_i}{\partial\tilde{w}_i} &= \frac{1}{a}\left\{\tilde{p}_i^{h*}[Y^h - \tilde{z}_i(1+\tilde{t}_i+\tau_i)] + \tilde{p}_i^{l*}Y^l - \tilde{w}_i(1+\tau_i)\right\} \\
&\quad - (1+\tau_i) - \frac{1}{a}\left[\frac{\gamma}{2}(1+\theta)^2(\tilde{z}_i^2 - \tilde{z}_j^2) + \tilde{w}_i - \tilde{w}_j\right](1+\tau_i) = 0, && \text{(C.1)} \\
\frac{\partial\tilde{\Pi}_j}{\partial\tilde{w}_j} &= \frac{1}{a}\left\{\tilde{p}_j^{h*}[Y^h - \tilde{z}_j(1+\tilde{t}_j+\tau_j)] + \tilde{p}_i^{l*}Y^l - \tilde{w}_j(1+\tau_j)\right\} \\
&\quad - (1+\tau_j) - \frac{1}{a}\left[\frac{\gamma}{2}(1+\theta)^2(\tilde{z}_j^2 - \tilde{z}_i^2) + \tilde{w}_j - \tilde{w}_i\right](1+\tau_j) = 0, && \text{(C.2)}
\end{aligned}$$

where the only difference to (A.1)–(A.2) lies in the tax factors $(1+\tau_i)$ and $(1+\tau_j)$. Substituting in equilibrium bonuses from (36) and equilibrium probabilities from (5a)–(5b) and simplifying leads to

$$\begin{aligned}
\tilde{w}_i^* &= \left[\frac{2}{3(1+\tau_i)} + \frac{1}{3(1+\tau_j)}\right]Y^l - a && \text{(C.3)} \\
&+ \frac{\gamma(1+\theta)\Omega^2}{6}\left[\frac{1}{(1+\tau_j)[(1-\theta)(1+\tau_j)+2\tilde{t}_j]} + \frac{4\tilde{t}_i - 5\theta(1+\tau_i) - (1+\tau_i)}{(1+\tau_i)((1-\theta)(1+\tau_i)+2\tilde{t}_i)^2}\right].
\end{aligned}$$

C.2 Derivation of optimal bonus tax

Differentiating (9) with respect to $\tilde{t}_i$, taking account of (36) and (C.3), leads to

$$\frac{\partial \tilde{N}_i}{\partial \tilde{t}_i} = \frac{1}{a}\left[\frac{\gamma(1+\theta)^2}{2}\frac{\partial(\tilde{z}_i^2)}{\partial \tilde{t}_i} + \frac{\partial \tilde{w}_i}{\partial \tilde{t}_i} - \frac{\partial \tilde{w}_j}{\partial \tilde{t}_i}\right] = \frac{-\gamma(1+\theta)\Omega^2}{3a(1+\tau_i)[(1-\theta)(1+\tau_i)+2\tilde{t}_i]^2} < 0. \tag{C.4}$$

Differentiating (37) with respect to $\tilde{t}_i$, using (C.4) and (C.3), gives

$$\begin{aligned}\frac{\partial \tilde{W}_i(\tilde{t}_i,\tilde{t}_j)}{\partial \tilde{t}_i} \quad &= \quad \tilde{N}_i\left[\tilde{z}_i^2\gamma(1+\theta) - \frac{4(1+\theta)\gamma\tilde{z}_i^2(\tilde{t}_i+\tau_i)}{(1-\theta)(1+\tau_i)+2\tilde{t}_i} + \frac{4\tau_i\gamma(1+\theta)\Omega^2(2\tau_i(1+\theta)+1+\tau_i-\tilde{t}_i)}{3(1+\tau_i)[(1-\theta)(1+\tau_i)+2\tilde{t}_i]^3}\right] \\ &- \quad \frac{\gamma(1+\theta)\Omega^2[(1+\theta)\gamma\tilde{z}_i^2(\tilde{t}_i+\tau_i)+\tilde{w}_i\tau_i]}{3a(1+\tau_i)[(1-\theta)(1+\tau_i)+2\tilde{t}_i]^2} = 0 \quad \forall\, i \neq j. \end{aligned} \tag{C.5}$$

