Loss Aversion around the World: Empirical Evidence from Pension Funds

Yuxin Xie*, Soosung Hwang♦, and Athanasios A. Pantelous#

Abstract

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JEL Classification: G11; G12; G15

Keywords: Loss Aversion; Cultural Dimensions; Reference-Dependent Utility; Pension Funds

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⋆ The authors would like to acknowledge the gracious supports of Samsung Research Fund, Sungkyunkwan University, 2013 and the EPSRC and ESRC Centre for Doctoral Training on Quantification and Management of Risk & Uncertainty in Complex Systems & Environments (EP/L015927/1). We would like to thank participants at the Southwestern Finance Association, World Finance Conference, and Korean Securities Association conferences, and at University of Liverpool, University of Glasgow, Sungkyunkwan University, Shanghai University, Xi'an Jiatong-Liverpool University as well as Wilko Bolt, Bahattin Buyuksahin, Eric Cardella, Andros Gregoriou, Chris Florackis, Daniel Folkinshteyn, Chulwoo Han, Vasileios Kallinterakis, Minseong Kim Gulser Meric, and Micaela Pagel for helpful comments.

*The School of Securities and Futures, Southwestern University of Finance and Economics, China, Tel: +86 15882373079, Email: yuxinxie@swufe.edu.cn.

♦ Corresponding author: College of Economics, Sungkyunkwan University, 25-2 Sungkyunkwan-ro, Jongno-Gu, Seoul 110-745, Republic of Korea, Tel. +82 (0)27600489, Email: shwang@skku.edu.

Department of Mathematical Sciences, University of Liverpool, United Kingdom. Tel: +44 (0)151 794 5079, Email: a.pantelous@liverpool.ac.uk.

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This version: 28th of September2017

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1. Introduction

Reference-dependent utility has attracted considerable attention in the literature since the introduction of loss aversion (Tversky and Kahneman, 1979) and disappointment aversion (Bell, 1985; Gul, 1991). Despite the difference between these two preferences (Ang *et al.*, 2005), they have a common feature that losses (disappointments) are weighted more than gains (elations). Many studies show that loss aversion can be used to explain decision making in finance and economics (e.g., Barberis and Huang, 2001; Lien and Wang, 2002; Lien and Wang, 2003; Berkelaar *et al.*, 2004; Ang *et al.*, 2005; Fielding and Stracca, 2007; Hwang and Satchell, 2010; Routledge and Zin, 2010; Giorgi and Post, 2011; Pagel, 2015).

Notwithstanding the popularity of reference-dependent utility, its applications in finance are not as straightforward as those of the conventional utility because of unknown parameters inherent in the reference-dependent utility. A typical approach is to estimate loss aversion for given values of other parameters (e.g., Tversky and Kahneman, 1992; Abdellaoui *et al.*, 2007; Fielding and Stracca, 2007; Tom *et al.*, 2007; Booij and van de Kuilen, 2009; Sokol-Hessner *et al.*, 2009; Hwang and Satchell, 2010). Others estimate loss aversion or subjective probability weighting from lottery-choice questions using surveys or experiments (e.g., Rieger *et al.*, 2015; Wang *et al.*, 2017). Although lottery-choice questions have merits that loss aversion can be estimated independently of other behavioral attitudes under a controlled situation, they may not properly simulate monetary incentives or stress in real investment decision making. This may raise concerns for weak correlations between estimated risk attitudes and actual risk-taking behaviors (Lönnqvist *et al.*, 2015).

We investigate loss aversion around the world using asset allocation of pension funds. Pension funds are widely used as a representative agent for asset allocation problems (Canner *et al.*, 1997; Campbell and Viceira, 2002). Their asset allocations reflect strategic decisions of boards of trustees or regulations of countries over long investment horizons, and thus are less dependent on the market conditions but would show cultural traits of countries.

For this purpose, we propose a novel method to estimate loss aversion together with other preference parameters in a multiple asset allocation problem where the optimal investment weights in risky assets are jointly influenced by loss aversion, risk aversion, and subjective probability weighting in addition to the performance of each asset class. Without considering the performance of asset classes, the difference in asset allocation may be misinterpreted as difference in investor preferences. We then investigate if the loss aversion we estimate using pension funds is associated with wealth level or cultural dimensions. If the way in which we express emotion is largely connected to our culture

(Matsumoto *et al.*, 2008; Mauss and Butler, 2010), then differences in loss aversion may be also motivated by cultural differences defined by Hofstede (2001).[1]

The reference-dependent utility function we use in this study consists of wealth utility as well as gain-loss utility, in which loss aversion, risk aversion, and subjective probability weighting are parameterized. The wealth utility reflects the absolute pleasure of consumption that has been used in the literature, and helps to avoid misleading results by ignoring utility from consumption (Barberis, 2013). Assuming that the gain-loss utility is additively separable for different asset classes as in Koszegi and Rabin (2007), and interpreting the gain-loss utility as a risk measure (Jia and Dyer, 1996), we obtain a nonlinear relationship among the optimal investment proportions, loss aversion, risk aversion, the expected excess returns, and the sensation of losses or gains. Using the first order conditions of the optimal asset allocation in pension funds, we estimate three parameters (loss aversion, risk aversion, and subjective probability weighting) simultaneously using the Generalized Method of Moments (GMM).

Our empirical results show that the average values (standard deviations) of loss aversion, risk aversion, and probability weighting of 31 OECD countries are 1.74 (0.64), 1.42 (0.13) and 0.78 (0.20), respectively. The estimates of loss aversion and subjective probability weighting are similar to those reported by Wang *et al*. (2017) and Rieger *et al.*

[1] Investigating the interaction between risk preferences and cultural measures has been significantly promoted in the last few years (Rieger *et al*., 2011; Rieger *et al*., 2015; Wang *et al*., 2017).

(2011), respectively. However, due to the differences in the estimation methods and decision makers, pension fund managers show the following distinct preferences with respect to those reported in the literature.

We find that loss aversion increases with wealth. When loss aversion is regressed on GDP per capita (as the proxy for wealth), the coefficient is positive and significant after controlling several other economic variables. This result is different from those of Wang *et al.* (2017) who do not find a significant relationship between loss aversion and wealth. Our results support that wealthier investors suffer higher disutility from disappointing outcomes.

