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Tournaments, Risk Aversion and Taxation

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Abstract: In this paper's tournament model the effect of income taxes on workers' effort depends on risk preferences. At risk neutrality and low levels of worker risk aversion effort falls with higher taxes, whereas with sufficient risk aversion effort increases in response to tax rises. In the former case, firms respond to higher taxes by reducing the wage spread and by increasing it in the latter case. It sheds light on why top earners' income has risen with tax reductions over the last five decades. With females being more risk averse it suggests tax reductions contribute to the CEO gender pay gap.

Keywords: Tournaments, taxes, risk-aversion, CEO pay.

JEL classification: J01, H31.

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1. Introduction

Over the last forty to fifty years most OECD countries experienced top tax rate falls coupled with an increase in the top income earners' share of GDP. In the US for instance the top marginal wage tax rate fell from 90 % in the early sixties to a current top marginal tax rate around 35%. In the same period the US top 1% of earners income share rose from approximately 8% to approaching 20%. Atkinson and Leigh (2010), find significant effects of tax changes on the very richest in Australia, Canada, New Zealand, the United Kingdom and the United States in the period 1970 to 2000. Their study finds a co-movement of top 1% income and the marginal tax rates in these countries and estimates the changes in the tax rates over this period can account for between one third and one half of the increase in the shares of the top 1% income groups.¹

This paper seeks to use tournament theory to gain new insight for the empirical regularity outlined above. It is as such the first article to investigate the effects of taxes on wage spreads within rank order tournaments, when the participating workers are risk averse. It extends traditional theory and provides an illustration of how competing employees' effort level responses to changes in taxation depend on their level of risk aversion. This then is shown to have important knock-on implications for the firms' design of tournaments and their choice of the wage spread between winners and losers when taxes change. Thus the model sheds light on the impact of labour taxes on the distribution of wages within firms, providing a useful framework that may help to explain some of the movement of top earners' income in response to changes in labour taxes over the last half century or so.

Ask a simple tournament related question: Does a proportional tax imposition increase or reduce effort levels? In the standard literature where competitors are risk neutral the answer is simple. It will reduce effort level, as the proportional tax will effectively reduce the

¹ Whilst the marginal tax rates of labour have fallen, Piketty and Saez (2007) indicate that progressivity has also been affected by a drop in corporate, estate and gift taxes. See Piketty and Saez (2001) and (2003) for further discussions on the determinants of income distribution.

difference between, that is the spread of, the after tax wages of winners and losers in the tournament. With risk aversion, and its accompanying diminishing utility of state contingent consumption, the answer is somewhat more complicated. Whilst imposing a proportional tax rate reduces the monetary difference between winning and losing, it also reduces the state contingent income levels to where the marginal utility of net income is greater. Though the wage spread falls, the difference in utility between winning and losing may actually rise under certain circumstances. This in turn implies that an increase in the proportional tax rate may increase the supply side effort level of workers rather than decrease it as previously found. How workers respond to taxes will then impact on the firms' demand side decisions of how to set the wage spread.

Whilst tournament theory has been used to explain why workers are paid progressively more within a firm hierarchy, the literature has little to say about how the wage distribution is affected by changes in taxation with one main exception by Persson and Sandmo (2005). The main and ex ante surprising insight of their paper is that firms respond to the reduction in the take home wage spread, a higher marginal tax rate implies, by increasing the pre and sometimes post wage-tax distribution. Thus taxes which are meant to redistribute may have a perverse effect on equity. Though their result is intuitively appealing, it does not fit recent decades' empirical experience of increasing inequity with falling top marginal tax rates. Our paper extends the Persson and Sandmo analysis and illustrates that their result does not necessarily hold. The model that follows demonstrates their result is valid only when workers are sufficiently risk averse under the condition means tested transfers from the state, and that with low levels of risk aversion their result may be reversed.

We apply the tournament theory in the rank order tradition by Lazear and Rosen (1981), since it is a particular good candidate for explaining wages at the upper levels of a firm's hierarchy and by implication the behaviour and wage outcome of top earners. The theory predicts, see e.g. Rosen (1986), that there will be an increasing ratio of pay between stages in a

firm's hierarchy. Evidence of this is found in the empirical work by Bognanno (2001), who finds pay rises strongly with hierarchical level. Furthermore, Baker, Gibbs and Holmstrom (1993), (1994a) and (1994b) find most hiring occurs at the lower levels of a firm, indicating that the internal labour market implied by tournament models may be more appropriate at higher levels within a firm hierarchy where there is less use of outside hires. They also show that salary as a function of level is increasing and highly convex as predicted by tournament theory. In this they are not alone. Lambert et al. (1993) also offer support for the convexity of the pay structure, whilst Eriksson (1999) similarly found a stable convex relation between Danish compensation and the level of jobs in a hierarchy.

Whilst most articles in the literature on contests assume risk neutrality some authors have considered risk aversion, such as for instance Skaperdas and Gan (1995) and Cornes and Hartley (2003). Though there in addition are some rank order tournament models in the labour market literature where risk aversion play a role these are relatively few.² The risk neutrality imposition most commonly assumed in the literature has the advantage of computational simplicity and clarity in results at virtually no sacrifice or cost. Indeed the usual effort inducing effects arising from a higher wage spread or lower levels of noise under risk neutrality see an easy transfer to tournament models with risk aversion. Yet the application of realism through the utilisation of risk aversion really does matter to the predictions of the question of how taxes affect tournaments. In part it is this realisation that clearly distinguishes this study from Persson and Sandmo (2005), who rely on the assumption of risk neutral workers, which implies workers will invariably reduce effort levels in response to the tighter spread between the loser's and the winner's take home wage that follows an imposition of or

² Whilst the initial rank order tournament exposition by Lazear and Rosen (1981) discusses risk aversion, most papers in the subsequent literature assumes risk neutrality with little loss of generality. There are however some notable exceptions, such as Kränkel (2008) who investigates risk taking with risk aversion in tournaments, and Green and Stokey (1983) who contrast the outcomes of contracts versus tournaments when workers are risk averse.

increase in the marginal tax rate on labour income. In contrast we will demonstrate that this is not always the case here.

What follows is a demonstration of how the qualitative directions of effects are critically dependent upon the degree of risk aversion. When risk aversion is high enough, we will demonstrate that workers increase their effort in response to the lower wage spread induced by a rise in taxes. Whilst this is a result of some straight forward intuition, it is on the face of it a surprising result as it seems to suggest that it is the more risk averse workers who will reduce their self-protective effort, in response to an increase in the wage spread due to a reduction in taxes. This paper is thus linked to papers such as Dionne and Eeckhoudt (1985) and Konrad and Skaperdas (1993), who find that the level of self-protection may fall with higher risk-aversion. Also relevant is Skaperdas and Gan (1993), who find in contests of limited liability that participants who are more risk averse exert higher effort than the less risk averse contestants.

The paper is further linked to the literature that seeks to investigate the underlying causes of the observed increase in top executive remuneration. Whereas Bebchuk et al. (2002) suggest that it is managerial power and rent seeking of executives at the expense of shareholders and owners that has driven the rise in CEO pay, Murphy and Zábojník (2004) suggest it is driven by increased competition for top executives. Similar competitive measures are present in Gabaix and Landier (2008) who link CEO pay to firm size. We offer an alternative approach and suggest a theoretical tax and tournament argument for why a firm, with high paid tournament contesting employees, may have increased the wages for these individuals in response to tax changes.

With females exhibiting different risk attitudes than males, one could expect to see a difference in the female-male wage differentiation in the upper echelons of a firm's internal labour market structure as for instance argued in Kulich et al. (2011). It is as such linked to literature that suggest female CEO's are likely to be paid less than their male counterparts as

outlined in several studies such as Bartlett and Miller (2005) and Wanzenried (2006). Arulampalam et al. (2007) find further the gender pay gap increases as one moves up the wage distribution. Whilst we will not directly comment on the pay gap, we will discuss the effect taxation has on the wage spread within a tournament, and thus by implication draw tentative conclusions as to the likely effect it has on the payoff spread between winning and losing females.

Our unusual result that it is possible to find effort increasing in response to a reduced spread of after tax wages, can be linked to a growing literature that questions the relationship between performance related pay and effort. A recent example of this is Kvaløy and Olsen (2014), who show that uncertainty in the enforcement of contracts may lead to less effort but stronger incentives being offered by firms, thus potentially generating a negative association of effort and performance related pay. There is also a literature where extrinsic incentives can crowd-out the intrinsic desire to conduct one's duties, see the survey by Frey and Jegen (2001) for early work. Other works include Bénabou and Tirole (2006) and Ellingsen and Johannesson (2008), where high powered incentives, such as performance related pay, may destroy the prosocial behaviour of the agent/worker. Lack of pro-social behaviour could in a tournament setting lead to further erosion of the effort payment relationship through industrial politics mechanisms, outlined in Lazear (1989), which demonstrates how wage compression can arise in order to avoid undesirable sabotage activities between workers in a firm. Finally, a question whether the observed difference in effort is due to selection rather than incentives is still unresolved in the literature. For instance in an empirical study of rank order tournaments, Leuven et al. (2011) find no effort effect of prizes when they control for sorting of workers.