We evaluate the above formula at the symmetric equilibrium where $\tilde{t}_i^{N,R} = \tilde{t}_j^{N,R}$ and $\tau_i = \tau_j$. The fixed wage (C.3) is then

$$\tilde{w}_i^* = \frac{Y^l}{1+\tau_i} - a + \frac{\gamma(1+\theta)\Omega^2[\tilde{t}_i - (1+\tau_i)\theta]}{(1+\tau_i)[(1-\theta)(1+\tau_i)+2\tilde{t}_i]^2}\ . \tag{C.6}$$

Using this in (C.5) and dividing by $\gamma(1+\theta)\Omega^2$ gives

$$\begin{aligned}&\frac{\partial \tilde{W}_i(\tilde{t}_i,\tilde{t}_j)}{\partial \tilde{t}_i}\frac{1}{\gamma(1+\theta)\Omega^2} = \frac{(1-\theta)(1+\tau_i)-2\tilde{t}_i-4\tau_i}{[(1-\theta)(1+\tau_i)+2\tilde{t}_i]^3} + \frac{4\tau_i[2\theta(1+\tau_i)+1+\tau_i-\tilde{t}_i]}{3(1+\tau_i)[(1-\theta)(1+\tau_i)+2\tilde{t}_i]^3} \\ &-\left[\frac{(1+\tau_i)(\tilde{t}_i+\tau_i)+\tau_i[\tilde{t}_i-(1+\tau_i)\theta]}{(1+\tau_i)[(1-\theta)(1+\tau_i)+2\tilde{t}_i]^2} + \frac{\tau_i[\frac{Y^l}{1+\tau_i}-a]}{\gamma(1+\theta)\Omega^2}\right]\left[\frac{\gamma(1+\theta)\Omega^2}{3a(1+\tau_i)[(1-\theta)(1+\tau_i)+2\tilde{t}_i]^2}\right] = 0. \end{aligned} \tag{C.7}$$

Multiplying eq. (C.7) by $3[(1-\theta)(1+\tau_i)+2\tilde{t}_i]^4(1+\tau_i)^2$ and rearranging terms yields a quadratic equation for $\tilde{t}_i^{N,R}$ given by

$$-\frac{A}{2}\tilde{t}_i^2 + B\tilde{t}_i - \frac{C}{2} = 0, \tag{C.8}$$

where the terms $A - C$ are in eq. (38) in the main text. The solution to (C.8) is then given in (38).

C.3 Proof of Proposition 3

Denote $B = B(\theta)$ and $C = C(\theta)$ as functions of θ. The optimal bonus tax $\tilde{t}_i^{N,R}$ in (38) is decreasing in θ iff:

$$B'(\theta) + \frac{2B(\theta)B'(\theta) - AC'(\theta)}{2\sqrt{(B(\theta))^2 - AC(\theta)}} < 0. \tag{C.9}$$

For $C(\theta)$, the following can be readily confirmed:

$$C'(\theta)\frac{1-\theta}{2} = -C(\theta) + 2\tau_i(1+\tau_i)(1-\theta)\gamma\Omega_a^2 > 0. \tag{C.10}$$

Therefore, if $B'(\theta) < 0$ (which holds, for example, if $\tau_i = 0$), then condition (C.9) is fulfilled immediately.