Individualistic countries are more loss averse than collectivistic countries. This is consistent with the view that individualistic investors tend to be overconfident of their expectations in risky assets, making themselves more disappointed for losses (Beugelsdijk and Frijns, 2010; Chui *et al.*, 2010; Frijns *et al.*, 2013; Breuer *et al.*, 2014). However, we do not find empirical evidence that loss aversion is affected by other cultural dimensions such as masculinity, power distance, or uncertainty avoidance (Wang *et al.*, 2017).

Interestingly, cultural dimensions affect asset allocation in pension funds. Countries whose individualism or masculinity is high prefer asset classes with slightly more risky but higher returns to bonds, whereas countries that dislike uncertainty prefer bonds to risky equities. Although bonds are not risk-free, pension fund managers prefer them as choices of risk-avoiding against equities and other investments.

Our main contribution is to provide a new method that can be used to estimate directly investor preferences. Many studies have conducted surveys or laboratory experiments with students in the fields of decision theory or psychology. However, differences exist in the way the decision makers behave in experiments and in real financial markets (Levitt and List, 2007; Lönnqvist *et al.*, 2015), because it is difficult to design experiments that include important components in practice, e.g., decision making with a large dollar amount of investment. Despite the similarities between our estimates of loss aversion and subjective probability weighting and those reported in the literature, we also find some differences in the preferences.

The remainder of this paper is organized as follows. In the next section, we propose our reference-dependent utility function and show how the optimal asset allocation in risky assets is affected by investor preferences. In Section 3, we report our estimates and investigate loss aversion with respect to wealth and cultural dimensions. Section 4 concludes the paper.

2. Asset Allocation with Reference-Dependent Utility

A reference-dependent utility is proposed to investigate how assets are allocated with respect to loss aversion, risk aversion, and subjective probability weighting. As in Koszegi and Rabin (2007), investors' utility depends on multi-dimensional wealth portfolios as well as reference dependent portfolios.

2.1. The Model of a Reference-Dependent Utility

The reference-dependent utility, $u(W, \mu_w)$, in this study consists of the typical wealth utility and the gain-loss utility as follows:[2]

$$u(W, \mu_w) \equiv \mu_w - \varphi[A|W - \mu_w|^v I^- - |W - \mu_w|^v (1 - I^-)], \tag{1}$$

where W represents the end-of-period wealth, μ_w is the expected wealth, and I^- is an indicator variable that equals one when $\mathrm{W} - \mu_w < 0$, and zero otherwise. For loss aversion, $A > 1$ is required to give extra weights on the sensation of loss.

The first component of the reference-dependent utility is the expected end-of-period wealth μ_w , which represents utility from consumption via wealth. As suggested by Jia and Dyer (1996), Koszegi and Rabin (2007), and Barberis (2013), neglecting the absolute pleasure of consumption surely leads to biased conclusions. Our reference-dependent utility increases linearly with the expected wealth, satisfying the non-satiation condition, and allowing our model to be tractable (Barberis, 2013). As required for the utility of consumption bundle of Koszegi and Rabin (2007), the wealth utility (expected wealth) is

[2] For an application of the reference-dependent utility in the asset allocation problem, we use wealth to represent consumption. When power utility is used in the gain-loss utility, the optimal investment proportion obtained from using wealth is not different from that with consumption because of its constant relative risk aversion (Campbell and Viceira, 2002).

differentiable and strictly increasing. This linear wealth utility makes the risk-return relationship clear in our reference-dependent frame. For example, when the popular *hyperbolic absolute risk aversion* (HARA) class of utility functions such as power utility or log-utility is used as wealth utility (e.g., Barberis and Huang, 2001; Gomes, 2005; Pagel, 2015), we have two risks in our reference-dependent utility: one from the concavity of the HARA class, and the other included in the gain-loss utility that is explained below.

The second component inside the square brackets in Eq. (1), which we refer to as the *gain-loss utility*, represents utility derived from gains and losses. We use the expected wealth as the reference point in the gain-loss utility for tractability. According to Koszegi and Rabin (2007), using expectations as the reference point would explain investors' behavior better than the status quo, and moreover, simplifies the optimization problem in asset allocation. The curvature parameter, v, decides convexity or concavity of sensation in the domain of either gains or losses. As in many previous studies, the curvature parameters for gains and losses are set equivalent to each other (Tversky and Kahneman, 1992; Abdellaoui, 2000; Barberis *et al.*, 2001; Ang *et al.*, 2005; Abdellaoui and Bleichrodt, 2007).

The *expected gain-loss utility*, i.e., the expectation of the second component in Eq. (1), stands for risk. For example, when $W - \mu_w$ is symmetric, the expected gain-loss utility, $\frac{(A-1)}{2}\mathbb{E}[|W - \mu_w|^v]$, is equivalent to absolute deviation ($v = 1$) or variance ($v = 2$). The expected gain-loss utility represents the relative size of $A\mathbb{E}[|W - \mu_w|^v I^-]$ to $\mathbb{E}[|W - \mu_w|^v(1 - I^-)]$, and thus includes information for the asymmetric distribution of wealth. This expected gain-loss utility has been interpreted as risk in the literature. Luce and Weber (1986) use a piecewise power utility to model perceived risk affected by losses more than by gains. Jia and Dyer (1996) elucidate that the expected gain-loss utility is a special case of their *standard measure of risk*. The expected gain-loss utility represents a measurable uncertainty (Knight, 1921) in which losses are weighted more than gains.

Our interpretation of risk and loss, measured by $\mathbb{E}[A|W-\mu_w|^v I^- - |W-\mu_w|^v(1-I^-)]$ and $\mathbb{E}[|W-\mu_w|^v I^-]$, respectively, indicates that these two are not independent of each other in our reference-dependent utility. This is not surprising since the expected loss with respect to a reference point has been used as a risk measure (downside risk) in the literature (Roy, 1952; Markowitz, 1959; Fishburn, 1977). The experimental results in Thaler *et al.* (1997) and Anzoni and Zeisberger (2017) clearly show that investors are relatively more risk averse for investments that entail potential losses.

With this interpretation, the parameter φ represents risk aversion, the trade-off relationship between the wealth utility and risk. The parameter A, on the other hand, specifies aversion to the relative sensation of loss to gain. When A increases, the expected gain-loss utility is dominated by lower partial moments, indicating that downside risk can be regarded as an extreme relative sensation of loss to gain as the sensation of gain becomes relatively negligible. Therefore, while φ represents aversion to a measurable uncertainty, A measures the relative sensation of loss to gain for given uncertainty.

