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Capital Income Taxation and Risk-Taking under Prospect Theory: The Continuous Distribution Case*

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Abstract

This study verifies whether the results of proportional capital income taxation on the risk-taking of a loss-averse investor will still hold when the return of a risky asset has a general continuous distribution. We extend the previous literature, which assumes a binomial distribution of asset returns for a risky asset. We also show that under reasonable assumptions risk-taking is finite and positive and thus a loss-averse investor will not choose infinite leverage despite no regulations being applied. In addition, unlike in the expected utility model, the capital income tax increase does not stimulate risk-taking when the reference level is the initial wealth or the gross after the tax return from investing the initial wealth into the risk-free asset. Furthermore, when investors set their reference level at the gross (pre-tax) return from investing the initial wealth into the risk-free asset, they increase not only risk-taking but also their private risks as measured by the standard deviation of their after-tax final wealth, which is not the case in the expected utility model.

1. Introduction

A large amount of research exists which examines the effects of taxation on risk-taking activity using the von Neumann and Morgenstern expected utility theory (Sandmo, 1985). The general finding is contrary to the popular notion that higher taxes tend to discourage risk-taking. This notion has not been supported by academic research starting with the seminal work of Domar and Musgrave (1944), particularly when full loss offset provisions are present in the tax code. The concept that risk-taking activity can be enhanced by taxation has continued to be supported by the consideration of more general expected utility models (Mossin, 1968; Stiglitz, 1969; Ahsan 1974, 1989). By risk-taking we refer to the proportion of initial wealth invested in the risky asset. Changes in capital income taxation, like any other tax change, generate income and substitution effects. The substitution effect encourages risk-taking activity (Mossin, 1968) because risk-averse investors react to the tax

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imposition by increasing the level of risk-taking in order to make the distribution of the after-tax return of the risky asset the same as that prior to taxation while keeping the expected utility unchanged. However, there is a negative income effect operating due to the loss of income from taxation, which offsets some of the substitution effect. Stiglitz (1969) showed that under reasonable assumptions[1] about attitudes towards risk, the positive substitution effect is stronger than the income effect, implying that an investor with expected utility preferences reduces her risk-free holdings in favor of more risky assets.

In addition to the analysis of risk-taking, public, private and total risks are also explored in the literature. These risks are equally important to analyze, especially given the recent concerns with large cyclical government budget deficits. Private risk is measured using the standard deviation of the after-tax wealth of the investor. Public sector risk is measured using the standard deviation of the tax revenue. It is the risk absorbed by the government via the tax policy. The government, by taxing returns from risky assets, in effect becomes a silent partner by getting an expected return but also absorbing some of the risk. Total risk is assumed to be the sum of the private and public sector risk. Under the expected utility models, capital income taxation reduces private risk. Private risk falls because the direct reduction in risk, caused by taxation, over-weights the increase in risk caused by the additional risk taking activity. Under the expected utility model, total risk increases because the increase in public risk is greater than the reduction in private risk.[2]

However, the expected utility model cannot explain many aspects of the behavior of asset returns. Prospect theory has been proposed as an alternative to describe investors' behavior under risk (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992). This theory can explain many of the anomalies observed in asset returns including the equity premium puzzle (Benartzi and Thaler, 1995; Barberis et al., 2001).[3] Kahneman and Tversky's experiments found that the utility does not depend on the level of final wealth, as is assumed in the expected utility model, but depends on the change in the level of wealth. The change in the level of wealth is measured as the difference between the investor's final wealth and some reference level. A common example for a reference level used in the literature is the wealth an investor would obtain from investing all of her initial wealth in a risk-free asset (Barberis et al., 2001; Gomes, 2005; Barberis and Xiong, 2009; Bernard and Ghossoub, 2010; He and Zhou, 2011). In addition, Kahneman and Tversky found that investors exhibit loss aversion. Loss-averse investors are more sensitive when they experience a loss in financial wealth relative to a reference level of wealth than when experiencing a (relative) gain. The utility function displays a non-differentiability at the origin and thus the slope is steeper in the loss domain than in the gain domain. Finally, investors also display risk aversion in the domain of gains but become risk lovers when they

[1] These assumptions are non-decreasing relative risk aversion and decreasing absolute risk aversion.

[2] These results of the expected utility model on the impact of capital income taxation on risk are driven by the implicit assumption that the public sector is more efficient at handling risk than the private sector (Ahsan and Tsigaris, 2009).

[3] Other alternatives to explain the behavior of asset returns include those of habit formation (Abel, 1990; Constantinides, 1990; Cambell and Cohrane, 1999), non-expected utility (Weil, 1990; Epstein and Zin, 1990), and market incompleteness due to uninsurable income risks (Heaton and Lucas, 1996; Constantinides and Duffie, 1996).

deal with losses. Barberis (2013) conducts a short literature survey on the contribution of prospect theory to various fields in economics.

Hlouskova and Tsigaris (2012) re-examined capital income taxation for a loss-averse investor, as described above, under some reference levels acceptable in the literature and a binomially distributed risky asset return. The impact of taxation on risk-taking as well as private, public and total risks depends also on how the reference level is affected by tax. This had not been explored previously. Contrary to the previous literature, which used the expected utility model, Hlouskova and Tsigaris (2012) found that it is possible for a capital income tax, under a full loss offset provision, not to stimulate risk-taking activity. When this is the case, then the reduction in the private sector risk is exactly offset by increased public sector risk. This would happen if the investor's reference level is set at her initial wealth. Hlouskova and Tsigaris (2012) also find examples when income tax stimulates risk-taking. This happens when the investor compares her reference level to others or to the gross pre-tax return from investing all of her initial wealth into a risk-free asset. In the latter case, the investor becomes risk-seeking, causing an increase not only in public risk, but in private risk as well.

In this paper we show that the impact of a proportional capital income tax on risk-taking, as well as on private and public sector risks, remain valid for a loss-averse investor when assumptions about the return of the risky asset are more general. While in Hlouskova and Tsigaris (2012) the results are presented under the assumption of the risky asset's return being binomially distributed, in this paper a general continuous distribution of the risky asset return is assumed. The effects of taxation on risk taking remain unaffected under any continuous distribution of the returns of the risky assets. Furthermore, our findings confirm that under this very general assumption, a sufficiently loss-averse investor will not choose infinite leverage. In other words, we show that the optimal proportion of the investment in risky assets is finite and positive, provided this is not restricted by financial regulations.