A further strand of literature that relates to our paper includes work by Rodriguez (1998) and Moene and Wallerstein (2001), who find more redistribution in countries that have a higher degree of wage dispersion prior to taxes being imposed. There may be several reasons for this. Guvenen et al. (2014) for instance argue that human capital returns are lower in more

progressive tax regimes and find human capital accumulation differences can account for about half the difference in wage distribution between US and Europe. Whereas some theoretical models in the political economy tradition, Benabou (2000) and Hassler *et al.* (2003) who discuss multiple equilibria, find equitable societies favour a higher degree of redistribution, others follow the tradition of Meltzer and Scott (1981) where a high mean income relative to the income of the median voter, that is higher inequality, will lead to more redistribution. We propose an alternative theory, where the wage dispersion within tournaments is endogenous and an increase in tax progressivity imply a tighter (wider) wage dispersion when risk aversion is low (high) enough.

Whilst tournament theory provides a convincing method to investigate the matter at hand, other potential explanations may contribute to our understanding of the negative correlation between top earner share and tax rates, see Matthews (2011). First, it should be noted that top income shares in empirical studies are typically based on declared income levels. Since there is less to be gained from evading and avoiding when taxes fall, it is possible the data may simply reflect that declared income, keeping actual income constant, is negatively related to tax rates. Second, the ease at which wealth is accumulated may rise with lower taxes. Thus as taxes fall the share of GDP attributed to the richest segments of society increases. A third argument is related to labour market incentives. Meghir & Phillips (2010) argue that taxes and the incentive to exert effort of high earners may be negatively related. They make a distinction between working hours and effort and contrast their argument to standard labour supply theory where it is quite possible that increases in taxes yield stronger incentives of high income earners' to work more hours whilst they at the same time exert less effort. We do not consider such aspects but add instead to this debate by exploring a simple tournament model with worker risk aversion, which provides a separating condition for tax reductions to cause a rise in top income wages.

Since the degree of risk aversion is particularly important in this paper, we proceed by providing a short broad brush approach of evidence on risk aversion in section 2. Section 3 offers a diagrammatical presentation, whereas Section 4 proceeds with a more formal exposition of the workers' effort response to tax changes. Section 5 discusses firm behaviour and its choice of wage spread. Finally Section 6 offers some concluding comments.

2. Empirical estimates of the relative risk aversion coefficient.

Our model will demonstrate that the separating condition for effort to fall or rise with taxes is a relative risk aversion (RRA) coefficient sufficiently above one. Finding a RRA less than one implies effort falls as taxes rise, whereas effort will increase when the RRA is sufficiently greater than one. To relate our results to the real world we turn to some available evidence. Studies have utilised many different contexts to elicit risk preferences. These include consumption and investment behaviour, insurance markets, labour markets, pensions, television game shows and laboratory experiments. The RRA coefficients vary considerably in this literature, with values falling both above and below unity. Rather than providing a comprehensive survey, we discuss instead a very limited selection of papers to indicate the variability in the RRA.

An early study by Friend and Blume (1975) argues the RRA coefficient exceeds 2. Hansen and Singleton (1982) consumption study finds it falls below unity, whereas the investment study by Hansen and Singleton (1983) finds that most estimates are in the 0.26 and 2.7 range. Lottery studies by Eisenhauer and Venturaz (2003) for Italy estimate a RRA coefficient ranging between 4.5 and 13.8, and Booij and van Praag (2009) for the Netherlands find it varies between 2 and 82. In Sweden, Pålsson (1996), the RRA coefficient is estimated to be in the range between 2 and 10. In a model of labour supply Chetty (2006) argues that the RRA coefficient is bounded to be less than 2. Recent evidence in a labour market context includes

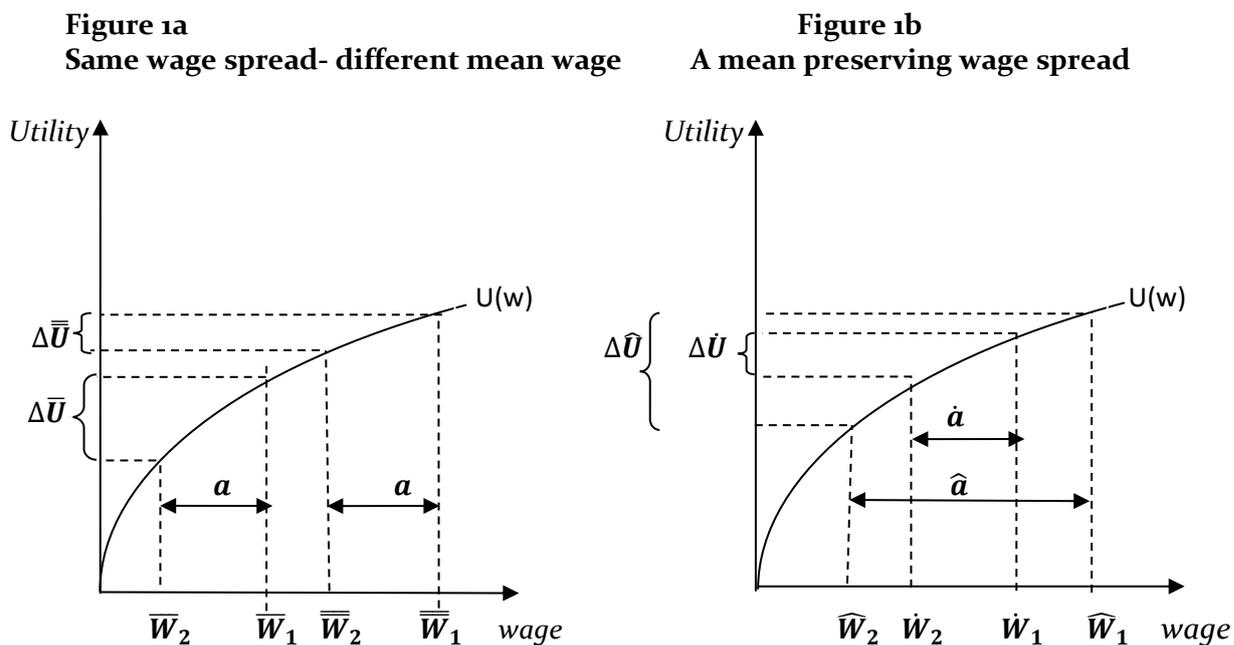
the finding by Goerke and Pannenberg (2012) stating an average individual relative risk measure of 3.04 for trade union members and 2.81 for non-members.

Meyer and Meyer (2005) review literature evidence and provide a convincing argument that the large variation in relative risk aversion could be due to differences in the measurement of outcomes, such as wealth and returns of investment. For instance, it matters to the estimation of the RRA coefficient whether human capital is included in the wealth measure. They further demonstrate that much of the variation between studies largely disappears after correcting for these measurement differences, resulting in a RRA coefficient for wealth that tends to be near but always greater than unity.

Though we are agnostic about the absolute value of the RRA measures, it should be noted that attitudes to risk and the RRA coefficient varies considerably between individuals, see e.g. Halek and Eisenhauer (2001), Cohen and Einav (2007) and Croson and Gneezy (2009). If we then take the Meyer and Meyer (2005) argument for a RRA coefficient around unity to be plausible and combine it with the considerable heterogeneity within the population, it may be reasonable to argue that one should expect to find a not insignificant number of individuals with a RRA coefficient below unity. Furthermore, there are good reasons to assume that contestants in tournaments are an adverse selection of the population. Females for instance, who tend to be less tolerant to risk, are less likely to partake in tournaments, see e.g. Levin et al. (1988) and Pålsson (1996). With high performers in the labour market being individuals who tend to have high levels of education, it becomes relevant to refer to the evidence of Shaw (1996) who found that human capital investment was negatively correlated with risk aversion. This might suggest that tournaments of high performers are likely to be an adverse selection of individuals who are relatively tolerant to risk as compared to the average individual in society. One of the more relevant papers in the literature for our purposes is Brenner (2015) who, in a large sample of US executives, find that the median executive has a RRA coefficient of 0.91.