2.2. Probability Transformation

It is well-documented that people distort probabilities by disproportionately directing their attention to outcomes. According to the cumulative prospect theory (CPT) of Tversky and Kahneman (1992), unlikely extreme outcomes are overweighed while highly possible events are underweighted. In order to simulate investors' subjective weights, suppose a single-parameter weighting function of Prelec (1998) in the gain-loss utility of Eq. (1):

$$w(F(x)) = exp\left[-(-\,ln(F(x)))^{\delta}\right], \tag{2}$$

where $F(x)$ is the cumulative probability of any possible outcome x, $x = W - \mu_w$ represents gains or losses, and $0 < \delta \leq 1$. The weighting function shows that unlikely (likely) outcomes are given more (less) weights as δ decreases. When the subjective weighting is applied to the gain-loss utility, the expected gain-loss utility can be presented as:

$$\mathbb{E}[A|x|^{v}I^{-} - |x|^{v}(1 - I^{-})] = Apu^{-} - (1 - p)u^{+}, \tag{3}$$

where $(1 - p)u^{+} = \int_{0}^{\infty} x^{v} w'(1 - F(x)) f(x)\, dx$, $pu^{-} = \int_{-\infty}^{0} (-x)^{v} w'(F(x)) f(x) dx$, $f(x)$ is the probability density function, p is the cumulative probability at the reference point, and $w'(1 - F(x))$ and $w'(F(x))$ are the derivatives of Prelec's weighting functions at the cumulative probabilities of $1 - F(x)$ and $F(x)$, respectively.

Although the rationale behind the subjective probability weighting is different from that behind the curvature parameter v, these two parameters are closely connected. The subjective weighting function is designed to replicate the probability distortion of outcomes, but alters the degree of risk attitude towards gains and losses with respect to the true probability, because $x^v[w'(1-F(x))f(x)] = [x^v w'(1-F(x))]f(x)$. In other words, for the true probability density function ($f(x)$), the subjective weighting function when combined with the value function of outcome, $x^v w'(1-F(x))$, can create concavity for losses and gains. Even though risk-aversion for gains and risk-loving for losses are assumed for a given subjective weighting function, the net effects of the risk attitude and the subjective weighting function become unclear under the true probability.

2.3 Optimal Asset Allocation with Reference-dependent Utility

The asset allocation problem for multiple asset classes (e.g., equities, bonds, cash, and other investments) in this study is a generalization of the typical asset allocation problem where only two classes of assets (e.g., equity and cash) are considered (Ang *et al.*, 2005; Fielding and Stracca, 2007; Hwang and Satchell, 2010). The initial wealth can be assumed to be 1 since the gain-loss utility with constant relative risk aversion preference is homogeneous in wealth. Then the end-of-period wealth W is an outcome of a portfolio q, where investment proportions $\alpha_1, \alpha_2, \ldots, \alpha_n$ of wealth are invested in n risky assets, and the remaining $(1-\sum_{i=1}^{n}\alpha_i)$ is invested in cash (the risk-free asset). Short positions are not allowed in a typical pension fund, suggesting $0 \le \alpha_i \le 1$ for all *i*. Let r_i and r_f be the return of risky asset *i* and risk-free asset, respectively. Then, gains or losses with respect to the expected wealth μ_w can be calculated by $W - \mu_w = \sum_{i=1}^{n} \alpha_i (r_i - \mu_i)$, where $\mu_i \equiv \mathbb{E}(r_i)$.

For the optimal asset allocation with multiple asset classes, the gain-loss utility (the second component of Eq. (1)) is assumed additively separable across different asset classes as in Koszegi and Rabin (2007).[3] When gains and losses in each asset class are defined as $r_i - \mu_i$, then the expected reference-dependent utility in Eq. (1) appears as follows:

$$U_{DA} = 1 + \sum_{i=1}^{n} \alpha_i(\mu_i - r_f) - \varphi[A \sum_{i=1}^{n} \alpha_i^v p_i u_i^- - \sum_{i=1}^{n} \alpha_i^v (1 - p_i) u_i^+], \qquad (4)$$

where p_i is the cumulative probability at the reference point for risky asset i.

Proposition 1 *For the expected reference-dependent utility in Eq.* (4)*, when* $v > 1$, *the optimal investment proportion with respect to risky asset* i *is as follows:*

$$\alpha_i^* = \left(\frac{\mu_i - r_f}{\varphi v (A p_i u_i^- - (1 - p_i) u_i^+)}\right)^{\frac{1}{v-1}}. \qquad (5)$$

Proof. When investors maximize their expected reference-dependent utility, the first order condition is

$$\frac{\partial U_{DA}}{\partial \alpha_i} = (\mu_i - r_f) - \varphi v \alpha_i^{v-1} (A p_i u_i^- - (1 - p_i) u_i^+) = 0, \qquad (6)$$

[3] If investment experience is thought of as a series of separate episodes as in Barberis and Xiong (2012), or if investors are inclined to narrow framing (Kahneman and Lovallo, 1993; Kahneman, 2003), then the gain-loss utility of an asset class can be considered separately from that of other asset classes.

from which we have the results in Eq. (5). The Hessian matrix for the second order condition becomes a diagonal matrix whose diagonal elements are:

$$\frac{\partial^2 U_{DA}}{\partial \alpha_i^2} = -\alpha_i^{v-2}\varphi v(v-1)(Ap_i u_i^- - (1-p_i)u_i^+),$$

which is

$$\left.\frac{\partial^2 U_{DA}}{\partial \alpha_i^2}\right|_{\alpha_i=\alpha_i^*} = -(\mu_i - r_f)(v-1)\alpha_i^{*-1} < 0,$$

under the assumption that $v > 1$, because the expected returns of risky assets are higher than that of the risk-free asset and $0 < \alpha_i^* \leq 1$. Therefore, the optimal investment proportion in Eq. (5) satisfies the necessary and sufficient condition when $v > 1$. *QED*

The results are interesting because $v > 1$ implies that investors are locally risk-seeking in gains and risk averse in losses. The reversed *S*-shape gain-loss utility is similar to the utility function of Markowitz (1952), Post *et al.* (2008), and Hwang and Satchell (2010). Although simple models without the level of wealth or with the assumption of $v = 1$ are popular in the literature for their tractability (Benartzi and Thaler, 1995; Barberis *et al.*, 2001; Pagel, 2015), they often produce corner solutions in asset allocation problems (Ang *et al.*, 2005; Hwang and Satchell, 2010). This problem may be mitigated by including the expected wealth and allowing $v > 1$. The condition $v > 1$, however, also causes problems in the optimization due to the non-concavity of the utility function in losses (Shefrin, 2008). As explained by Thaler *et al.* (1997), the curvature parameter v (risk aversion or loving in the domain of either gain or loss) is only mild, and many studies assume $v = 1$.