The remainder of the paper is organized as follows: Section 2 presents the model. Section 3 presents the solution of the model, which is continued in Section 4 on capital income taxation and the analysis of its impact on risk-taking and risks. Finally, concluding remarks are presented in Section 5.

2. The Model

The model is a one-period model[4] to maximize final wealth at the end of the period W, where investors make decisions on how they will allocate their initial wealth $W_0 > 0$.[5] There are two assets: a risk-free asset with a net of the dollar (certain) return r^0 and a risky asset which yields the stochastic, continuously distributed return r with the probability density function $f(\cdot)$ such that $\mathbb{E}\left(|r|^2\right) < +\infty$.[6] Let x

[4] The seminal and most influential work of the one-period wealth model is by Arrow (1971). Mossin (1968) and Stiglitz (1969) were the first to use the one-period model to examine the impact of taxation on risk-taking.

[5] We implicitly assume that investors make their decisions sequentially: first, they reach consumption and savings decisions and, once that is done, they decide on where to allocate their savings. In this paper we examine the latter decision.

be the proportion of the initial wealth invested in the risky asset. Then the investor allocates the amount of xW_0 into a risky asset and the amount of $(1-x)W_0$ into a risk-free asset. In addition, we assume an (certain) income tax, $\tau \in (0,1)$. Thus, the risk-free asset yields the after-tax return $(1-\tau)r^0$ (net of the dollar invested) while the risky asset yields the after-tax return $(1-\tau)r$. Based on this, the terminal uncertain (after-tax) wealth, W, is

$$W = \left[1+(1-\tau)\left((1-x)r^0 + xr\right)\right]W_0 = \left[1+(1-\tau)r^0 + (1-\tau)\left(r-r^0\right)x\right]W_0 \qquad (1)$$

The investor with loss-averse preferences is assumed to maximize the expectation of the following value function:

$$U(W-\Gamma) = \begin{cases} \dfrac{(W-\Gamma)^{1-\gamma}}{1-\gamma}, & W \geq \Gamma \\ -\lambda \dfrac{(\Gamma - W)^{1-\gamma}}{1-\gamma}, & W < \Gamma \end{cases} \qquad (2)$$

which is derived from terminal wealth, W, relative to a reference level, Γ. The reference dependence is one of the main features of prospect theory, where people receive their utility from relative gains ($W-\Gamma$ when $W>\Gamma$) and losses ($\Gamma - W$ when $W<\Gamma$), which are determined by reference levels. They reflect the investor's preferences (goals) with which to compare their final wealth. Some of the common reference levels used in the literature are the following: $\Gamma = W_0$, i.e. the investor uses her initial wealth as a reference level, or

$$\Gamma = \Gamma_0 \equiv \left(1+(1-\tau)r^0\right)W_0 \qquad (3)$$

i.e. she uses the after-tax gross return from investing all of the initial wealth in the risk-free asset that we will refer to as Γ_0, etc.

The λ parameter captures the loss aversion and is greater than unity. The intuition behind loss aversion is that in general losses are disliked more than "equally sized" gains, i.e. investors are more sensitive when they experience a loss in wealth than when experiencing a gain of the same size. Thus, the utility is steeper in the loss domain ($W<\Gamma$) than in the gain domain $(W>\Gamma)$.

The investor is risk averse in the domain of relative gains $(W>\Gamma)$ and *risk loving* in the domain of relative losses $(W<\Gamma)$, i.e. the investor's utility function is concave in the domain of gains $\left(\dfrac{d^2U}{dW^2}<0\right)$ but convex in the domain of losses $\left(\dfrac{d^2U}{dW^2}>0\right)$.

[6] The assumption of the risky asset being continuously distributed is the generalization of our previous work (see Hlouskova and Tsigaris, 2012).

Finally, the γ parameter determines the curvature of the value function for both relative gains and losses and we assume $0 < \gamma < 1$ so that we are coherent with the experimental findings of Tversky and Kahneman (1992).

The investor is assumed to choose the proportion of the risky asset x by solving

$$\max_{x} : \mathbb{E}\left(U(W - \Gamma)\right) \tag{4}$$

where $U(W - \Gamma)$ is given by (2) and the terminal wealth by (1). Note that we assume an unconstrained problem and thus the possibility of infinite leverage is not excluded by constraints. Wealth relative to the reference level is given by

$$W - \Gamma = \left[1 + (1-\tau)r^0 + (1-\tau)\left(r - r^0\right)x\right]W_0 - \Gamma = (1-\tau)\left(r - r^0\right)W_0 x + \Omega \tag{5}$$

where $\Omega \equiv \left(1 + (1-\tau)r^0\right)W_0 - \Gamma = \Gamma_0 - \Gamma$ is the residual of the relative wealth level around zero risky investment, i.e. $W - \Gamma\,|_{x=0} = \Omega$. The Ω term and the reference level Γ are certain and thus known to the investor. As in our previous paper, $\Omega > 0$ reflects investors with relatively low reference levels (e.g. investors that have more modest investment goals). The lower the reference level, the higher the value of Ω.[7] On the other hand, a negative $\Omega < 0$ represents investors with high reference levels (high goals), i.e. reference levels that are higher than what they can earn if they invest all of their initial wealth in the risk-free asset ($\Gamma > \Gamma_0$).

Based on (2) and (5) the value function becomes

$$U(W - \Gamma) = \begin{cases} \dfrac{\left[(1-\tau)W_0 x\right]^{1-\gamma}}{1-\gamma}(r - \tilde{r})^{1-\gamma}, & x > 0,\ r \ge \tilde{r} \\ -\lambda\dfrac{\left[(1-\tau)W_0 x\right]^{1-\gamma}}{1-\gamma}(\tilde{r} - r)^{1-\gamma}, & x > 0,\ r \le \tilde{r} \\ \dfrac{\Omega^{1-\gamma}}{1-\gamma}, & x = 0,\ \Omega > 0 \\ -\lambda\dfrac{(-\Omega)^{1-\gamma}}{1-\gamma}, & x = 0,\ \Omega < 0 \\ \dfrac{\left[(1-\tau)W_0(-x)\right]^{1-\gamma}}{1-\gamma}(\tilde{r} - r)^{1-\gamma}, & x < 0,\ r \le \tilde{r} \\ -\lambda\dfrac{\left[(1-\tau)W_0(-x)\right]^{1-\gamma}}{1-\gamma}(r - \tilde{r})^{1-\gamma}, & x < 0,\ r \ge \tilde{r} \end{cases} \tag{6}$$

where

$$\tilde{r} \equiv r^0 - \frac{\Omega}{(1-\tau)W_0 x} \tag{7}$$

[7] Note that in expected utility models, investors do not have a reference level, i.e. $\Gamma = 0$.