3. A diagrammatic presentation of tournament gains.

Tournament theory with risk neutral agents demonstrates that effort is higher, *ceteris paribus*, when the wage spread between the ‘winning’ wage w_1 and the ‘losing’ wage w_2 is greater. The average wage plays a scant role in the risk neutral analysis, apart from the obvious participation constraint considerations that specify the average wage must be at least as high as elsewhere. Matters are different when risk aversion is introduced and utility is a concave function of the wage. So though risk aversion is an assumption that usually can be dropped with ease in tournament theory as it merely tends to introduce unnecessary complexity without significant changes in results, there are a couple of nuances that in themselves are small, but when combined to study the effect of a tax imposition can be shown to make a significant difference to the determination of effort. The two key effects can be summarised in figure 1a and figure 1b.



In figure 1a the wage spread a is by given by $a = \bar{w}_1 - \bar{w}_2 = \bar{w}_1 - \bar{w}_2$. It follows simply from this figure that the wage spread will yield a higher difference in utility when the mean wage is small, as is illustrated with $\Delta \bar{U} > \Delta U$. A given wage spread has its largest effect on tournament effort when wages are low in the risk averse case, since the benefit of winning in

terms of utility is highest when wages are low. It is in effect a straightforward and rather trivial reflection of diminishing marginal utility that is absent from the more conventional risk neutral tournament analysis. The tournament theory implications of figure 1b are even less demanding. As more effort is induced the larger the difference between the benefit of winning and the value derived from losing, it follows that effort increases as the spread in utility widens. In other words reducing the mean preserving wage spread from \hat{a} to \hat{a} as in figure 1b reduces the spread in utility from $\Delta\hat{U}$ to $\Delta\hat{U}$. This in turn reduces the effort of risk averse workers in the same predictable manner that is omnipresent in tournament theory with risk neutrality.

The simple intuition associated with figures 1a and 1b, allows us to offer some conjectures about the effect of a proportional tax rate imposition on wages on the willingness to exert effort. We note the tax will yield a proportional decrease in the take home wage spread, that is the difference between the after tax income of a winner and a loser. For a risk neutral individual the reduction in the net of tax wage spread will affect effort adversely as the benefits of winning have diminished. For a risk averse individual matters are more complicated. Not only does a tax imposition compress the absolute spread as in figure 1b which affects effort adversely it also reduces the workers net average pay, as illustrated in figure 1a, affecting effort positively. Reducing the net wage spread is never positive for effort inducement *ceteris paribus*, as in figure 1b, whilst moving the spread further down the utility function will tend to increase effort levels, as in figure 1a. These two opposing effects are both at play when a proportional tax is imposed or increased and the workers are risk averse. Thus the interaction of these two simple effects yields an uncertainty in the effort response to a tax change that has previously been neglected in a tournament setting.

Which or when either of the two effects dominates is at the heart of the theoretical arguments that follow. Though we have yet to provide the formal analysis, we can tentatively reflect on the utility effects of figures 1a and 1b. It is evident by casual observation of the

figures that the magnitudes of the effects are dependent on the shape, that is the concavity, of the utility function. For instance the effect of figure 1a becomes starker for more concave utility functions. Concavity in turn is a reflection of risk aversion. Thus the separating condition between effort inducing and effort preventing taxation will depend critically upon the level of risk aversion.

4. Tournaments with risk aversion.

We proceed with a formal, straightforward tournament model, allowing for either risk averse or risk neutral worker attitudes. Though worker characteristics may vary through the economy, we assume stratification implies firms construct pair-wise tournaments for observably identical workers. With the two workers denoted i and j , each choose effort level μ_i and μ_j respectively in response to the winner being rewarded the net income y_1 and the loser being paid the net income y_2 . These net incomes are only realised after the tournament has ended, wages are paid and any taxes and transfers to and from the state have occurred. The firms cannot witness effort directly but can instead observe the worker outputs, q_i and q_j that are only imperfect proxies for effort:

$$q_i = \mu_i + \varepsilon_i \tag{1a}$$

$$q_j = \mu_j + \varepsilon_j \tag{1b}$$

Where the random noise components ε_i and ε_j are most usually referred to as luck. We follow the convention of the literature and assume the random noise components cannot be ascertained by workers in advance of effort being exerted.

The winner of the tournament is the individual that has produced the most output. With identical competitors; the outcome is governed by a Nash equilibrium, where both workers exert the same level of effort. Though effort is invariant between individual competitors, the random elements typically differ, implying variation in outputs and thus pay.

In a departure from the majority of papers in the tournament literature we make no a

priori risk neutrality restrictions, but allow instead workers to be either risk neutral or averse. We assume that the objective function is separable in income and effort and that the workers' individually identical objective is comprised of the expected utility of the tournament 'gamble' net of the cost of effort. The maximisation problem of worker i involves choosing the effort level that maximises the objective function V_i :

$$\underset{\mu_i}{Max} \quad V_i = pu(y_1) + (1 - p)u(y_2) - C(\mu_i) \quad (2)$$

Where p is the probability of winning the tournament, $u(\cdot)$ is the utility derived from the state dependent income and $C(\cdot)$ is the cost function that depends on effort. The utility $u(\cdot)$ of income is increasing and concave in income, whilst the cost of effort $C(\cdot)$ is increasing but convex in effort. The problem is symmetric for worker j . Thus the equivalent optimisation problem to expression (2) is omitted for worker j . Worker i chooses the effort which is characterised by the following first order condition:

$$\frac{\partial V_i}{\partial \mu_i} = \frac{\partial p}{\partial \mu_i} (u(y_1) - u(y_2)) - C'(\mu_i) = 0 \quad (3)$$

It should be noted that the probability $p \equiv \text{prob}(q_i > q_j)$ that worker i wins the tournament can be related to the cumulative distribution function, G , of the random variable $\varepsilon_j - \varepsilon_i$, since: $p = \text{prob}(\mu_i + \varepsilon_i > \mu_j + \varepsilon_j) = \text{prob}(\mu_i - \mu_j > \varepsilon_j - \varepsilon_i) = G(\varepsilon_j - \varepsilon_i)$. It is also worth emphasising the symmetric Nash equilibrium with identical agents implies that $\mu_i = \mu_j$. It follows that $\frac{\partial p}{\partial \mu_i} = \frac{\partial G(0)}{\partial \mu_i} = g(0)$. We can therefore rewrite (3) as:

$$g(0)(u(y_1) - u(y_2)) - C'(\mu_i) = 0 \quad (4)$$

Expression (4) yields the usual result that effort will rise with a reduction of the importance of luck (an increase in $g(0)$). It also follows that effort increases when the spread of

payments widens, since an increase in the spread increases $u(y_1) - u(y_2)$.³ This result therefore translates directly from the usual rank order tournament literature. Such an outcome should come as no surprise, as it is clearly evident in the illustration given by figure 1b. However, the effect of an increase in the winner's payment as compared to a reduction in the losers payment is no longer the same, as is normally the case in the standard tournament theory with risk neutrality. Instead we have:

$$\frac{d\mu_i}{dy_1} = \frac{g(0)u'(y_1)}{\frac{\partial^2 V}{\partial \mu_i^2}} \neq \frac{d\mu_i}{dy_2} = \frac{g(0)u'(y_2)}{\frac{\partial^2 V}{\partial \mu_i^2}} \quad \rightarrow \quad \frac{d\mu_i}{dy_1} = -\frac{u'(y_1)}{u'(y_2)} \frac{d\mu_i}{dy_2} \quad (5a)$$

Where $\frac{\partial^2 V_i}{\partial \mu_i^2} = \frac{\partial^2 p}{\partial \mu_i^2}(u(y_1) - u(y_2)) - C''(\mu_i) < 0$ is a required second order condition for the maximisation of the worker's objective function.⁴

In order to gain further insight into the effects reflected by expression (5a), we note that the tournament firm does not set the winner and loser's payments y_1 and y_2 directly. Instead the firm merely sets wages, and not the after tax (and transfers) income levels. With this in mind let the respective net incomes of winning and losing; $y_1=(1-t)w_1+G$ and $y_2=(1-t)w_2+G$ be the two disposable state contingent income levels, where w_i is the pre-tax state contingent wage, t is the marginal tax on labour income and the lump sum demogrant G is a transfer from the state. It is in other words a simple progressive tax rate system where the average tax increases with income. We can now evaluate the effect of wages on effort:

$$\frac{d\mu_i}{dw_1} = \frac{g(0)(1-t)u'(y_1)}{\frac{\partial^2 V_i}{\partial \mu_i^2}} \neq \frac{d\mu_i}{dw_2} = \frac{g(0)(1-t)u'(y_2)}{\frac{\partial^2 V_i}{\partial \mu_i^2}} \quad \rightarrow \quad \frac{d\mu_i}{dw_1} = -\frac{u'(y_1)}{u'(y_2)} \frac{d\mu_i}{dw_2} \quad (5b)$$

With strict concavity of the utility function, expressions (5a) and (5b) imply the effect on effort of reducing the losers' income will be stronger than the effect on effort of an increase

³ This follows since $\frac{\partial^2 V_i}{\partial \mu_i \partial y_1} = g(0)u'(y_1) > 0$, $\frac{\partial^2 V_i}{\partial \mu_i \partial y_2} = -g(0)u'(y_2) > 0$ and $C''(\mu_i) > 0$.