The semi-elasticity of A with respect to φ, $\frac{\partial lnA}{\partial \varphi} = -\frac{(\mu_i - r_f)}{\varphi(\mu_i - r_f) + (1-p_i)v\varphi^2\alpha^{v-1}u_i^+} < 0$, suggests that loss aversion (A) increases when risk aversion (φ) decreases although both loss aversion and risk aversion decrease the optimal investment proportion (α_i^*). This confirms our earlier explanation in Section 2.1 that loss aversion and risk aversion are not independent of each other. Moreover, if investors become more risk tolerant as wealth increases, their loss aversion decreases. Later, in the empirical tests, we investigate if wealthier investors suffer higher disutility from disappointing outcomes.

2.4 Estimation of Loss Aversion Parameters

The optimal investment proportion in Eq. (5) is a non-linear function of loss aversion (A), risk aversion (φ), the expected excess return of risky asset i, curvature (v) and subjective probability weighting (δ) that are included in the expected sensation of gain (u_i^+) and loss (u_i^-) as in Eq. (3). The lack of clarity between curvature and subjective weighting parameters explained in subsection 2.2 clearly shows difficulties in estimating all four parameters A, φ, δ and v at the same time.

In order to minimize the difficulties in the estimation but keep the original rationale behind the reference-dependent utility, we estimate loss aversion (A), risk aversion (φ), and probability weighting (δ) simultaneously for given curvature (v) and the investment proportions in risky assets (α_i) and the expected excess returns ($\mu_i - r_f$) using the first order condition in Eq. (6) in the Generalized Method of Moments (GMM) framework. In fact, it is possible to estimate any three parameters out of the four parameters (A, φ, δ, and v), because we have three orthogonality conditions from three risky asset classes in pension funds – *equities*, *bonds*, and *other investments* (we explain about the data in detail later). The three parameters A, φ, and δ are chosen because the curvature in the domain of gain and loss is mild (Thaler *et al.*, 1997) and as discussed above many studies simply assume $v = 1$.

Our major results are reported with $v = 1.1$, which is chosen for the following reasons. First, as explained by Thaler *et al.* (1997), if risk aversion or loving in the domain of either gain or loss is mild, asset allocation decision would not be sensitive to a small change in v. Second, our analytical results in Proposition 1 require $v > 1$. For robustness of the results, we have tested various other values of v, the results of which are not qualitatively different from those with $v = 1.1$.

Suppose the data $\boldsymbol{\mathcal{Y}}_t = (r_{1t}, r_{2t}, r_{3t}, \alpha_{1t}, \alpha_{2t}, \alpha_{3t}, v)'$ for the estimation of $\boldsymbol{\theta} = (A\,, \varphi\,, \delta)'$. In the just-identified GMM specification, the (3×1) vector of orthogonality conditions from the first order condition in Eq. (6) are

$$\mathbb{E}\big(h(\boldsymbol{\theta}^*, \boldsymbol{\mathcal{Y}}_t)\big) = (\boldsymbol{\mu}_t - r_f \boldsymbol{e}) - \varphi v \boldsymbol{\alpha}^{v-1} \circ (A\boldsymbol{p} \circ \boldsymbol{u}^- - (\boldsymbol{e} - \boldsymbol{p}) \circ \boldsymbol{u}^+) = \mathbf{0}, \qquad (7)$$

where $\boldsymbol{\theta}^*$ represents the true value of $\boldsymbol{\theta}$, $\boldsymbol{e} = (1, 1, 1)'$, and $\circ$ is the Hadamard product (each element ij is the product of elements ij of the two matrices). The sample average of $h(\boldsymbol{\theta}, \boldsymbol{\mathcal{Y}}_t)$ is

$$g(\boldsymbol{\theta}; \boldsymbol{\mathcal{Y}}) = \frac{1}{T}\sum_{t=1}^{T} h\big(\boldsymbol{\theta}, \boldsymbol{\mathcal{Y}}_t\big),$$

where

$$h(\boldsymbol{\theta}, \boldsymbol{\mathcal{Y}}_t) = (\boldsymbol{r}_t - r_f\boldsymbol{e}) - \varphi v \boldsymbol{\alpha}_t^{v-1} \circ (A \circ \left(-\boldsymbol{I}_t^- \circ (\boldsymbol{r}_t - \bar{\boldsymbol{r}}_t)\right)^v \circ w'(\boldsymbol{e} - \boldsymbol{F}_t) -$$

$$(\boldsymbol{I}_t^+ \circ (\boldsymbol{r}_t - \bar{\boldsymbol{r}}_t))^v \circ w'(\boldsymbol{F}_t)), \qquad (8)$$

and the elements in vector $\boldsymbol{I}_t^+$ are $I_{it}^+ = 1$, when $r_{it} - \bar{r}_{it} > 0$ and zero otherwise and $\boldsymbol{I}_{it}^- = \boldsymbol{e} - \boldsymbol{I}_{it}^+$, respectively. For a subjective weighting function for the cumulative probability $\boldsymbol{F}_t = F(\boldsymbol{x})$ of outcome $\boldsymbol{x} = \boldsymbol{r}_t - \bar{\boldsymbol{r}}_t$, we use Prelec (1998) one parameter version: $w(F(\boldsymbol{x})) = exp\left[-(-ln(F(\boldsymbol{x})))^\delta\right]$, where $0 < \delta \leq 1$. The multiplier functions are

$$w'(\boldsymbol{F}_t) = \frac{\delta}{\boldsymbol{F}_t} \circ \left(-ln(\boldsymbol{F}_t)\right)^{\delta-1} \circ exp\left(-\left(-ln(\boldsymbol{F}_t)\right)^\delta\right)$$

and

$$w'(\boldsymbol{e} - \boldsymbol{F}_t) = \frac{\delta}{\boldsymbol{e} - \boldsymbol{F}_t} \circ \left(-ln(\boldsymbol{e} - \boldsymbol{F}_t)\right)^{\delta-1} \circ exp\left(-\left(-ln(\boldsymbol{e} - \boldsymbol{F}_t)\right)^\delta\right),$$

where $\boldsymbol{F}_t = F(\boldsymbol{r}_t - \bar{\boldsymbol{r}}_t)$.