This implies the following form of the expected value function

$$
\mathbb{E}\big(U(W-\Gamma)\big)=\begin{cases}\dfrac{\big((1-\tau)W_0(-x)\big)^{1-\gamma}}{1-\gamma}\left[\int_{-\infty}^{\tilde{r}}(\tilde{r}-r)^{1-\gamma}f(r)dr\right. \\ \qquad\qquad\left.-\lambda\int_{\tilde{r}}^{+\infty}(r-\tilde{r})^{1-\gamma}f(r)dr\right], x<0 \\ \dfrac{1}{1-\gamma}\left[|\Omega|^{1-\gamma}-(1+\lambda)\Big(\big(-\Omega\big)^{+}\Big)^{1-\gamma}\right],\ x=0 \\ \dfrac{\big((1-\tau)W_0x\big)^{1-\gamma}}{1-\gamma}\left[\int_{\tilde{r}}^{+\infty}(r-\tilde{r})^{1-\gamma}f(r)dr\right. \\ \qquad\qquad\left.-\lambda\int_{-\infty}^{\tilde{r}}(\tilde{r}-r)^{1-\gamma}f(r)dr\right], x>0\end{cases} \tag{8}
$$

3. Optimal Portfolio of a Loss-Averse Investor

In this section we present the solution to problem (4). The main finding is that a sufficiently loss-averse investor will demand a finite positive amount of the risky asset if she is compensated for the risk and her reference level does not coincide with Γ_0 (the gross after-tax return of investing all initial wealth in the risk-free asset), i.e. $\mathbb{E}\left(r-r^0\right)>0$, and $\Omega\neq 0$.

The case with $\Omega=0$ and $\tau=0$ is already solved in the literature but worth briefly discussing it prior to the main findings (see Bernard and Ghossoub, 2010; and He and Zhou, 2011). When tax is included and $\Omega=0$, the derivations are straightforward and the same results apply. It can be shown that if the loss-averse parameter is such that $\lambda>\max\left\{K_\gamma,\dfrac{1}{K_\gamma}\right\}$, where

$$
K_\gamma=\frac{\int_{-\infty}^{r^0}\left(r^0-r\right)^{1-\gamma}f(r)dr}{\int_{r^0}^{+\infty}\left(r-r^0\right)^{1-\gamma}f(r)dr} \tag{9}
$$

then investment in the risky asset will not occur ($x^*=0$) even if $\mathbb{E}\left(r-r^0\right)>0$.[8] In other words, an investor with a sufficiently high degree of loss aversion and with the reference level being the after-tax amount the investor would have received at the end of the period had she invested all of her initial wealth W_0 in the risk-free asset (i.e. $\Gamma=\Gamma_0$) would not invest in the risky asset (and thus everything would be

[8] This follows from the fact that expected value function (8) is increasing (in x) for $x<0$ and $\lambda>K_\gamma$, decreasing for $x>0$ and $\lambda>1/K_\gamma$ and is continuous at $x=0$.

invested in the risk-free asset). K_γ could be interpreted as the *attractiveness* of short selling the risky asset relative to investing in the risky asset and represents a threshold loss aversion level (He and Zhou, 2011).

Next we present the main findings regarding the conditions which ensure the existence of the positive optimal proportion to invest in the risky asset. Unlike in Hlouskova and Tsigaris (2012), where the solution was given explicitly, the optimal portfolio is given implicitly in the form of an equation's solution.

Proposition 1: *Let* $\mathbb{E}\left(r-r^0\right)>0$, $\Omega>0$ *and* $\lambda>\max\left\{\hat{K}_\gamma,1/K_\gamma\right\}$. *Then the optimal proportion* $x^*\equiv x^*_{\lambda,\Gamma}$ *of an investor to invest in the risky asset is positive,* $x^*>0$, *and satisfies*

$$\left.\begin{aligned}&\int_{r^0-\frac{\Omega}{(1-\tau)W_0x^*}}^{+\infty}\left[(1-\tau)W_0\left(r-r^0\right)x^*+\Omega\right]^{-\gamma}\left(r-r^0\right)f(r)dr\\&-\lambda\int_{-\infty}^{r^0-\frac{\Omega}{(1-\tau)W_0x^*}}\left[(1-\tau)W_0\left(r^0-r\right)x^*-\Omega\right]^{-\gamma}\left(r^0-r\right)f(r)dr=0\end{aligned}\right\}\tag{10}$$

where

$$\hat{K}_\gamma=\max\left\{K_\gamma(\hat{r})\equiv\frac{\int_{-\infty}^{\hat{r}}(\hat{r}-r)^{1-\gamma}f(r)dr-\left(\hat{r}-r^0\right)^{1-\gamma}}{\int_{\hat{r}}^{+\infty}(r-\hat{r})^{1-\gamma}f(r)dr}\middle|\hat{r}\geq r^0\right\}\tag{11}$$

Proof: See *Appendix*.

It can be shown that $\hat{K}_\gamma$ is bounded from above and thus there exist such loss-averse parameters that satisfy $\lambda>\max\left\{\hat{K}_\gamma,1/K_\gamma\right\}$. Note that the positive value of Ω implies that the reference level of the investor is below the gross after-tax return from the investment of all initial wealth into the risk-free asset, $\Gamma<\Gamma_0$, i.e. the investor is *modest* in setting her goals.

Proposition 2: *Let* $\mathbb{E}\left(r-r^0\right)>0$, $\Omega\neq0$, *and* $\lambda>\max\left\{K_\gamma,1/K_\gamma\right\}$. *Then there exists the local finite maximum* $x^*\equiv x^*_{\lambda,\Gamma}>0$ *of (4) that satisfies (10).*

Proof: See *Appendix*.

The assumptions of Proposition 2 are weaker than the assumptions of Proposition 1. Namely, the minimum degree of loss aversion of the investor is smaller and both cases of the reference level, below and above Γ_0, can be assumed (unlike in Proposition 1, where only modest goals, $\Gamma<\Gamma_0$, are possible).