⁴ We assume in the remainder of this paper that higher order derivatives of this probability are all equated to zero.

of the winner's income. As incentives are the strongest at lower wages, it could imply a tougher race to the bottom than what is commonly described in the literature. That is, tournament firms facing risk averse workers may prefer a wage spread with lower average wages for effort consideration alone, though the firms are still restricted from setting wages too low by the workers' participation constraint, as they also would be in the standard case when they face risk neutral workers.

Whilst firms set wages, the state sets taxes and transfers. These then jointly determine the net payment spread that influences effort. It is for this reason we may also be interested in the ceteris paribus supply side effect on effort of increases in taxes and transfers. By totally differentiating expression (4) above we can derive the effects of such changes on effort:

$$\frac{d\mu_i}{dG} = \frac{g(0)(w'(y_1) - w'(y_2))}{\frac{\partial^2 v_i}{\partial \mu_i^2}} \leq 0 \quad (6a)$$

$$\frac{d\mu_i}{dt} = \frac{-g(0)((w_1)w'(y_1) - (w_2)w'(y_2))}{\frac{\partial^2 v_i}{\partial \mu_i^2}} \quad (6b)$$

It is apparent the second order derivative in the denominator, common in both expressions above, has to be positive in order to satisfy the second order conditions for a maximum. Whilst expression (6a) is unambiguously positive, and implies increases in government transfers acts as a disincentive to exert effort,⁵ signing expression (6b) is more problematic. This latter expression (6b) can be positive or negative. With risk neutrality, where $wu'(y)=w$, it follows that since $w_1 > w_2$ that the sign of expression (6b) is less than zero. That is, under the normal risk neutrality assumption in the literature, a proportional tax rate increase would reduce the level of effort. This negative relationship does however not necessarily hold when we depart from risk neutrality and allow more general specifications of utility that include the possibility of risk aversion. Since we know the sign of the relationship between effort and taxes depends on the numerator we can now write:

⁵ Strict inequality of expression (6a) applies if we exclude the possibility of risk neutrality.

$$\frac{d\mu_i}{dt} \gtrless 0 \text{ if } w_1 u'(y_1) - w_2 u'(y_2) \gtrless 0 \quad (7a)$$

With $w_1 > w_2$ this in turn implies:

$$\frac{d\mu_i}{dt} \gtrless 0 \text{ if } \frac{\partial(wu'(y))}{\partial w} \gtrless 0 \quad (7b)$$

The condition as expressed by (7b) therefore depends on:

$$\begin{aligned} \frac{\partial(wu'(y))}{\partial w} &= u'(y) + (1-t)wu''(y) \\ &= u'(y) + (G + (1-t)w)u''(y) - Gu''(y) \\ &= u'(y)(1 - RRA) - Gu''(y) \end{aligned} \quad (8)$$

Where the relative risk aversion coefficient RRA, is such that $RRA = -\frac{yu''(y)}{u'(y)}$. We can from expressions (7b) and (8) make several observations. First, note with risk neutrality that both RRA and the second order derivative of the utility function are zero. Here the derivative on the left hand side of expression (8) is strictly positive if RRA equals zero. Thus effort will decrease with tax rises for the risk neutral. Second, it follows by extension that effort will also fall in response to higher taxes, with risk aversion when the RRA is less or equal to one and transfers from the state are positive. Third, matters are more complex when RRA exceeds unity. Here effort could either increase or decrease depending on the relative opposing effects in (8). Fourth, and however, consider the simplified case where government transfers are insignificant and set equal to zero. Such a situation may be more plausible than it first appears, when one considers the increasing trend for means tested benefits, which are only paid out to individuals under a certain threshold income. With tournaments occurring at the top end of the income distribution it is therefore possible that the effective transfers to both individual tournament participants are close to zero. Under such circumstances we can write.

$$\frac{d\mu_i}{dt} \gtrless 0 \text{ if } RRA \gtrless 1 \quad \text{when } G=0 \quad (9)$$

Here effort will increase in response to rising proportional tax rates as long as the relative risk aversion exceeds unity. Thus despite the fact that the wage spread is decreasing, the more risk averse participant, with a RRA exceeding unity (and $G=0$), will seek more self-protection through higher effort levels. The converse is true for lower relative risk aversion coefficients, below unity. Again we refer to the simple intuition that accompanies figures 1a and 1b. The overall effect of a tax increase on the spread of utility is a compound effect: Though a tax increase always renders the worker worse off irrespective of the risk aversion coefficient, it will increase the spread between winning and losing in terms of utility for sufficiently concave utility functions. This will therefore have the novel effort increasing effect in response to higher taxes. And it is this simple intuitive result which sets this paper apart and which drives some of the remaining results. It is worth reminding ourselves of the literature which typically have, according to Meyer and Meyer (2005) risk aversion coefficients close to but exceeding unity, but nevertheless noting the considerable heterogeneity amongst individuals. Linking tournament theory to CEO pay it is therefore constructive to note again Brenner (2015) who found that top executives typically have risk aversion coefficients less than unity, implying that top executives are likely to respond to higher taxes by reducing their effort level.

Restricting our analysis to the case when the transfers from the state are zero may matter less than what one might expect, as relaxing this assumption will retain the same qualitative results. Indeed it remains the case when $G>0$ that the more risk averse the individual is the more likely it is that effort will increase with taxes. However, the critical relative risk aversion coefficient where workers above which they increase effort in response to tax increases has change somewhat. We now note that a $RRA=1$ will yield lower effort in response to tax-rises when $G>0$. Sufficiently more risk averse individuals will however respond to higher taxes by exerting more effort levels as previously anticipated. Whilst we will look at the case of $G>0$, when we discuss the balanced budget approach below, we will in order to

keep matters simple in section 5 return to the case where the tournament contesting individuals have incomes above the means tested threshold so that they receive no government transfers.

This is not all, however. Both transfers and taxes will also influence the effectiveness of wage spreads on effort. Thus a series of comparative statics results follow which in turn can be compared and contrasted to results found in previous literature:

$$\frac{\partial^2 \mu_i}{\partial w_1 \partial G} = \frac{g(0)(1-t)u''(y_1)}{\frac{\partial^2 V_i}{\partial \mu_i^2}} < 0 \quad (10a)$$

$$\frac{\partial^2 \mu_i}{\partial w_2 \partial G} = \frac{-g(0)(1-t)u''(y_2)}{\frac{\partial^2 V_i}{\partial \mu_i^2}} > 0 \quad (10b)$$

$$\frac{\partial^2 \mu_i}{\partial w_1 \partial t} = \frac{-g(0)((1-t)w_1 u''(y_1) + u'(y_1))}{\frac{\partial^2 V_i}{\partial \mu_i^2}} = \frac{-g(0)u'(y_1)(1-RRA) - g(0)Gu''(y_1)}{\frac{\partial^2 V_i}{\partial \mu_i^2}} \begin{matrix} \geq 0 \text{ when } RRA \geq 1 \\ \text{and } G=0 \end{matrix} \quad (10c)$$

$$\frac{\partial^2 \mu_i}{\partial w_2 \partial t} = \frac{g(0)((1-t)w_2 u''(y_2) + u'(y_2))}{\frac{\partial^2 V_i}{\partial \mu_i^2}} = \frac{g(0)u'(y_2)(1-RRA) - g(0)Gu''(y_1)}{\frac{\partial^2 V_i}{\partial \mu_i^2}} \begin{matrix} \leq 0 \text{ when } RRA \geq 1 \\ \text{and } G=0 \end{matrix} \quad (10d)$$

Expressions (10a) and (10b) together demonstrate that the effect a given wage spread has on effort depends on the level of transfers from the state. In short; effort falls for a given pre-tax wage spread if transfers from the state increase. There is nothing particularly surprising or novel about this result, which simply says that transfers from the state to both winner and losers acts as a disincentive to effort levels, or more precisely that increasing the wage spread will have a smaller effect on effort when transfers are high.

More interesting is the supply side effect of the wage spread on effort as taxes vary, that is reflected by expressions (10c) and (10d). Here the effect of the wage spread on effort will vary dependent on both taxes and the relative risk aversion coefficient. When the RRA is greater than one, we know from before that effort will increase with taxes, whereas the opposite is the case when it is less than unity. Now for the first time we can deduce that an increase in tax will magnify the effect of a change in the wage spread has on effort when the RRA is greater unity.