As $\boldsymbol{\mathcal{Y}}_t$ is strictly stationary and $h(\boldsymbol{\theta}, \boldsymbol{\mathcal{Y}}_t)$ is continuous, by the law of large numbers we have

$$g(\boldsymbol{\theta}; \boldsymbol{\mathcal{Y}}) \xrightarrow{p} \mathrm{E}(h(\boldsymbol{\theta}, \boldsymbol{\mathcal{Y}}_t)).$$

The GMM estimator $\widehat{\boldsymbol{\theta}}$ is

$$\widehat{\boldsymbol{\theta}} = \arg\min g(\boldsymbol{\theta}; \boldsymbol{\mathcal{Y}})' \widehat{\boldsymbol{\Omega}}_T^{-1} g(\boldsymbol{\theta}; \boldsymbol{\mathcal{Y}}). \qquad (9)$$

For the weighting matrix $\widehat{\boldsymbol{\Omega}}_T^{-1}$ we use

$$\widehat{\boldsymbol{\Omega}}_T^{-1} = \left[\frac{1}{T}\sum_{t=1}^T h(\widehat{\boldsymbol{\theta}}, \boldsymbol{\mathcal{Y}}_t) h(\widehat{\boldsymbol{\theta}}, \boldsymbol{\mathcal{Y}}_t)'\right]^{-1}, \qquad (10)$$

which is the variance-covariance matrix of sample mean of $h(\widehat{\boldsymbol{\theta}}, \boldsymbol{\mathcal{Y}}_t)$.

We use iterated GMM to obtain the optimal estimator $\widehat{\boldsymbol{\theta}}$. The initial weighting matrix is set to $\widehat{\boldsymbol{\Omega}}_T^{-1} = \boldsymbol{I}$ (the indentity matrix) and then is updated with the GMM estimate $\widehat{\boldsymbol{\theta}}$

from the optimization in Eq. (9). Eqs. (9) and (10) are repeated until convergence. In the *n-th* iteration, the estimate $\widehat{\boldsymbol{\theta}_n}$ is found using a popular machine learning method known as Limited-memory BFGS.[4] Since $g(\boldsymbol{\theta};\boldsymbol{\mathcal{Y}})$ is not a globally convex function with a unique minimum, local minima are possible. As a solution to this problem, we use various starting values and exclude any resulting estimates that have little economic sense or lead to large standard errors.[5] The standard errors of the estimates are calculated using the Hessian matrix evaluated at $\widehat{\boldsymbol{\theta}}$. The Hessian matrix is the matrix of second partial derivatives of $g(\widehat{\boldsymbol{\theta}};\boldsymbol{\mathcal{Y}})'\widehat{\boldsymbol{\Omega}}_T^{-1}W_T(\widehat{\boldsymbol{\theta}};\boldsymbol{\mathcal{Y}})$. The square root of the diagonal terms gives us the standard errors of the estimates.

3. Empirical Tests

We estimate loss aversion together with risk aversion and subjective probability weighting using asset allocations in pension funds of 31 countries for the period from

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[4] The limited-memory in the family of Quasi-Newton methods that approximates the Broyden–Fletcher–Goldfarb–Shanno (BFGS) algorithm using a limited amount of computer memory, more details about this algorithm can be found in Liu and Nocedal (1989).

[5] An alternative method would be the Bayesian estimation with informative priors, which is far more complicated. The robustness of our estimates is also tested by using the loss aversion coefficients and the subjective probability weighting parameters reported by Wang *et al* (2017) and Rieger *et al*. (2015), respectively, as starting values.

2004 to 2015. Pension funds are widely used as a representative agent for asset allocation problems (Canner *et al.*, 1997; Campbell and Viceira, 2002). Their asset allocations can be regarded as the optimal weights α_i^*s as they are the outcome of strategic asset allocation decision of board of trustees or regulations of these countries over long investment horizons. Therefore, it is less dependent on the market conditions but would rather show cultural traits of countries, allowing us to investigate the relationship between loss aversion and cultural dimensions.[6]

[6] As in most other empirical tests in finance, we use *ex post* returns due to the difficulties in obtaining expected returns of various asset classes in each country. Empirical results with *ex post* returns, however, may not be necessarily consistent with the analytical results with *ex ante* returns (Elton, 1999; Fama and French, 2002). Some studies use expected returns estimated under the assumption of certain models (e.g., Fama and French, 2002; Chen, et al., 2008). However, these estimates may suffer misspecification problems when the choice of models or variables does not represent the full set of information. Moreover, the estimation of expected returns in 'other investments' (derivatives, infra, properties, etc.) is not as straightforward as those of equities or bonds. In order to minimize this problem, we use low frequency annual data.

3.1 Data

We collect asset allocations of pension funds across 31 countries included in the OECD Global Pension Statistics for the period from 2004 to 2015.[7] The number of countries and sampling period are restricted by the data availability of pension funds' asset allocations, returns and cultural measures we consider in this study.[8] The assets are

[7] The OECD launched the Global Pension Statistics Project (GPS) in 2002 for a growing need from policy makers, the regulatory community, and private sector participants, to compare programme developments and experiences to those of other countries. The statistics cover an extensive range of funded and private pension plans. The data availability before 2004 rapidly worsens.

[8] Among the 35 OECD countries, nine countries (Estonia, Korea, Netherlands, New Zealand, Ireland, Slovak Rep, Portugal, Latvia and Luxembourg) are excluded because their asset allocation data for the entire sample period are not available or identification of asset classes is not clear. Some countries such as Estonia, Netherlands, Portugal, and Luxembourg show substantial foreign investments which are not clearly classified into any of our four asset classes. On the other hand, five non-OECD countries (Brazil, Hong Kong, Pakistan, South Africa and Thailand) in the OECD Global Pension Statistics are included to increase the power of our tests as much as possible. As the number of countries in the OECD Global Pension Statistics increases, a more robust analysis would be possible in the future.

grouped into four classes, i.e., equities, bonds, other investments, and risk-free assets, according to their significance in investment proportions.

3.1.1 Investment Weights in Asset Classes

The investment weights (α_i^*) in these four asset classes are collected from OECD Global Pension Statistics, where national asset allocations of pension funds are maintained and updated annually. Investment proportions in three asset classes – equities, bonds, and risk-free assets − are straightforward. However, significant proportions of pension funds are invested in other investment vehicles, which include, but are not limited to, loans, land and buildings, unallocated insurance contracts, hedge funds, private equity funds, structured products, and other mutual funds. Such a wide variety poses enormous difficulties in tracking the performance of each asset class in each country. Moreover, details of investment proportions in these other investment vehicles are not known. Therefore, the investment in the assets except for equities, bonds, and risk-free assets is grouped and named as 'other investments'.