Proposition 3: *Let* $\mathbb{E}\left(r-r^0\right)>0$, $\Omega \neq 0$, $\lambda > \max\left\{1, 1/K_\gamma\right\}$, *and* $\gamma \in \left(0, \gamma^*\right)$, *where*

$$\gamma^* = \inf_d \max_\gamma \left\{ G(d,\gamma) > 0, 0 \le \gamma \le 1 \right\} \tag{12}$$

$$G(d,\gamma) = \int_{-\infty}^{d} (d-r)^{-\gamma} \left(r-r^0\right) f(r)dr + \lambda \int_{d}^{+\infty} (r-d)^{-\gamma} \left(r-r^0\right) f(r)dr \tag{13}$$

Then the optimal proportion $x^* \equiv x^*_{\lambda,\Gamma}$ is finite positive and satisfies (10).

Proof: See *Appendix.*

Note that the assumption on the curvature parameter γ being small enough replaces assumptions $\Omega > 0$ and $\lambda > \hat{K}_\gamma$ as stated in Proposition 1. A smaller degree of loss aversion (than in Proposition 1) and also higher goals $\left(\Gamma > \Gamma_0\right)$ are possible but at the expense that the value function does not deviate too much from the linear loss-averse utility which was examined analytically in Fortin and Hlouskova (2011) and He and Zhou (2011).

Thus, the optimal proportion $x^* > 0$ of the initial wealth W_0 of a sufficiently loss-averse investor is the global maximum of (4) if she is either modest in setting her goals (as in Proposition 1)[9] or if the curvature parameter γ of her prospect utility is sufficiently small (see Proposition 3) and her reference level does not coincide with Γ_0. Both modest goals (reference level below Γ_0) and high goals (reference level above Γ_0) are possible. On the other hand, $x^* > 0$ is the local maximum of (4) when no additional assumption is required, see Proposition 2.

4. Capital Income Taxation, Risky Investment and Risks

Here we explore the impact of the capital income tax on the optimal proportion to invest in the risky asset as well as its impact on private, public and total risk. As stated in the introduction, private risk is the standard deviation of the terminal wealth. This can be expressed mathematically as follows: $S(W) = (1-\tau)W_0 x^* \sigma$, where σ is the standard deviation of the risky asset's return. On the other hand, public sector risk is defined as the standard deviation of taxes, $S(T) = \tau W_0 x^* \sigma$. Finally, total risk is the sum of private and public risks, i.e. $S(W) + S(T) = W_0 x^* \sigma$.

The impact of a change of capital income tax on the choice of a risky asset is summarized in the following proposition.

Proposition 4: *Let* $\Omega \neq 0$, $x^* \equiv x^*_{\lambda,\Gamma} > 0$ *be the optimal solution of (4) that satisfies (10). Then*

[9] That is, when the reference level of final wealth is smaller than the gross after-tax wealth from investing all of the initial wealth in the risk-free asset Γ_0.

$$\frac{dx^*}{d\tau} = x^*\left(\frac{1}{1-\tau} + \frac{\frac{d\Omega}{d\tau}}{\Omega}\right) = \begin{cases} > 0, & \text{if } \frac{d\Omega}{d\tau}\Big/\Omega > -\frac{1}{1-\tau} \\ = 0, & \text{if } \frac{d\Omega}{d\tau}\Big/\Omega = -\frac{1}{1-\tau} \\ < 0, & \text{if } \frac{d\Omega}{d\tau}\Big/\Omega < -\frac{1}{1-\tau} \end{cases} \tag{14}$$

Proof. See Appendix.

Equation (14) can be written as follows: $\frac{dx^*}{d\tau} = \frac{x^*}{1-\tau} + \frac{x^*}{\Omega}\frac{d\Omega}{d\tau}$. The first term is the typical stimulus substitution effect of capital income taxation found in the expected utility literature (Mossin, 1968) and it is interesting to find this effect also in the loss-averse model.[10] The second term depends on how tax affects $\Omega = \Gamma_0 - \Gamma$, i.e. on the sign of $\frac{d(\Gamma_0 - \Gamma)}{d\tau}$ and on the sign of Ω. The sign of Ω depends on whether the investor sets a high reference level relative to Γ_0 ($\Omega < 0$) or a low reference level ($\Omega > 0$). For the expected power utility model, the second term in (14) can be expressed as $\frac{x_p^*}{\Gamma_0}\frac{d\Gamma_0}{d\tau}$, where $x_p^* > 0$ is the optimal risky asset holding. The term $\frac{x_p^*}{\Gamma_0}\frac{d\Gamma_0}{d\tau}$ represents the income effect, which is negative since $\frac{d\Gamma_0}{d\tau} < 0$ and $\Gamma_0 > 0$ and thus moves in the opposite direction from the first term, which is $\frac{x_p^*}{1-\tau}$. In the expected power utility model the second term is weaker than the first term, resulting in $\frac{dx_p^*}{d\tau} = \frac{x_p^*}{(1-\tau)\left(1 + r^0(1-\tau)\right)} > 0$. However, when the investor has loss-averse preferences, the impact of capital income taxation differs from the expected utility model due to reference dependent preferences (see equation (14)).[11] Moreover, different solutions (which depend on both the reference level Γ and the parameter of loss aversion λ) imply also different effects of capital income taxation. *Table 1* presents four examples and the expected power utility (being the benchmark case) to summarize the impacts of capital income taxation for loss-averse in-

[10] Mossin (1968) was the first to show this effect to be the substitution effect of a tax change under full loss offset provisions with the expected utility model. To illustrate, consider one risky asset and money. Final wealth is $W = \left(1 + x(1-\tau)r\right)W_0$. If the investor selects $x = \frac{x_0^*}{1-\tau}$, where x_0^* is the initial pre-tax risky asset holdings, then the pre-tax final wealth is equal to the post-tax value. Hence, the investor increases risk-taking, $x > x_0^*$ to face the same distribution after tax as the one before taxation (and without any loss of utility). When the risk-free asset yields a positive return, there are income effects to consider.

[11] This follows from $\Gamma = \Gamma_0 - \Omega$ for a loss-averse investor and $\Gamma = 0$ for the expected utility investor.

Table 1 The Impact of the Capital Income Tax on Risk-Taking and Private, Public Sector and Total Risk for Different Loss-Averse Investors.

Power utility: $\frac{W^{1-\delta}}{1-\delta}$ **where** $\delta > 1$ **has the solution** $0 < x_p^* < +\infty$.

Notation: $\Gamma_0 = \left(1+(1-\tau)r^0\right)W_0$ **and** $\tilde{\Gamma}_0 = \left(1+(1-\tau)r^0\right)\tilde{W}_0$.