Here an increase in the wage spread will have a bigger effect on effort when taxes are high. This should be contrasted to the case when the RRA is less than one, where the wage spread effect on effort falls as taxes increase.

Before we proceed with the analysis of how firms respond it may be useful to investigate the special case where the tax revenues collected in the tournament are used to finance the government transfers to the tournament participants.

A balanced tax budget tournament.

Assume now that the contract is such that the taxes generated from the winner and loser in the tournament, benefit nobody outside the tournament but are instead only used to pay for the transfers the two competing workers receive from the state. We refer to this as a balanced tax budget tournament. Note in the vast majority of cases that this is fairly implausible. For instance it is unlikely that a well-paid worker, who is competing for a CEO position but who is unsuccessful, will be in a net positive receipt of transfers from the state. It is likewise unlikely that a tournament lower down the income distribution is such that the net tax liability is exactly offset between winner and loser. Though it is not particularly realistic and will not be used extensively in what follows in the following sections, it is a useful benchmark. So leaving plausibility aside for the time being, consider a two person world where government taxes equals transfers, such that the average transfer G is given by $G=t(w_1+w_2)/2$. An increase in government involvement is then reflected by a high t which thereby facilitates a higher G . Now expression (4) reflects the optimal choice of effort also in the balanced budget case. Using this and noting that $u(y_1) = u\left((1 - \frac{1}{2}t)w_1 + \frac{1}{2}tw_2\right)$ and $u(y_2) = u\left((1 - \frac{1}{2}t)w_2 + \frac{1}{2}tw_1\right)$ we can investigate a balance budget increase in tax on individual supply side effort:

$$\frac{d\mu_i}{dt} = \frac{g(0)\frac{1}{2}(w_1-w_2)(u'(y_1)+u'(y_2))}{\frac{\partial^2 V_i}{\partial \mu_i^2}} < 0 \quad (11)$$

We therefore arrive at the result that increasing taxes and benefits will reduce effort levels. Though this result concludes that greater state involvement is associated with lower levels of effort, it is predicated on a highly stylised tournament model where the winner's net contribution in taxes exactly offsets the loser's net gain in transfers. In a society with just two members or types of workers this interpretation may make perfect sense. Here the poorest citizen, the loser of the tournament, gets a net transfer from the richest in society, the winner of the tournament. However in a more realistic setting a balanced budget approach may be stretching the model a little too far. Tournaments within firms are seldom organised in such a way that competing participants contain both individuals who come from the top and the bottom end of the wage distribution. Indeed, as follows from previous discussion, this is hardly representative of most labour contracts or tournament contests within firms. Again we appeal to the argument that tournament theory is more appropriate for the upper levels of a firm's hierarchy where there is a relative high rate of promotion internally, see e.g. Baker et al. (1994a, 1994b). Thus a worker who partakes in a tournament at the upper levels of a firm hierarchy, which the worker ends up losing, is still likely to remain a high income earner who in a progressive tax system will remain a net contributor of taxes. We will therefore, in contrast to the monopsonistic analysis contained in Persson and Sandmo (2005), not investigate the balanced budget approach further but instead proceed in the following section with the unbalanced budget approach, where $G=0$.

5. The choice of wage spread.

We have so far restricted our study to supply side effects only. This leaves the analysis far from complete, for to determine the resulting wage distribution it is not enough to merely know how much effort workers exert at a given wage spread or how workers change their effort in taxation regimes. We must also consider actions by the tournament firm, that is we must include demand side behaviour to complete our investigations. Whereas workers on the

supply side choose their optimal effort in the response to the wage profile within the firm, the firm sets the wage profile optimally in order to maximise profits. By incorporating the firm's decision making into our model, as outlined below, we are able to close the model and pin down the wage distribution at the top end of the firm's hierarchy, to further draw inferences about the effect of the tax system on top earners.

When the firm sets the wage spread in the tournament he does so in the full knowledge of how the workers will respond, the manner of which is outlined above, with the sole purpose of maximising profits. Noting the expected output is identical to effort and normalising prices to one, the ex ante profit the firm derives from each homogenous worker is simply the effort less the expected average wage. We assume that the optimisation programme facing the firm is such that the firm will seek to maximise its profit, π , subject to the workers' participation constraint that specify the value, V , to the representative worker of a tournament has to exceed his outside (employment) option \bar{V} .⁶ Thus the following optimisation programme applies:

$$\begin{aligned} \text{Max}_{w_1, w_2} \quad \pi &= \mu - \left(\frac{1}{2}w_1 + \frac{1}{2}w_2\right) & (12) \\ \text{s.t.} \quad pu((1-t)w_1 + G) &+ (1-p)u((1-t)w_2 + G) - C(\mu) \geq \bar{V} \end{aligned}$$

A standard Lagrangean \mathcal{L} , with the associated Lagrangean multiplier λ , is then straightforwardly defined. Optimisation follows simply and is reflected in the resulting first order conditions:

$$\frac{\partial \mathcal{L}}{\partial \lambda} = \bar{V} - \{pu((1-t)w_1 + G) + (1-p)u((1-t)w_2 + G) - C(\mu)\} = 0 \quad (13a)$$

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial w_1} &= \frac{\partial \pi}{\partial w_1} - \lambda \frac{\partial V}{\partial w_1} \\ &= \frac{\partial \mu}{\partial w_1} - \frac{1}{2} - \lambda \left(p(1-t)u'(y_1) + \frac{\partial \mu}{\partial w_1} \left(\frac{\partial p}{\partial \mu} (u(y_1) - u(y_2)) - C'(\mu_i) \right) \right) = 0 \end{aligned} \quad (13b)$$

⁶ We henceforth drop the subscript i , as workers are identical.

$$\begin{aligned}
\frac{\partial \mathcal{L}}{\partial w_2} &= \frac{\partial \pi}{\partial w_2} - \lambda \frac{\partial V}{\partial w_2} \\
&= \frac{\partial \mu}{\partial w_2} - \frac{1}{2} - \lambda \left((1-p)(1-t)u'(y_2) + \frac{\partial \mu}{\partial w_2} \left(\frac{\partial p}{\partial \mu} (u(y_1) - u(y_2)) - C'(\mu) \right) \right) = 0
\end{aligned} \tag{13c}$$

This system of equations then characterises the chosen wage spread in the tournament. By applying risk neutrality, where $u'(y_1) = u'(y_2) = 1$, to the above expressions it follows that we have $C'(\mu) = 1 - t$, recovering the optimising expression from Persson and Sandmo (2005). However, with risk aversion of workers matters are a little more complicated. In order to proceed we make three observations and/or assumptions. First, given the identical workers, both have an equal probability of winning or losing the tournament, that is $p = 1/2$. Second, from previously, by the application of the envelope theorem, we have $\frac{\partial p}{\partial \mu} ((u(y_1) - u(y_2)) - C'(\mu)) = 0$. Third, we assume a symmetric tax incidence so that taxes/benefits affect the tournament and outside option in equal measures, that is $\frac{dV}{dt} = \frac{d\bar{V}}{dt}$ and $\frac{dV}{dG} = \frac{d\bar{V}}{dG}$.⁷ By total differentiation of the first order conditions we derive the following matrix equation:

$$\mathbf{A} \begin{bmatrix} d\lambda/dt \\ dw_1/dt \\ dw_2/dt \end{bmatrix} = \mathbf{b}^t \tag{14}$$

Where:

$$\mathbf{A} = \begin{bmatrix} 0 & -\frac{1}{2}(1-t)u'(y_1) & -\frac{1}{2}(1-t)u'(y_2) \\ -\frac{1}{2}(1-t)u'(y_1) & \frac{\partial^2 \mu}{\partial w_1^2} - \frac{\lambda}{2}(1-t)^2 u''(y_1) & \frac{\partial^2 \mu}{\partial w_1 \partial w_2} = 0 \\ -\frac{1}{2}(1-t)u'(y_2) & \frac{\partial^2 \mu}{\partial w_1 \partial w_2} = 0 & \frac{\partial^2 \mu}{\partial w_2^2} - \frac{\lambda}{2}(1-t)^2 u''(y_2) \end{bmatrix}$$

$$\mathbf{b}^t = \begin{bmatrix} 0 \\ -\frac{\partial^2 \mu}{\partial w_1 \partial t} - \frac{1}{2}\lambda(u'(y_1) + (1-t)w_1 u''(y_1)) \\ -\frac{\partial^2 \mu}{\partial w_2 \partial t} - \frac{1}{2}\lambda(u'(y_2) + (1-t)w_2 u''(y_2)) \end{bmatrix}$$

⁷ This is not as much an assumption as it follows from the envelope theorem that if the workers optimise their effort within the firm and as well as in the outside option firm that $\frac{dV}{d\mu} = 0$ and $\frac{d\bar{V}}{d\mu} = 0$. It then follows that $\frac{dV}{dt} = \frac{dV}{d\mu} \frac{d\mu}{dt} = 0$, $\frac{d\bar{V}}{dt} = \frac{d\bar{V}}{d\mu} \frac{d\mu}{dt} = 0$, $\frac{dV}{dG} = \frac{dV}{d\mu} \frac{d\mu}{dG} = 0$ and $\frac{d\bar{V}}{dG} = \frac{d\bar{V}}{d\mu} \frac{d\mu}{dG} = 0$.