Panel A of Table I reports the average weights on asset classes for each country during our sampling period. On average, 45.90% of pension funds is invested in bonds, followed by other investments (23.63%), and equities (21.84%). The investment proportions in the three risky asset classes are negatively correlated (panel B). The correlation coefficients in the investment proportions between equities and bonds and between bonds and other investment are -0.54 and -0.68, respectively, and statistically significant. However, we do not find substitution relationship between equities and other investment whose correlation coefficient is close to zero, i.e., 0.04.

3.1.2 Returns of Asset Classes

The returns of the four asset classes are calculated as follows using the DataStream database. First, equity returns are calculated from the composite index of the major stock exchange in each country. Table II reports that the average annual log-return (standard deviation, SD) of the 31 countries is 7.26% (28.43%).

Second, bond returns are calculated with equal weight on the total returns of government and corporate bonds. *Ten-year benchmark government bonds* are used as government bonds.[9] The quality of corporate bond data is not as good as that of the government bond data among emerging markets. To mitigate this defect, we consider three international indexes: FTSE Euro Corporate Bond Index for those developed markets outside the Eurozone (Denmark, Hong Kong, Iceland, Japan and Norway); IBoxx Euro Corporate Bond Index for countries within the Eurozone (Finland, France, Germany, Greece, Italy, Slovenia and Spain); and finally, BofA-Merrill Lynch Emerging Markets Corporate Plus Index for emerging markets (Mexico, Poland, Pakistan, South Africa, Thailand and Turkey). For the remaining countries (Australia, Canada, Chile, Israel, the United Kingdom

[9] The data of ten-year government bonds is non-applicable in Turkey, hence, a similar bond price index with a 5-year maturity is applied.

and the United States), country-specific indices can be found. The average annual bond log-return (SD) for all countries is 5.74% (6.52%).

Third, for other investments, considering the diversity of this asset group, we construct a composite index using MSCI World Real Estate, Dow Johns Brookfield GLB INFRA, S&P Listed Private Equity, and HFRI Fund of Funds Composite, for real estates, infrastructure, hedge funds, and private equities, respectively. These four return series are equally weighted to create the 'other investments' asset class. The average annualized log-return (SD) for other investments is 8.44% (22.72%).

Finally, for the risk-free rates, we use 30-day T-bill rates. If T-bill returns are not available, 30-day interbank rates or repo-rates are used. Countries within the Eurozone share an identical interbank rate. Notably, high short-term interest rates are observed in a few countries due to their financial policies or rapid capital growth. For example, the risk-free rates in Brazil, Iceland, South Africa and Turkey are all over 8%. High risk-free rates produce negative excess returns for some countries, rendering abnormal loss aversion that will be discussed later.

3.1.3. National culture dimensions

A growing number of studies have found how cultural differences affect asset pricing and financial decision since the cultural dimension theory developed by Geert Hofstede (2001). For example, individualism increases foreign investment (Beugelsdijk and Frijns, 2010), financial risk-taking (Breuer *et al.*, 2014), and overconfidence that leads to overoptimism towards future returns (Markus and Kitayama, 1991; Van Den Steen, 2004; Chui et al., 2010).

We investigate cross-cultural variations of loss aversion using four primary cultural dimensions in Hofstede's culture measures (Hofstede, 2001), i.e., individualism, masculinity, power distance, and uncertainty avoidance. If cultural dimensions are positively related with loss aversion as in Wang *et al.* (2017), then they may affect asset allocation too.

Individualism (IDV) is a measure of the degree to which individuals are integrated into groups. Higher IDV indicates the more individualistic society where people have less social support and focus on their own abilities to differentiate themselves from others. According to Hsee and Weber (1999) and Chui *et al.* (2010), investors in individualistic culture are more loss averse and overconfident. On the other hand, masculinity (MAS) represents the distribution of preferences to a competitive or corporative society. In masculinity societies that are characterized by achievement, heroism, assertiveness and material rewards for success, investors are driven by investment performance too much and they become more sensitive to losses than those in feminine societies (Abdellaoui and Bleichrodt, 2007). The power distance (PD) refers to the extent to which less powerful members accept the unequal distribution of power. Higher PD refers that people tend to accept a hierarchical order in which everybody has a place without any further justification. Power distance would increase loss aversion because people feel more helpless and thus avoid losses when inequlity increases (Inesi, 2010). Finally, the uncertainty avoidance (UA) reflects the extent to which people feel either uncomfortable or comfortable in unstructured situations which are novel, unknown, surprising, and ambiguous. When people are keen on avoiding uncertainty, they would become more sensitive to losses.

3.2. Cross-Country Loss Aversion

The three parameters – loss aversion, risk aversion, and subjective probability weighting – estimated in the presence of the performance of each asset class are reported in Panel A, Table III. The numbers in brackets represent the standard errors of estimates. In general, the estimates based on asset allocation of pension funds are similar to those estimated from experiments and surveys (Rieger *et al*., 2011; Wang *et al.* (2017).

First, the average value and standard deviation of loss aversion estimates are 1.74 and 0.64, respectively. The level is slightly lower than those suggested in the literature (e.g., Tversky and Kahneman, 1992; Pennings and Smidts, 2003; Fielding and Stracca, 2007; Tom *et al.*, 2007; Hwang and Satchell, 2010; Wang *et al.*, 2017). Anomalous loss aversion coefficients that contradict the theoretical prediction appear in some countries, mainly due to the relatively low excess returns of risky assets: for example, Iceland exhibits a "loss-seeking" pattern ($A = -0.11$). Since it is difficult to interpret loss-seeking behaviour, we exclude Iceland from the further analysis.[10]

Second, the average risk aversion parameter φ is 1.42 and the standard deviation is 0.13. If loss aversion is disregarded, i.e., $A = 1$, then the risk aversion parameter is equivalent to the Arrow-Pratt coefficient of relative risk-aversion. Our estimates of risk aversion that range from 1 to 1.6 are slightly lower than those suggested in the literature.[11] However, if loss aversion is negatively related with risk aversion as in Thaler *et al.* (1997) and our Proposition 1, the estimate of loss aversion or risk aversion should be lower than that without considering each other.

Third, the average value of subjective weightings δ is about 0.78 with standard deviation of 0.2. This is close to 0.74 suggested in Gonzalez and Wu (1999). Pension fund managers over-estimate the probabilities of low and high returns that are unlikely whereas

[10] When Iceland is omitted, the average values of λ, φ, and δ for the remaining 30 countries are 1.80, 1.42, and 0.75, respectively.