Condition: $\tilde{W}_0 \neq W_0$ **in Example 3**.

	Power utility	Example 1	Example 2	Example 3	Example 4
Γ	0	W_0	Γ_0	$\tilde{\Gamma}_0$	$\left(1+r^0\right)W_0$
Ω	Γ_0	$(1-\tau)r^0W_0 > 0$	0	$\Gamma_0 - \tilde{\Gamma}_0$	$-\tau r^0 W_0 < 0$
$\frac{dx^*}{d\tau}$	$\frac{x_p^*}{(1-\tau)\left(1+(1-\tau)r^0\right)} > 0$	0	0	$\frac{x_{\lambda,\Gamma}^*}{(1-\tau)\left(1+(1-\tau)r^0\right)} > 0$	$\frac{x_{\lambda,\Gamma}^*}{\tau(1-\tau)} > 0$
$\frac{dS(W)}{d\tau}$	$-\frac{(1-\tau)r^0W_0\sigma x_p^*}{1+(1-\tau)r^0} < 0$	$-W_0\sigma x_{\lambda,\Gamma}^* < 0$	0	$-\frac{(1-\tau)r^0W_0\sigma x_{\lambda,\Gamma}^*}{1+(1-\tau)r^0} < 0$	$\frac{1-\tau}{\tau}W_0\sigma x_{\lambda,\Gamma}^* > 0$
$\frac{dS(T)}{d\tau}$	$\frac{\left(1+(1-\tau)^2r^0\right)W_0\sigma x_p^*}{(1-\tau)\left(1+(1-\tau)r^0\right)} > 0$	$W_0\sigma x_{\lambda,\Gamma}^* > 0$	0	$\frac{\left(1+(1-\tau)^2r^0\right)W_0\sigma x_{\lambda,\Gamma}^*}{(1-\tau)\left(1+(1-\tau)r^0\right)} > 0$	$\frac{2-\tau}{1-\tau}W_0\sigma x_{\lambda,\Gamma}^* > 0$
$\frac{d\left(S(W)+S(T)\right)}{d\tau}$	$\frac{W_0\sigma x_p^*}{(1-\tau)\left(1+(1-\tau)r^0\right)} > 0$	0	0	$\frac{W_0\sigma x_{\lambda,\Gamma}^*}{(1-\tau)\left(1+(1-\tau)r^0\right)} > 0$	$\frac{W_0\sigma x_{\lambda,\Gamma}^*}{\tau(1-\tau)} > 0$

vestors for different reference levels. These examples were analyzed also in Hlouskova and Tsigaris (2012) and demonstrate the cases when results (of the impact of taxation on the risky asset and private, public and total risks) differ from the expected power utility model (Examples 1, 2 and 4) and when the results coincide (Example 3) with respect to the direction.

The loss-averse investor of Example 1 sets her reference level at her initial wealth level. In this case, the investor has $\Omega = (1-\tau)r^0 W_0 > 0$ (modest goals as $\Gamma < \Gamma_0$). The tax increase reduces the positive Ω value (by reducing Γ_0) and this effect offsets exactly the first term in (14), which represents the stimulating effect of capital income taxation. Hence, a reference level set at the current asset position and, unlike in the expected utility model, has no stimulating effect on risk-taking. Furthermore, private risk falls with increasing tax and this reduction is also exactly offset by an increase in public sector risk, leaving total risk in the economy unchanged.

Example 2 can be considered as a completely tax neutral policy, as the investor's reference level is set at the gross after-tax return from investing all of her wealth in the risk-free asset (Γ_0).[12] In this case the investor will not invest in the risky asset. Hence, capital income taxation has no effect on risk-taking or on private, public and total risk.

The reference level of Example 3 is defined similarly as in Example 2, except that the initial wealth is substituted by the initial wealth of another investor $\left(\tilde{W}_0\right)$. Falk and Knell (2004) argued that people set reference levels in order to compare themselves to others. Thus, Ω depends on the difference between the initial wealth of the investor and that of the other to which she is comparing herself: $\Omega = \left(1 + r^0(1-\tau)\right)\left(W_0 - \tilde{W}_0\right) = \Gamma_0 - \tilde{\Gamma}_0$ where $\tilde{\Gamma}_0 = \left(1 + (1-\tau)r^0\right)\tilde{W}_0$. If $W_0 > \tilde{W}_0$ (i.e., $\Omega > 0$), then a loss-averse investor is governed by the self-enhancement motive. On the other hand, if $W_0 < \tilde{W}_0$ ($\Omega < 0$) then she is driven by the self-improvement motive. For example, investors might set low reference levels if they compare their initial wealth to investors who have a lower level. These investors are governed by the self-enhancement motive. However, other investors might compare their initial wealth with investors that are more successful and who have higher initial wealth. These investors will set their reference level high to reflect the wealth of richer investors. They place importance on the self-improvement motive, as they want to improve their situation and catch up with others. In both cases, the capital income tax increase stimulates risk-taking $\left(\frac{dx^*}{d\tau} > 0\right)$. In summary, capital income taxation has the same directional effects as in the expected utility case, namely stimulation of risk-taking, reduction of private risk and increase of public sector and total risk.

[12] This is the case considered in Bernard and Ghossoub (2010) and discussed briefly on the beginning of Section 3.

In all of the above-mentioned examples the second term in equation (14) moves in the opposite direction to the first term just like in the expected power utility model. Sometimes the second term in equation (14) fully offsets the first term as in Example 1 but the second term in equation (14) is never greater than the stimulating effect described by the first term.

In Example 4, risk-taking is also stimulated by tax. However, this example differs from the other examples by a very high reference level (i.e. a very high goal resulting in $\Omega < 0$) which is the gross (pre-tax) return from investing all of the investor's wealth in the risk-free asset, i.e. $\Gamma = \left(1 + r^0\right) W_0$. This benchmark wealth is quite common in the literature (see Barberis et al., 2001; Barberis and Xiong, 2009; Gomes, 2005; Bernard and Ghossoub, 2010; He and Zhou, 2011). As $\Omega < 0$ and $\frac{d\Omega}{d\tau} < 0$, the second term in equation (14) is positive and thus reinforces the stimulating substitution effect of the first term. This results in the increase of both risk-taking and private risk (when capital income tax increases).