Note that the determinant of the bordered Hessian A has to be positive in order to satisfy the requirement for a maximum.⁸ That is: $|A| = -\left(\frac{1}{2}(1-t)u'(y_2)\right)^2 \left\{\frac{\partial^2 \mu}{\partial w_1^2} - \frac{\lambda}{2}(1-t)^2 u''(y_1)\right\} - \left(\frac{1}{2}(1-t)u'(y_1)\right)^2 \left\{\frac{\partial^2 \mu}{\partial w_2^2} - \frac{\lambda}{2}(1-t)^2 u''(y_2)\right\} > 0$.

Let us consider the case where government transfers are means tested so that $G=0$.⁹ There are then two separating cases to consider; first when the relative risk aversion (RRA) coefficient is less than unity and second when it is (sufficiently) greater than unity.

Case 1; when $RRA < 1$.

We refer to the appendix where it is shown that $|A_2^t| < 0$ when $RRA < 1$. Thus by Cramer's rule we have $\frac{dw_1}{dt} = \frac{|A_2^t|}{|A|} < 0$, when $RRA < 1$. In this case an increase in taxes will reduce the wage offered to winning workers by the firm. Thus more redistribution reduces the wages of the top earners. We also note that $|A_3| > 0$. Thus by Cramer's rule we have $\frac{dw_2}{dt} > 0$, when $RRA < 1$. That is, as taxes increase the firm will for these worker preferences increase the losers' wage. We now denote the before tax wage spread as $R = \frac{w_1}{w_2}$. The effect on this wage spread of an increase in tax-rates can be shown to be given as: $\frac{dR}{dt} = \frac{\frac{dw_1}{dt}w_2 - w_1\frac{dw_2}{dt}}{w_2^2}$. This is unambiguously negative as long as $RRA < 1$. It is now evident the before tax wage distribution, between winners and losers, narrows with an increase in tax. Intuitively, as figures 1a and 1b illustrate, the relative gain between winning and losing falls with higher taxes when the relative risk aversion coefficient is low enough. This then implies that if the relative risk aversion coefficient is less than unity effort falls, as is demonstrated by expression (9). Hence the relative gain to the firm of increasing wage dispersion falls for the firm, as reflected by expressions (10c) and (10d)

⁸ All the derivations of subsequent determinants required for our results are given in the Appendix.

⁹ This is merely done for simplicity to shorten the proofs in the appendix and to provide a clearer and simpler discussion. Relaxing this restriction has no qualitative effect on the results. Of the two following cases, Case 1 remains unchanged when $G > 0$, whereas in Case 2 the relative risk aversion coefficient would have to be sufficiently above unity for the same results to carry through when $G > 0$.

when $RRA < 1$. Firms therefore reduce the wage spread in response to higher taxes when risk aversion is low. For the sake of completeness it is a result that also holds in the limit when the worker is risk neutral.¹⁰

Note now that this case results in a consistency with the empirical regularity of tax rates and top income earnings being negatively correlated, when taken together with Brenner's (2015), finding that top executives have RRA's falling short of unity. Indeed, it follows from the above theoretical results that reductions in taxes will imply top earners, the winners of the tournament, will earn more both before and after taxes. As taxes fall the top earners increase their effort, whilst firms respond by increasing the wage spread in the tournament.

Case 2; when $RRA > 1$.

When on the other hand $RRA > 1$ the results are diametrically opposed to Case 1. Note it follows from (9) that effort increases with higher taxation for the more risk averse, that is $\frac{d\mu}{dt} > 0$ when $RRA > 1$. As the appendix shows $|A_2^t| > 0$ and $|A_3| < 0$ when $RRA > 1$ we have by applying Cramer's rule both $\frac{dw_1}{dt} > 0$, and $\frac{dw_2}{dt} < 0$. The effect of taxes on the wage spread of an increase in tax-rates, $\frac{dR}{dt} = \frac{\frac{dw_1}{dt}w_2 - w_1\frac{dw_2}{dt}}{w_2^2}$ is therefore unambiguously positively as long as $RRA > 1$. Here the firms respond to tax rate changes by increasing the wage spread. This is again reflected by the findings of expression (10c) and (10d) that sees the effect of increasing the wage spread is amplified by higher taxes when $RRA > 1$. Any increase in taxation for redistributive purposes would in this case of relative high risk aversion lead to the unintended perverse consequence of increasing the spread between the winner and loser of wage contests, which in turn will lead to within firm inequality.

¹⁰ Whilst this finding may at first appear to contradict Persson and Sandmo (2005) it should be noted their monopsony result was predicated on a balanced budget approach in contrast to the unbalanced budget framework in the present model.

A response to a drop in taxes could perversely be met by a reduction of effort in this case, that leads the firm to find it less profitable to maintain a high wage spread. The firm therefore could choose to offer a more compressed tournament wage structure to the more risk averse following a fall in taxes. If firms are able to statistical discriminate between groups, it could turn out to have important equity implications. For the winning individuals belonging to more risk averse groups, such as females and non-executives, could very well see the gains of winning a tournament being diminished with falling taxes. It links to the literature on female executive pay, which typically finds females receive lower remuneration than their male counterparts, see e.g. Elkinawy and Stater (2011) who interestingly find that this difference is more pronounced for lower level executives. This is consistent with our results and Brenner's (2015) finding that lower level executives are on average more risk averse than higher level executives.

Overall remarks concerning both cases.

By considering Case 1 and Case 2 together a certain sense of fairness follows. Taxes reduce effort levels for low risk aversion workers. In this event the workers are doubly punished: First by the lower disposable income taxes imply and then second by the firm's response of further lowering the top earning/winner's wage. The story is opposite for highly risk averse individuals who respond to higher taxes by increasing their effort, for which they are at least partially compensated by an increase in their top earning wage. In summary both cases illustrate a reward to effort, through the positive relationship between effort and the top earner's remuneration. If we therefore believe our tournament explanation of the rise in remuneration of top earners is a consequence of the drop in taxes, it is worth noting that this rise in wages has not been costless to these executives who now exert more effort than previously.

The overall effect of taxes on tournament wages and the distribution of wages within firms are complicated. With the top executive in a firm being the ultimate winner of the tournament

structure within a firm, and in the terms of Rosen (1981) the 'superstar', the effect of the reduction in taxes on top executive pay may be easily predictable. For if we appeal to Brenner (2015) who finds that the median relative risk aversion coefficient is 0.91 for executives within firms and top executives having lower risk aversion on average, Case 1 is simply applicable, implying higher CEO remuneration in response to a drop in the marginal tax rate on wages. Thus our model fits the data well. However, the effect of the tax reduction on wages lower down a firm hierarchy may be less easy to ascertain. Here, it is possibly with support of Brenner, who find lower level executives are more likely to be more risk averse, that the relative risk aversion coefficient could exceed unity. We are then in the realms of Case 2 which should see a wage compression as a result of the tax reduction. In other words, the winners of the lower level executive tournament will experience lower wages and the losers higher wages as a result of the tax reductions. Hence some workers lower down the hierarchy will experience lower whereas others higher wages. As a result the overall tax effect on the wage of any tournament participating lower level executive is a priori uncertain. We note that this complexity mirrors the empirical results of Saez (2004) for the US 1960-2000 who finds significant effects of the marginal tax rate on the top 1 % of earners' income share, whilst very small effects on the top 1%-5% and the top 5%-10% earner's income share. In his and in our paper; clarity and the effect of taxes on wages is more striking for the top earners, whilst matters are more complex lower down the income distribution,

6. Conclusion and discussion.

We have shown in the following paper that tournament workers' risk attitudes are important in determining their supply side effort response to changes in the marginal tax rate on labour income. This will in turn influence the firm's design of tournaments so that the wage spread within single tournaments should narrow with increasing taxes for the relatively less risk averse participant and conversely widen with the relatively more risk averse participant. With

CEO's being relatively less risk averse than other groups in society it may therefore be true that top earners' income is negatively related to the tax rate. Thus we argue the wage distribution should narrow in response to tax rises within the upper parts of the firm's hierarchy. We conjecture as this happens in each firm with tournaments as an incentive mechanism for top executives that within society there will be a compression at the top end of the wage distribution as taxes increase and conversely a widening as taxes fall. The analysis provides a taxation reason for the empirical observation of the increasing remuneration of top earners over the last few decades in response to lower taxation. Furthermore work attitudes to risk matters to how firms choose to design competitive tournaments, implying that participants who belong to more risk averse groups, such as females and lower level executives, should have seen a compression of their wages in response to the experience of falling tax rates whilst at the same time seen a fall in the top wage they could potentially earn.