[11] Many earlier studies suggest that the admissible range of the coefficient of the constant relative risk aversion lies between one and two (Friend and Blume, 1975; Kydland and Prescott, 1982). However, in the portfolio optimization, the risk aversion parameter is typically assumed to be in the region of 2 to 4 (Fabozzi *et al.*, 2007).

they under-estimate those around the average return. Although these pension fund managers possess better knowledge of asset returns, their subjective probability weights do not deviate from what has been found in psychological experiments.

How are our estimates compared with those of previous studies? For example, Wang *et al.* (2017) estimate cross-country loss aversion using a survey known as International Test on Risk Attitudes (INTRA), which is closely related to our goals but differs from two important treatments. Firstly, they evaluate the level of loss aversion from lottery questions whereas ours are estimated using asset allocation in pension funds (i.e. real-life decisions). Secondly, in Wang *et al.* (2017), loss aversion is estimated separately to risk aversion and probability weighting; in contrast, we estimate loss aversion together with risk aversion and probability weighting.

Panels B and C of Table III report some statistics that compare our estimates with those of others in the literature. For the 27 countries, common in Wang *et al.* (2017) and our study, the Spearman correlation between these two sets of loss aversion estimates is 0.38 and is statistically significant. Moreover, the mean (standard deviation) of our loss aversion estimates is 1.87 (0.52) while Wang *et al.* (2017) report 2.01 (0.37). The difference is not statistically significant. The subjective probability weighting parameters we estimate are also similar to those reported by Rieger et al. (2015). The Spearman rank correlation coefficient is 0.54 for the 21 countries included in Rieger et al. (2011) and our study, and it is statistically significant.

Therefore, despite the differences in the utility functions used to estimate loss aversion or subjective probability weighting, the methods (survey, experiment, and asset allocation in pension funds), and decision makers (students and fund managers), it is interesting to find similarities between the estimates. We argue, however, that our estimates would better reflect investors' preferences towards risk and loss in practice because loss aversion is estimated together with both risk aversion and subjective weighting using the performance of major asset classes and their asset allocation decisions.

3.3. The effects of wealth level on loss aversion

Using the estimates of loss aversion, we investigate if wealthier investors suffer higher disutility from disappointing outcomes. Despite the negative relationship between loss aversion and risk aversion, it is not clear if loss aversion increases with wealth. Wang *et al.* (2017) do not find any significant relationship between wealth and loss aversion they estimate using survey data.

We regress the estimated loss aversion on GDP per Capita (as the proxy for wealth) (GDPER) as well as other control variables that represent the development of financial markets. The panel regression model is as follow:

$$LN(LA_k) = \beta_0 + \beta_1 CGDP_{k,t} + \beta_2 DGDP_{k,t} + \beta_3 GDPER_{k,t}$$

$$+\beta_4 IF_{k,t} + \beta_5 PSI_{k,t} + \beta_6 RE_{k,t} + \varepsilon_k.$$

Five control variables include the *scale of financial recourses* (credit to private sector, as the % of GDP, CGDP) (Chui *et al.*, 2010), the investable *freedom index* (published by the heritage foundation to measure stock market openness, IF) (Bekaert *et al.* (2007), the *political stability* (issued by the World Bank to reflect perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, PSI) (Lesmond, 2005; Eleswarapu and Venkataraman, 2006; Bekaert *et al.*, 2007), the *financial leverage* (government's debt to GDP ratio, DGDP), and *regulatory efficiency* (published by the heritage foundation, which equally consists of three sub-indices: business freedom, labor freedom and monetary freedom, RE). In the panel regression, each explanatory variable has 12 yearly observations for each of the 30 countries.

Regression results in Table IV show that loss aversion is higher in wealthier countries: the coefficients on GDPER are positive and significant at the 5% level in all cases. The positive coefficients on CGDP, RE, and IF suggest that loss aversion is also high in the countries where their financial markets are advanced, or are efficient and liquid. The negative coefficient on DGDP implies that countries with lower loss aversion adopt aggressive fiscal expending. Therefore, loss aversion increases as investors are wealthier and financial markets are mature.

3.4. Attitudes in investment decision with respect to cultural dimensions

Can loss aversion be explained by cultural dimension measures developed by Hofstede (2001)? Wang *et al.* (2017) report that individualism, power distance, and masculinity increase loss aversion. To explore this question, we conduct a regression of estimated loss aversion on four cultural dimensions in addition to 12-year average of GDP per capita (GDPER):

$$LN(LA_k) = \beta_0 + \beta_1 IDV_k + \beta_2 GDPER_k + \beta_3 MAS_k + \beta_4 PD_k + \beta_5 UA_k + \varepsilon_k.$$

As in Chui *et al.* (2010) and Wang *et al.* (2017), the results in Panel A of Table V show that loss aversion increases with individualism regardless of model specifications. Individualistic investors suffer more disutility from losses than collective investors do. People from a more independent or overconfident culture may be less capable in dealing with losses (failures) and emotional regulation (e.g., Miyamoto and Ma, 2011; Miyamoto *et al.*, 2014). In contrast, collectivistic people are less loss-averse in general as their culture often encourage people to support each other and set moderate goals (e.g., Cohen and Wills, 1985; Hsee and Weber, 1999). However, for the other three cultural dimensions, the relation is not significant. Interestingly, GDP per Capita (GDPER) which we use as a proxy for wealth is not significant in the presence of individualism, because of the high correlation between GDPER and IDV, i.e., 0.66.

Our regression results in Panel B do not show any significant association between Hofstede's cultural measures and the other two preference parameters, i.e., risk aversion and subjective probability weighting. This result is not consistent with those of Rieger *et al.* (2015) who find robust influence of culture (IDV and UA) on risk preferences that are estimated without disentangling potential interactions with loss aversion and subjective probability weighting. Since these behavior traits are difficult to be decomposed via hypothetical lottery-choice questions, we argue that our results would reveal further insights about the three elements of prospect theory.

3.5. Asset allocation with respect to cultural dimensions

Finally, we test if the four cultural dimensions can directly explain investment proportions in the risky assets (RP_k) using the following regression equation:

$$RP_k = \beta_0 + \beta_1 MAS_k + \beta_2 INDV_k + \beta_3 UAI_k + \varepsilon_k.$$

PD is not used as an explanatory variable because it is not significant in all cases in our preliminary tests.