Finally, the effect of the capital income tax on the total risk is proportional to the impact of the tax on the optimal (positive) proportion of initial wealth invested in the risky asset as $\frac{d\left(S(W) + S(\tau)\right)}{d\tau} = W_0 \sigma \frac{dx^*}{d\tau}$. If the capital income tax stimulates risk-taking it will increase total risk. If the capital income tax has no effect on risk taking, then the total risk remains unchanged and thus the change in private risk is offset by a change in public sector risk.

All impacts of taxation on risk taking and risks coincide (in the directional sense) with the ones obtained in Hlouskova and Tsigaris (2012). However the size might differ as solutions could differ.

5. Conclusion

We have verified a portfolio choice framework, as introduced in Hlouskova and Tsigaris (2012), of a loss-averse investor yielding the predictions on how capital income taxation affects risk taking and various risks. The conditions of the model were generalized in assuming the risky asset's return to be continuously distributed instead of having a binomial distribution. The main results coincide with this framework. Namely, a sufficiently loss-averse investor will invest a finite positive amount in the risky asset. In addition, there are reference levels that result in no stimulation of risk-taking due to a capital income tax increase even when the tax code provides full loss offset provisions (contrary to the expected utility models where the tax increase stimulates investment in the risky asset). Another difference with respect to the expected utility model is when private risk (the standard deviation of the final wealth) increases with the tax. This happens when the reference level is given by the pre-tax wealth level generated from investing everything in the risk-free asset. Thus, we find cases when risks depend differently on tax as they do in the expected utility model. We present examples when private risk falls at exactly the same rate at which public sector risk increases, leaving the total risk in the economy unaffected. We also find an example when both private and public sector risks increase with capital income taxation. In the future it would be of interest to explore the social welfare implications of the change in the economy's risks.

Even though the results coincide with the findings in Hlouskova and Tsigaris (2012) only in terms of the direction of change of risk-taking and risks with respect to the change of tax, the magnitude of the change could not be compared because the solution is implicit and not explicit. Thus, in future research different assumptions on the risky asset's return distribution, such as fat-tailed distributions versus normal distribution, could be considered to reveal the degree of impact of taxes.

Furthermore, the results of our research are driven by the implicit assumption that the public sector is more efficient at handling risk than the private sector, as is indicated in the traditional literature. This assumption can be relaxed in the future with loss-averse investors and the impact re-examined as in Ahsan and Tsigaris (2009), who demonstrated that risky investment is discouraged under capital income taxation with expected utility models even under full loss offset provisions provided that the government is no more efficient in handling risk than the private sector.

Modeling frameworks for which these results may be of importance are in intertemporal consumption-savings and labor-leisure decisions where people set reference levels. We leave this exploration for future research.

APPENDIX

Proof of Proposition 1: Note that

$$\mathbb{E}\left(U(W-\Gamma)\right)|_{x<0} < \mathbb{E}\left(U(W-\Gamma)\right)|_{x=0} \tag{15}$$

if

$$\frac{1-\gamma}{\left((1-\tau)W_0(-x)\right)^{1-\gamma}}\mathbb{E}\left(U(W-\Gamma)\right) = \int_{-\infty}^{\tilde{r}}\left(\tilde{r}-r\right)^{1-\gamma} f(r)dr - \lambda\int_{\tilde{r}}^{+\infty}\left(r-\tilde{r}\right)^{1-\gamma} f(r)dr$$
$$< \left(\tilde{r}-r^0\right)^{1-\gamma}$$

where $\tilde{r} = r^0 - \dfrac{\Omega}{(1-\tau)W_0 x}$. Thus if

$$\lambda > \frac{\int_{-\infty}^{\tilde{r}}\left(\tilde{r}-r\right)^{1-\gamma} f(r)dr - \left(\tilde{r}-r^0\right)^{1-\gamma}}{\int_{\tilde{r}}^{+\infty}\left[r-\tilde{r}\right]^{1-\gamma} f(r)dr}$$

then (15) holds.

Note that for $x > 0$

$$\frac{d}{dx}\mathbb{E}\left(U(W-\Gamma)\right) = \int_{r^0-\frac{\Omega}{(1-\tau)W_0 x}}^{+\infty}\left[(1-\tau)W_0\left(r-r^0\right)x+\Omega\right]^{-\gamma}(1-\tau)W_0\left(r-r^0\right)f(r)dr$$
$$+\lambda\int_{-\infty}^{r^0-\frac{\Omega}{(1-\tau)W_0 x}}\left[(1-\tau)W_0\left(r^0-r\right)x-\Omega\right]^{-\gamma}(1-\tau)W_0\left(r-r^0\right)f(r)dr$$

which gives for $\mathbb{E}\left(r-r^0\right)>0$ and $\Omega>0$

$$\lim_{x\to 0^+}\frac{d}{dx}\mathbb{E}(U(W-\Gamma))=\int_{-\infty}^{+\infty}\frac{(1-\tau)W_0(r-r^0)}{\Omega^\gamma}f(r)dr=\frac{(1-\tau)W_0\mathbb{E}(r-r^0)}{\Omega^\gamma}>0 \quad (16)$$

Note in addition that for $x>0$

$$\mathbb{E}\left(U(W-\Gamma)\right)=\frac{\left[(1-\tau)W_0x\right]^{1-\gamma}}{1-\gamma}\left[-\lambda\int_{-\infty}^{\tilde{r}}\left(\tilde{r}-r\right)^{1-\gamma}f(r)dr+\int_{\tilde{r}}^{+\infty}\left(r-\tilde{r}\right)^{1-\gamma}f(r)dr\right]$$

Thus

$$\lim_{x\to+\infty}\mathbb{E}\left(U(W-\Gamma)\right)=+\infty\times\left[-\lambda\int_{-\infty}^{r^0}\left(r^0-r\right)^{1-\gamma}f(r)dr+\int_{r^0}^{+\infty}\left(r-r^0\right)^{1-\gamma}f(r)dr\right]=-\infty \quad (17)$$

as $\lambda>1/K_\gamma$.

Based on the fact that $\mathbb{E}\left(U(W-\Gamma)\right)|_{x<0}<\mathbb{E}\left(U(W-\Gamma)\right)|_{x=0}$, $\mathbb{E}\left(U(W-\Gamma)\right)$ being continuous, (16) and (17), it follows that the solution of (4) is positive so that the first order conditions are satisfied, i.e. $\frac{d}{dx}\mathbb{E}\left(U(W-\Gamma)\right)|_{x=x^*}=0$ for $x^*>0$, which coincides with (10).