APPENDIX

Assume throughout appendix that $G=0$.

Sign of $|A_2^t|$:

Define A_2^t as:

$$A_2^t = \begin{bmatrix} 0 & 0 & -\frac{1}{2}(1-t)u'(y_2) \\ -\frac{1}{2}(1-t)u'(y_1) & -\frac{\partial^2 \mu}{\partial w_1 \partial t} - \frac{1}{2}\lambda(u'(y_1) + (1-t)w_1 u''(y_1)) & 0 \\ -\frac{1}{2}(1-t)u'(y_2) & -\frac{\partial^2 \mu}{\partial w_2 \partial t} - \frac{1}{2}\lambda(u'(y_2) + (1-t)w_2 u''(y_2)) & \frac{\partial^2 \mu}{\partial w_2^2} - \frac{\lambda}{2}(1-t)^2 u''(y_2) \end{bmatrix}$$

Determinant of A_2 is from (14) given by:

$$\begin{aligned} |A_2^t| &= \left(\frac{1}{2}(1-t)\right)^2 (u'(y_1)u'(y_2)) \left(-\frac{\partial^2 \mu}{\partial w_2 \partial t} - \frac{1}{2}\lambda(u'(y_2) + (1-t)w_2 u''(y_2))\right) \\ &\quad - \left(\frac{1}{2}(1-t)\right)^2 u'(y_2)^2 \left(-\frac{\partial^2 \mu}{\partial w_1 \partial t} - \frac{1}{2}\lambda(u'(y_1) + (1-t)w_1 u''(y_1))\right) \\ &= \left(\frac{1}{2}(1-t)\right)^2 \left[-(u'(y_1)u'(y_2)) \frac{\partial^2 \mu}{\partial w_2 \partial t} - \frac{1}{2}u'(y_1)u'(y_2)\lambda(u'(y_2) + (1-t)w_2 u''(y_2)) \right. \\ &\quad \left. + u'(y_2)^2 \frac{\partial^2 \mu}{\partial w_1 \partial t} + \frac{1}{2}u'(y_2)^2 \lambda(u'(y_1) + (1-t)w_1 u''(y_1)) \right] \\ &= \left(\frac{1}{2}(1-t)\right)^2 \left[-(u'(y_1)u'(y_2)) \frac{\partial^2 \mu}{\partial w_2 \partial t} - \frac{1}{2}(u'(y_1)u'(y_2))^2 \lambda \left(1 - \frac{-(1-t)w_2 u''(y_2)}{u'(y_2)}\right) \right. \\ &\quad \left. + u'(y_2)^2 \frac{\partial^2 \mu}{\partial w_1 \partial t} + \frac{1}{2}u'(y_1)u'(y_2)^2 \lambda \left(1 - \frac{-(1-t)w_1 u''(y_1)}{u'(y_1)}\right) \right] \\ &= \left(\frac{1}{2}(1-t)\right)^2 \left[-(u'(y_1)u'(y_2)) \frac{\partial^2 \mu}{\partial w_2 \partial t} - \frac{1}{2}(u'(y_1)u'(y_2))^2 \lambda(1 - RRA) \right. \\ &\quad \left. + u'(y_2)^2 \frac{\partial^2 \mu}{\partial w_1 \partial t} + \frac{1}{2}u'(y_1)u'(y_2)^2 \lambda(1 - RRA) \right] \\ &= \left(\frac{1}{2}(1-t)\right)^2 \left[u'(y_2)^2 \frac{\partial^2 \mu}{\partial w_1 \partial t} - (u'(y_1)u'(y_2)) \frac{\partial^2 \mu}{\partial w_2 \partial t} \right] \quad (A_2) \end{aligned}$$

Thus (A2), (10c) and (10d) imply $|A_2^t| > 0$ when $RRA > 1$, whilst $|A_2^t| < 0$ when $RRA < 1$.

Sign of $|A_3^t|$:

$$A_3^t = \begin{bmatrix} 0 & -\frac{1}{2}(1-t)u'(y_1) & 0 \\ -\frac{1}{2}(1-t)u'(y_1) & \frac{\partial^2 \mu}{\partial w_1^2} - \frac{\lambda}{2}(1-t)^2 u''(y_1) & -\frac{\partial^2 \mu}{\partial w_1 \partial t} - \frac{1}{2}\lambda(u'(y_1) + (1-t)w_1 u''(y_1)) \\ -\frac{1}{2}(1-t)u'(y_2) & 0 & -\frac{\partial^2 \mu}{\partial w_2 \partial t} - \frac{1}{2}\lambda(u'(y_2) + (1-t)w_2 u''(y_2)) \end{bmatrix}$$

$$|A_3| = \left(\frac{1}{2}(1-t)\right)^2 u'(y_1)u'(y_2) \left(-\frac{\partial^2 \mu}{\partial w_1 \partial t} - \frac{1}{2}\lambda(u'(y_1) + (1-t)w_1 u''(y_1))\right)$$

$$\begin{aligned}
& -\left(\frac{1}{2}(1-t)\right)^2 u'(y_1)^2 \left(-\frac{\partial^2 \mu}{\partial w_2 \partial t} - \frac{1}{2}\lambda(u'(y_2) + (1-t)w_2 u''(y_2))\right) \\
& = \left(\frac{1}{2}(1-t)\right)^2 \left[-u'(y_1)u'(y_2)\frac{\partial^2 \mu}{\partial w_1 \partial t} - \frac{1}{2}u'(y_1)^2 u'(y_2)\lambda\left(1 - \frac{-(1-t)w_1 u''(y_1)}{u'(y_1)}\right)\right. \\
& \quad \left.+ u'(y_1)^2 \frac{\partial^2 \mu}{\partial w_2 \partial t} + \frac{1}{2}u'(y_1)^2 u'(y_2)\lambda\left(1 - \frac{-(1-t)w_2 u''(y_2)}{u'(y_2)}\right)\right] \\
& = \left(\frac{1}{2}(1-t)\right)^2 \left[-u'(y_1)u'(y_2)\frac{\partial^2 \mu}{\partial w_1 \partial t} - \frac{1}{2}u'(y_1)^2 u'(y_2)\lambda(1 - RRA)\right. \\
& \quad \left.+ u'(y_1)^2 \frac{\partial^2 \mu}{\partial w_2 \partial t} + \frac{1}{2}u'(y_1)^2 u'(y_2)\lambda(1 - RRA)\right] \\
& = \left(\frac{1}{2}(1-t)\right)^2 \left[-u'(y_1)u'(y_2)\frac{\partial^2 \mu}{\partial w_1 \partial t} + u'(y_1)^2 \frac{\partial^2 \mu}{\partial w_2 \partial t}\right] \tag{A3}
\end{aligned}$$

Thus it follows from (A3), (10c) and (10d) that $|A_3| < 0$ when $RRA > 1$, whilst it follows that $|A_3| > 0$ when $RRA < 1$.

References

- Arulampalam, Wi , Booth, Alison L. and Bryan, Mark L. 2007. "Is there a Glass Ceiling over Europe? Exploring the Gender Pay Gap across the Wage Distribution." *Industrial and Labor Relations Review*, 60(2): 163-186.
- Atkinson, Anthony B. and Leigh, Andrew. 2010. "The Distribution of Top Incomes in Five Anglo-Saxon Countries over the Twentieth Century." *IZA- Discussion Paper Series*, No. 4937.
- Baker, George, Gibbs, Michael and Holmstrom, Bengt. 1993. "Hierarchies and Compensation: A Case Study." *European Economic Review*, 37: 366-378.
- _____. 1994 a. "The Internal Economics of the Firm: Evidence from Personnel Data." *Quarterly Journal of Economics*, 109: 881-919.
- _____. 1994b. "The Wage Policy of a Firm." *Quarterly Journal of Economic*, 109: 921-955.
- Bartlett, Robin L. and Miller, Timothy I. 1985. "Executive Compensation: Female Executives and Networking." *The American Economic Review*, Papers and Proceedings, 75(2): 266-270.
- Bebchuk, Lucian Arye, Fried, Jesse and Walker, David. 2002. "Managerial Power and Rent Extraction in the Design of Executive Compensation." *University of Chicago Law Review*, 69: 751-846.
- Bénabou, Roland. 2000 "Unequal Societies: Income Distribution and the Social Contract." *The American Economic Review*, 90(1): 96-129.
- Bénabou, Roland and Tirole, Jean. 2006. "Incentives and Prosocial Behavior." *The American Economic Review*, 96(5): 1652-1678.
- Bognanno, Michael L. 2001. "Corporate Tournaments." *Journal of Labor Economics*, 19: 290-315.
- Booij, Adam S. and van Praag, Bernard M.S. 2009. "A Simultaneous Approach to the Estimation of Risk Aversion and the Subjective Time Discount Rate." *Journal of Economic Behavior & Organization*, 70: 374-388.
- Brenner, Steffen. 2015. "The Risk Preferences off US Executives." *Management Science*, 61(6): 1344-1361.
- Chetty, Raj. 2006. "A New Method of Estimating Risk Aversion." *The American Economic Review*, 96(5): 1821-1834.
- Cohen, Alma and Einav, Liran. 2007. "Estimating Risk Preferences from Deductible Choice." *The American Economic Review*, 97(3): 745-788.
- Cornes, Richard. and Hartley, Roger. 2003. "Risk aversion, heterogeneity and contests." *Public Choice*, 117: 1-25.