If $B'(\theta) > 0$, condition (C.9) holds iff $B'(\theta)[\sqrt{(B(\theta))^2 - AC(\theta)} + B(\theta)] < AC'(\theta)/2$. Using (C.10) and rearranging, this is equivalent to:

$$-(B'(\theta))^2 2\tau_i(1+\tau_i)(1-\theta)\gamma\Omega_a^2 < \frac{A}{4}(C'(\theta))^2 - C'(\theta)B'(\theta)\left[B(\theta) + \frac{1-\theta}{2}B'(\theta)\right] \tag{C.11}$$

Since $B(\theta)$ is a linear function of θ, we have $B(\theta) = (1-\theta)B(0) + \theta B(1)$ and $B'(\theta) = B(1) - B(0)$. Hence

$$B(\theta) + \frac{1-\theta}{2}B'(\theta) = \frac{1-\theta}{2}B(0) + \frac{1+\theta}{2}B(1) < 0 \text{ for all } \theta \in (0,1),$$

since $B(0) < 0$ and $B(1) < 0$. Therefore, the LHS of (C.11) is negative and the RHS of (C.11) is positive. Hence, condition (C.9) also holds for $B'(\theta) > 0$ and $\partial\tilde{t}_i^{N,R}/\partial\theta < 0$ is true for all levels of $B(\theta)$.

The equilibrium bonus payment is immediately seen to rise in θ from eq. (36). Also, evaluating the fixed wage expression (C.3) at the common Nash equilibrium tax rate $\tilde{t}_i^{N,R}$ in (38) gives

$$\frac{\partial\tilde{w}_i^*}{\partial\theta} = \gamma\Omega^2\frac{(2\tilde{t}_i - 3\theta - 1 - 3\tau_i\theta - \tau_i)}{((1-\theta)(1+\tau_i) + 2\tilde{t}_i)^3}\left[1 + \tilde{t}_i + \tau_i - (1+\theta)\frac{\partial\tilde{t}_i^{N,R}}{\partial\theta}\right], \tag{C.12}$$

which is negative since $\tilde{t}_i^{N,R}(\tau_i,\theta) \leq \tilde{t}_i^{N,R}(0,\theta) = t_i^{N,R}(\theta)$. Finally, (C.4) shows that the outflow of managers in response to a higher bonus tax rises in θ. $\square$