Proof of Proposition 2: Note that the definition of the investor's utility, (8), implies that for $x<0$

$$\mathbb{E}\left(U(W-\Gamma)\right)=\frac{\left((1-\tau)W_0(-x)\right)^{1-\gamma}}{1-\gamma}\left[\int_{-\infty}^{\tilde{r}}(\tilde{r}-r)^{1-\gamma}f(r)dr-\lambda\int_{\tilde{r}}^{+\infty}(r-\tilde{r})^{1-\gamma}f(r)dr\right]$$

Thus,

$$\lim_{x\to-\infty}\mathbb{E}\left(U(W-\Gamma)\right)=+\infty\times\left[\int_{-\infty}^{r^0}\left(r^0-r\right)^{1-\gamma}f(r)dr-\lambda\int_{r^0}^{+\infty}\left(r-r^0\right)^{1-\gamma}f(r)dr\right]=-\infty$$

as $\lim_{x\to-\infty}\tilde{r}=\lim_{x\to-\infty}\left(r^0-\frac{\Omega}{(1-\tau)W_0x}\right)=r^0$ and $\lambda>K_\gamma$ (i.e. the expression in brackets is negative). Note in addition that

$$\lim_{x\to 0^+}\frac{d}{dx}\mathbb{E}\left(U(W-\Gamma)\right)=\left\{\begin{array}{c}\int_{-\infty}^{+\infty}\frac{(1-\tau)W_0\left(r-r^0\right)}{\Omega^\gamma}f(r)dr=\frac{(1-\tau)W_0\mathbb{E}\left(r-r^0\right)}{\Omega^\gamma}>0\\ \text{if } \Omega>0\\ \\ \lambda\int_{-\infty}^{+\infty}\frac{(1-\tau)W_0\left(r-r^0\right)}{(-\Omega)^\gamma}f(r)dr=\lambda\frac{(1-\tau)W_0\mathbb{E}\left(r-r^0\right)}{(-\Omega)^\gamma}>0\\ \text{if } \Omega<0\end{array}\right\}>0$$

(18)

as $\mathbb{E}\left(r-r^0\right)>0$. Based on this, the continuity of $\mathbb{E}\left(U(W-\Gamma)\right)$ (in x) and (17) it follows that there is at least one local maximum x^* of problem (4) such that $x^*>0$ and (10) is satisfied.

Proof of Proposition 3: Note that based on (13)

$$G(d,0)=\int_{-\infty}^{d}\left(r-r^0\right)f(r)dr+\lambda\int_{d}^{\infty}\left(r-r^0\right)f(r)dr=\mathbb{E}\left(r-r^0\right)+(\lambda-1)\int_{d}^{\infty}\left(r-r^0\right)f(r)dr$$

$$=\begin{cases}>0 \quad \text{if } d\geq r^0,\\ >\mathbb{E}\left(r-r^0\right)+(\lambda-1)\int_{-\infty}^{\infty}\left(r-r^0\right)f(r)dr=\lambda\mathbb{E}\left(r-r^0\right)>0 \quad \text{if } d<r^0\end{cases}$$

as $\mathbb{E}\left(r-r^0\right)>0$ and $\lambda>1$. The continuity of $G(d,\gamma)$ implies the existence of γ^* (as given by (12)) so that $G(d,\gamma)>0$ for any $\gamma<\gamma^*$. This, and the fact that for $x<0$

$$\frac{d}{dx}\mathbb{E}\left(U(W-\Gamma)\right)=\left((1-\tau)W_0\right)^{1-\gamma}(-x)^{-\gamma}G\left(\tilde{r},\gamma\right),\ \text{where } \tilde{r}=r^0-\frac{\Omega}{(1-\tau)W_0x}$$

implies that $\frac{d}{dx}\mathbb{E}\left(U(W-\Gamma)\right)>0$ for any $\gamma<\gamma^*$, $x<0$ and $\Omega\neq 0$. This, (18), (17) and $\mathbb{E}\left(U(W-\Gamma)\right)$ being continuous imply that the solution of (4) is positive so that the first order conditions are satisfied, i.e. $\frac{d}{dx}\mathbb{E}\left(U(W-\Gamma)\right)|_{x=x^*}=0$ for $x^*>0$, which coincides with (10).

Proof of Proposition 4: The proof is based on implicit function differentiation and equation (10). Let

$$\frac{d}{dx}\mathbb{E}\left(U(W-\Gamma)\right)=0$$

and thus let

$$F(\tau,x)\ \equiv\int_{\tilde{r}}^{+\infty}\frac{r-r^0}{(r-\tilde{r})^{\gamma}}f(r)dr-\lambda\int_{-\infty}^{\tilde{r}}\frac{r^0-r}{(\tilde{r}-r)^{\gamma}}f(r)dr=0 \tag{19}$$

where $\tilde{r}=r^0-\frac{\Omega}{(1-\tau)W_0x^*}$. Then

$$\frac{dx}{d\tau}=-\frac{\frac{dF}{d\tau}}{\frac{dF}{dx}} \tag{20}$$

Note that

$$\int \frac{r-r^0}{(r-\tilde{r})^\gamma} dr = \frac{(r-\tilde{r})^{2-\gamma}}{2-\gamma} + \frac{(r-\tilde{r})^{1-\gamma}\left(\tilde{r}-r^0\right)}{1-\gamma}$$

$$\int \frac{r^0-r}{(\tilde{r}-r)^\gamma} dr = -\frac{(\tilde{r}-r)^{2-\gamma}}{2-\gamma} + \frac{(\tilde{r}-r)^{1-\gamma}\left(\tilde{r}-r^0\right)}{1-\gamma}$$

Using this and

$$\lim_{r\to\pm\infty} |r|^{2-\gamma} f(r) = 0 \tag{21}$$

when applying integration by parts to (19) gives

$$\begin{aligned} F(\tau,x) = &-\int_{\tilde{r}}^{+\infty}\left(\frac{(r-\tilde{r})^{2-\gamma}}{2-\gamma} + \frac{(r-\tilde{r})^{1-\gamma}\left(\tilde{r}-r^0\right)}{1-\gamma}\right)\frac{df(r)}{dr}dr \\ &+\lambda\int_{-\infty}^{\tilde{r}}\left(-\frac{(\tilde{r}-r)^{2-\gamma}}{2-\gamma} + \frac{(\tilde{r}-r)^{1-\gamma}\left(\tilde{r}-r^0\right)}{1-\gamma}\right)\frac{df(r)}{dr}dr = 0 \end{aligned} \tag{22}$$