- Croson, Rachel, and Gneezy, Uri. 2009. "Gender Differences in Preferences." *Journal of Economic Literature*, 47: 1-27.
- Dionne, Georges and Eeckhoudt, Louis. 1985. "Self-Insurance, Self-Protection and Increased Risk Aversion." *Economics Letters*, 17: 39-42.
- Ellingsen, Tore and Johannesson, Magnus. 2008. "Pride and Prejudice: The Human Side of Incentive Theory." *The American Economic Review*, 98(3): 990-1008.
- Eisenhauer, Joseph G. and Venturaz, Luigi. 2003. "Survey Measures of Risk Aversion and Prudence." *Applied Economics*, 35: 1477-1484.
- Elkinawy, Susan and Stater, Mark. 2011. "Gender Differences in Executive Compensation: Variation with Board Gender Composition and Time." *Journal of Economics and Business*, 63: 2345.
- Eriksson, Tor. 1999. "Executive Compensation and Tournament Theory: Empirical Tests on Danish Data." *Journal of Labor Economics*, 17(2): 262-280.
- Frey, Bruno S., and Jegen, Reto. 2001. "Motivation Crowding Out." *Journal of Economic Surveys*, 15(5): 589-611.
- Friend, Irwin and Blume, Marshall E. 1975. "The Demand for Risky Assets." *The American Economic Review*, 65(5), 900-922.
- Gabaix, Xavier and Landier, Augustin. 2008. "Why has CEO Pay Increased so much?" *Quarterly Journal of Economics*, 123(1): 49-100.
- Goerke, Laszlo and Pannenberg, Markus. 2012. "Risk Aversion and Trade-Union Membership." *Scandinavian Journal of Economics*, 114(2): 275-295.
- Green, Jerry R. and Stokey, Nancy L. 1983. "A Comparison of Tournaments and Contracts." *Journal of Political Economy*, 91(3): 349-364.
- Guvenen, Fatih, Kuruscu, Burhanettin and Ozkan, Serdar (2014) "Taxation of Human Capital and Wage Inequality: A Cross-Country Analysis." *Review of Economic Studies*, 81(2): 818-850.
- Halek, Martin and Eisenhauer, Joseph G. 2001. "Demography of Risk Aversion." *The Journal of Risk and Insurance*, 68(1): 1-24.
- Hansen, Lars Peter and Singleton, Kenneth J. 1982. "Generalized Instrumental Variables Estimation of Nonlinear Rational Expectations Models." *Econometrica*, 50(5): 1269-1286.
- _____. 1983. "Stochastic Consumption, Risk Aversion, and the Temporal Behavior of Asset Returns." *Journal of Political Economy*, 91(2): 249-265.
- Hassler, John, Rodríguez Mora, José V., Storesletten, Kjetil and Zilibotti, Fabrizio. 2003. "The Survival of the Welfare State." *The American Economic Review*, 93(1): 87-112.

- Konrad, Kai A. and Skaperdas, Stergios. 1993. "Self-insurance and Self-protection: A Nonexpected Utility Analysis." *The GENEVA Papers on Risk and Insurance Theory*, 18: 131-146.
- Kräkel, Matthias 2008 "Optimal risk taking in an uneven tournament game with risk averse players." *Journal of Mathematical Economics*, 44: 1219–1231.
- Kulich, Lara, Trojanowski, Grzegorz, Ryan, Michelle K., Haslam, S. Alexander., and Renneboog, Luc D. R. 2011. "Who Gets the Carrot and who gets the Stick? Evidence of Gender Disparities in Executive Remuneration." *Strategic Management Journal*, 32: 301 – 321.
- Kvaløy, Ola and Olsen, Trond E. 2014. "The Tenuous Relationship between Effort and Performance Pay." *Journal of Public Economics*, Articles in Press.
- Lambert, Richard A., Larcker, David F. and Weigelt, Keith. 1993. "The Structure of Organizational Incentives." *Administrative Science Quarterly*, 38(3): 438-461.
- Lazear, Edward P. 1989. "Pay Equality and Industrial Politics." *Journal of Political Economy*, 97(3): 561-580.
- Lazear, Edward P. and Rosen, Sherwin. 1981. "Rank-Order Tournaments as Optimum Labor Contracts." *Journal of Political Economy*, 89(5): 841-864.
- Leuven, Edwin, Oosterbeek, Hessel, Sonnemans, Joep and van der Klaauw, Bas. 2011. "Incentives versus Sorting in Tournaments: Evidence from a Field Experiment." *Journal of Labor Economics*, 29(3): 637-658.
- Levin, Irwin P., Snyder, Mary A. and Chapman, Daniel P. 1988. "The Interaction of Experiential and Situational Factors and Gender in a Simulated Risky Decision- Making Task." *Journal of Psychology*, 122(2): 173-181.
- Matthews, Stephen. 2011. "Trends in Top Incomes and their Tax Policy Implications." *OECD Taxation Working Papers*, No. 4, OECD Publishing.
- Meghir, Costas and Phillips, David. 2010. "Labour Supply and Taxes." In: Mirrlees, J., S. Adam, T. Besley, R. Blundell, S. Bond, R. Chote, M. Gammie, P. Johnson, G. Myles, and J. Poterba (eds). *Dimensions of Tax Design: The Mirrlees Review*. Oxford, UK: Oxford University Press: 1-87.
- Meltzer, Allan H. and Richard, Scott F. 1981. "A Rational Theory of the Size of Government." *Journal of Political Economy*, 89(5): 914-927.
- Meyer, Donald J. and Meyer, Jack. 2005. "Relative Risk Aversion: What Do We Know?" *The Journal of Risk and Uncertainty*, 31(3): 243–262.

- Murphy, Kevin J. and Zájbojnik, Ján. 2004. "CEO Pay and Appointments: A Market-Based Explanation for Recent Trends." *The American Economic Review, Papers and Proceedings*, 94: 192-196.
- Persson, Mats and Sandmo, Agnar. 2005. "Taxation and Tournaments." *Journal of Public Economic Theory*, 7(4): 543-559.
- Piketty, Thomas. and Saez, Emmanuel. 2001. "Income Inequality in the United States, 1913-1998." *National Bureau of Economic Research Working Paper 8467*, NBER, Cambridge, MA.
- _____. 2003. "Income Inequality in the United States, 1913-1998." *Quarterly Journal of Economics*, 118(1): 1-39.
- _____. 2007. "How Progressive is the U.S. Federal Tax System? A Historical and International Perspective." *Journal of Economic Perspectives*, 21(1): 3-24.
- Pålsson, Anne-Marie. 1996. "Does the Degree of Relative Risk Aversion Vary with Household Characteristics?" *Journal of Economic Psychology*, 17: 771-787.
- Rosen, Sherwin. 1981. "The Economics of Superstars." *The American Economic Review* 71(5): 845-858.
- _____. 1986. "Prizes and Incentives in Elimination Tournaments." *The American Economic Review*, 76(4): 701-715.
- Saez, Emmanuel. 2004. "Reported Incomes and Marginal Tax Rates, 1960-2000: Evidence and Policy Implications." NBER Working Paper 10273, National Bureau Of Economic Research.
- Shaw, Kathryn L. 1996. "An Empirical Analysis of Risk Aversion and Income Growth." *Journal of Labor Economics*, 14(4): 626-653.
- Skaperdas, Stergios. and Gan, Li. 1995. "Risk Aversion in Contests." *The Economic Journal*, 105: 951-962.
- Wanzenried, Gabrielle. 2008. "How Feminine is Corporate America? A Recent Overview." *Journal of Economic Inequality*, 6:185-209.