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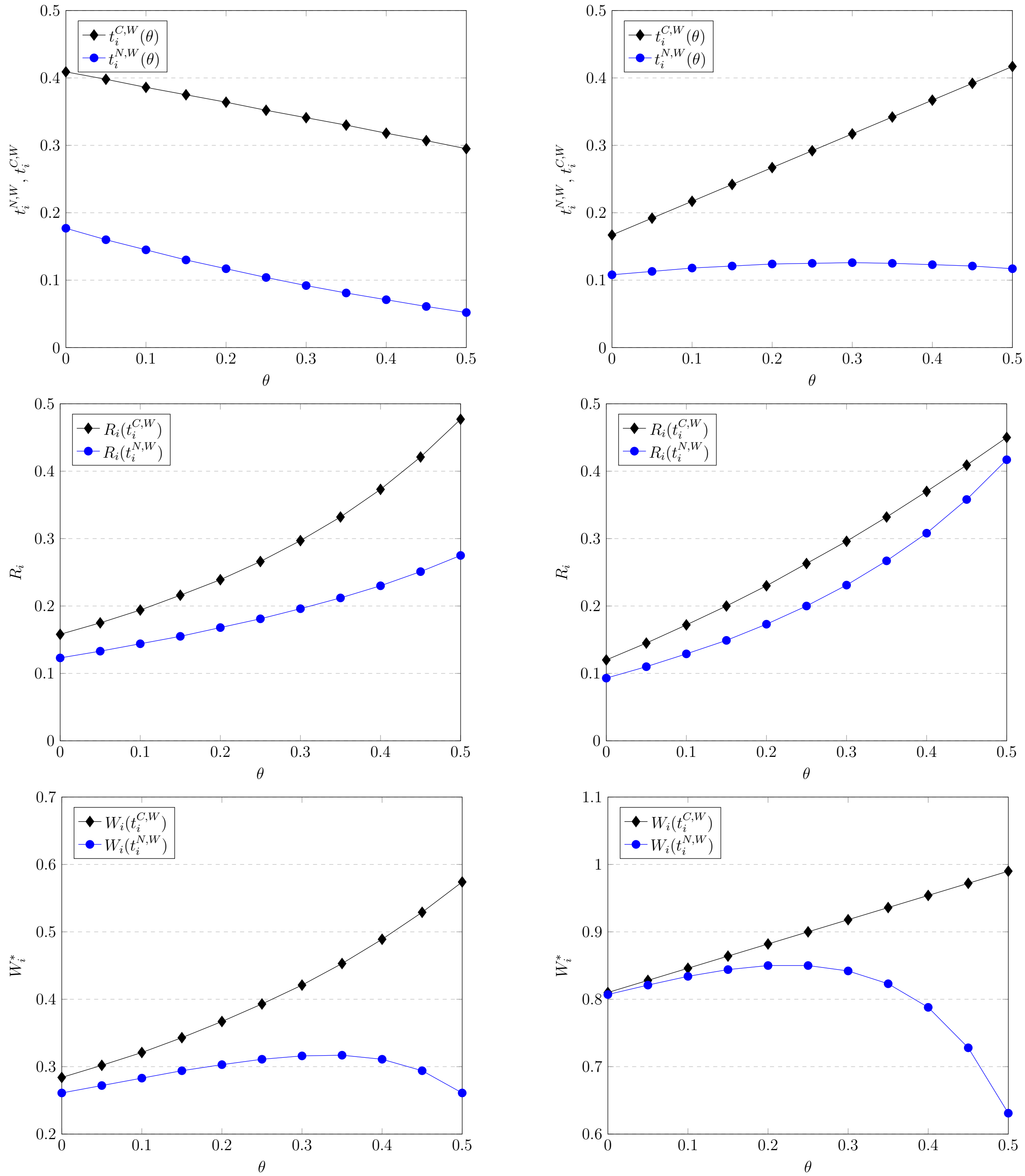
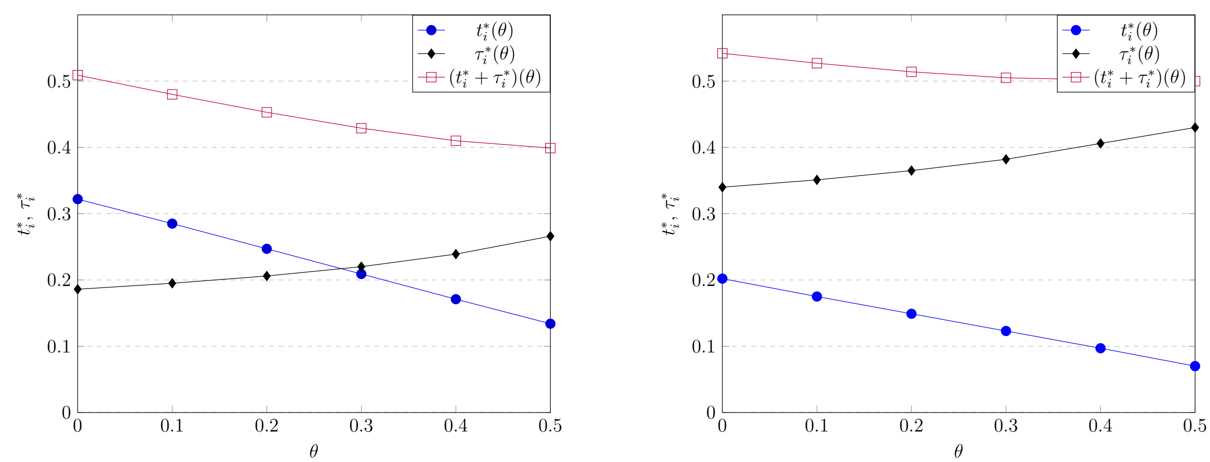


(a) Low λ case ($\lambda = 0.1$)

(b) High λ case ($\lambda = 0.5$)

Figure 1: Changes in θ under cooperative and non-cooperative tax policies



(a) Low mobility ($a = 0.6$)

(b) Intermediate mobility ($a = 0.5$)

Figure 2: Tax effects of changes in θ under two-tier income taxation