As $\frac{d\tilde{r}}{dx} = \frac{\Omega}{(1-\tau)W_0\left(x^*\right)^2}$ and $\frac{d\tilde{r}}{d\tau} = -\frac{\Omega + \frac{d\Omega}{d\tau}(1-\tau)}{(1-\tau)^2 W_0 x^*}$ then (22) implies

$$\left.\begin{aligned} \frac{dF}{dx}\Big|_{x=x^*} &= \frac{d\tilde{r}}{dx}\left[\lambda\int_{-\infty}^{\tilde{r}}\left(\frac{\gamma}{1-\gamma}(\tilde{r}-r)^{1-\gamma} + \frac{\tilde{r}-r^0}{(\tilde{r}-r)^\gamma}\right)\frac{df(r)}{dr}dr \right.\\ &\qquad \left. -\int_{\tilde{r}}^{+\infty}\left(\frac{\gamma}{1-\gamma}(r-\tilde{r})^{1-\gamma} - \frac{\tilde{r}-r^0}{(r-\tilde{r})^\gamma}\right)\frac{df(r)}{dr}dr\right] \\ \frac{dF}{d\tau}\Big|_{x=x^*} &= \frac{d\tilde{r}}{d\tau}\left[\lambda\int_{-\infty}^{\tilde{r}}\left(\frac{\gamma}{1-\gamma}(\tilde{r}-r)^{1-\gamma} + \frac{\tilde{r}-r^0}{(\tilde{r}-r)^\gamma}\right)\frac{df(r)}{dr}dr \right.\\ &\qquad \left. -\int_{\tilde{r}}^{+\infty}\left(\frac{\gamma}{1-\gamma}(r-\tilde{r})^{1-\gamma} - \frac{\tilde{r}-r^0}{(r-\tilde{r})^\gamma}\right)\frac{df(r)}{dr}dr\right] \end{aligned}\right\} \tag{23}$$

(20) and (23) then imply (14). Note that (21) follows from assuming the second moment of the risky asset's return r to be finite; i.e., $\mathbb{E}\left(|r|^2\right) < +\infty$.

REFERENCES

Abel AB (1990): Asset prices under habit formation and catching up with the Joneses. *American Economic Review*, 80:38–42.

Ahsan SM (1974): Progression and risk-taking. *Oxford Economic Papers*, 26:318–328.

Ahsan SM (1989): Choice of tax base under uncertainty: Consumption or income? *Journal of Public Economics*, 40:99–134.

Ahsan SM, Tsigaris P (2009): The efficiency cost of capital income taxation under imperfect loss offset provisions. *Public Finance Review*, 37:710–731.

Arrow KJ (1971): The theory of risk aversion. In: Yrjo Jahnssonin Saatio (Ed.): *Aspects of the Theory of Risk Bearing*. Helsinki. Reprinted in: *Essays in the Theory of Risk Bearing*, Markham Publ. Co., Chicago, pp. 90–109.

Barberis N (2013): Thirty years of prospect theory in economics: A review and assessment. *Journal of Economic Perspectives*, 27:173–196.

Barberis N, Huang M, Santos T (2001): Prospect theory and asset prices. *Quarterly Journal of Economics*, 116:1–53.

Barberis N, Xiong W (2009): What drives the disposition effect? An analysis of a long-standing preference-based explanation. *Journal of Finance*, 64:751–784.

Benartzi S, Thaler RH (1995): Myopic loss aversion and the equity premium puzzle. *Quarterly Journal of Economics*, 110:73–92.

Berkelaar AB, Kouwenberg R, Post T (2004): Optimal portfolio choice under loss aversion. *Review of Economics and Statistics*, 86:973–987.

Bernard C, Ghossoub M (2010): Static portfolio choice under cumulative prospect theory. *Mathematics and Financial Economics*, 2:277–306.

Campbell JY, Cochrane JH (1999): By force of habit: A consumption-based explanation of aggregate stock market behavior. *Journal of Political Economy*, 107:205–251.

Constantinides GM (1990): Habit formation: A resolution of the equity premium puzzle. *Journal of Political Economy*, 98:519–543.

Constantinides GM, Duffie D (1996): Asset pricing with heterogeneous consumers. *Journal of Political Economy*, 104:219–240.

Domar ED, Musgrave RA (1944): Proportional income taxation and risk taking. *Quarterly Journal of Economics*, 58:388–422.

Epstein LG, Zin SE (1990): First-order risk aversion and the equity premium puzzle. *Journal of Monetary Economics*, 26:387–407.

Falk A, Knell M (2004): Choosing the Joneses: Endogenous goals and reference standards. *Scandinavian Journal of Economics*, 106:417–435.

Fortin I, Hlouskova J (2011): Optimal asset allocation under linear loss aversion. *Journal of Banking and Finance*, 35:2974–2990.

Giorgi EG de (2011): Loss aversion with multiple investment goals. *Mathematics and Financial Economics*, 5:203–227.

Gomes FJ (2005): Portfolio choice and trading volume with loss-averse investors. *Journal of Business*, 78:675–706.

He XD, Zhou XY (2011): Portfolio choice under cumulative prospect theory: An analytical treatment. *Management Science*, 57:315–331.

Heaton J, Lucas DJ (1996): Evaluating the effects of incomplete markets on risk sharing and asset pricing. *Journal of Political Economy*, 104:443–487.

Hlouskova J, Tsigaris P (2012): Capital income taxation and risk taking under prospect theory. *International Tax and Public Finance*, 19:554–573.

Kahneman D, Tversky A (1979): Prospect theory: An analysis of decision under risk. *Econometrica*, 47:363–391.

Mossin J (1968): Taxation and risk-taking: An expected utility approach. *Economica*, 35:74–82.

Sandmo A (1985): The effect of taxation on savings and risk taking. In: Auerbach AJ, Feldstein M (Eds.): *Handbook of Public Economics*. Vol. I. Amsterdam, North Holland.

Stiglitz JE (1969): The effects of income, wealth and capital gains taxation on risk taking. *Quarterly Journal of Economics*, 83:263–283.

Tversky A, Kahneman D (1992): Advances in prospect theory: Cumulative representation of uncertainty. *Journal of Risk and Uncertainty*, 5:297–323.

Weil P (1990): Non-expected utility in macroeconomics. *Quarterly Journal of Economics*, 105: 29–42.