As reported in panel C of Table V, a higher level of individualism or uncertainty avoidance increases proportions in risky assets, but the masculinity makes a negligible impact on investment proportions in the risky assets. However, the results are different for different asset classes: investment in other investments increases with individualism and masculinity whereas investment in bonds decreases with these two. These results suggest that individualistic and masculinistic countries prefer high risk–high return asset classes to less risky assets such as bonds. By contrast, uncertainty avoidance affects investment in equities in an opposite way to that in bonds: when uncertainty avoidance increases, investment in bonds increases while investment in equities decreases. These results are consistent with the relationship in the investment proportions between the three asset classes in panel B of Table I: investment in other assets or equities is an alternative to that in bonds, but investment in equities is not related with that in other investments.

Therefore, although we do not find evidence for the effects of cultural dimensions on investment in the risky assets except for individualism and uncertainty avoidance, each of the three asset classes respond differently to these cultural dimensions. Countries with high individualism or masculinity prefer asset classes with slightly more risky but higher returns to bonds, whereas countries that dislike uncertainty prefer bonds to risky equities. Although bonds are not risk-free, pension fund managers prefer them as choices of risk-avoiding against equities and other investments.

3.6. Robustness Tests[12]

Our main results with v = 1.1 are based on the literature that the curvature is not severe, and our analytical result that requires $v > 1$. However, our choice of v is arbitrary and thus we further test if our main results are robust to different values of v, i.e., v = 1.25, 1.5 and 2. Since a larger v represents a more risk seeking in gains, loss aversion should increase with v. As expected, the average loss aversion values are 1.84, 1.95, and 2.32 for v = 1.25, 1.5 and 2, respectively. On the contrary, we find no clear pattern in the subjective probability weighting as v changes.

In all three cases, the correlation coefficients between our estimated of loss aversion and those of Wang *et al.* (2017) are still positive and significant. Based on the 27 countries

[12] More detailed empirical results can be obtained from the authors upon request.

we have in common with Wang *et al.* (2017), the Spearman' rank correlations are 0.35, 0.39 and 0.34 when v =1.25, 1.5 and 2, respectively.

More importantly, as reported in Table VI, regression results with respect to wealth and cultural dimensions are consistent with our main results with v = 1.1. In addition to Iceland who has a negative loss aversion, Chile has been removed from the robustness test because of its exceptionally high loss aversion (over 4) when v increases. Panel A shows that loss aversion increases with wealth (GDPER) for v = 1.25, 1.5 and 2 after controlling CGDP, DGDP, IF, and RE. Similarly, results in Panel B confirm that individualism increases loss aversion despite different values of v.[13]

Finally, we investigate if our results still hold when the five non-OECD countries (Brazil, Hong Kong, Pakistan, South Africa and Thailand) are excluded, or when the substantial foreign investments of the four countries (Estonia, Netherlands, Portugal and Luxembourg) are assumed be investment in other investments. The results confirm that loss aversion increases with wealth and individualism (detailed results not reported). Our results are also robust to Greece that shows a large negative equity return during the sample period. Excluding Greece or replacing Greek equity returns with the global equity returns does not change our main results.

[13] As showed in Panel A, Table V, other cultural measures such as MAS, PD and UA can hardly explain loss aversion. We only report the results with GDPER as an independent variable.

4. Conclusion

In assessing investors' attitude to losses, one major difficulty is that all preference parameters are in theory, mutually intertwined, and thus estimating one for given values of others would not reveal what investors' real preferences. In this paper, we propose a method that can estimate loss aversion, risk aversion, and subjective probability weights simultaneously in the multiple asset allocation problem. Our estimates of loss aversion are in general consistent with those estimated from international surveys.

However, we find that investors become more averse to disappointments as wealth increases. In addition, among the four cultural dimensions of Hofstede (2001), individualism alone is positively associated with loss aversion. A potential inference of this relation is that loss aversion might help reduce overconfidence: if investors are overconfident or optimistic towards a certain risky prospect, they may become increasingly disappointed at losses. Such cognitive dissonance may force investors to cool down and re-evaluate their situation. However, cultural dimensions explain investments in some asset classes. Highly individualistic or masculinistic investors prefer high risk and high return assets to bonds, whereas investors who dislike uncertainty prefer bonds to riskier assets.

Finally, if investors are loss averse as well as risk averse, then the premium for a risky asset should reflect a compensation of disappointments from loss as well as risk. We leave the decomposition of the risk premium for future study.

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Table I Asset Allocations of Pension Funds

The asset allocations of pension funds of the 31 OECD countries are average investment proportions over the sampling period from 2004 to 2015. The "Other Investments" category includes loans, land and buildings, unallocated insurance contracts, hedge funds, private equity funds, structured products and other mutual funds. If the OECD pension funds statistics does not have any records for a specific country, asset weights are substituted using some other similar indicators such as “Asset Allocations of Institutional Investors assets" or "Personal Pension Fund Assets". In the case no suitable substitutes can be applied, missing data are filled by the total average of available samples. Panel B reports Spearman rank correlation coefficients between investment proportions.

A. Investment Proportions in Asset Classes

	Equity	Bond	Other Investments	Risk-free Asset
Australia	32.16%	9.36%	47.60%	10.88%
Austria	31.44%	51.71%	10.98%	5.87%
Belgium	22.36%	22.71%	47.58%	7.35%
Brazil	17.52%	27.37%	55.04%	0.07%
Canada	29.26%	29.60%	36.90%	4.24%
Chile	25.96%	48.73%	24.02%	1.29%
Czech Republic	2.96%	82.66%	5.59%	8.79%
Denmark	18.75%	60.25%	20.25%	0.75%
Finland	39.96%	38.21%	19.83%	2.00%
France	34.68%	47.39%	10.30%	7.63%
Germany	10.86%	36.49%	48.53%	4.12%
Greece	4.13%	48.51%	4.97%	42.39%
Hong Kong	53.00%	26.32%	6.96%	13.72%
Hungary	8.49%	66.44%	19.98%	5.09%
Iceland	25.17%	50.38%	18.50%	5.95%
Israel	5.32%	79.45%	10.35%	4.88%
Italy	12.63%	42.73%	38.89%	5.75%
Japan	11.37%	36.21%	38.81%	13.61%
Mexico	15.42%	82.13%	2.04%	0.41%
Norway	27.81%	55.47%	12.63%	4.09%
Pakistan	30.04%	43.49%	3.28%	23.19%
Poland	41.08%	53.08%	0.96%	4.88%
Slovenia	3.19%	63.91%	12.17%	20.73%
South Africa	21.44%	7.34%	65.83%	5.39%
Spain	13.22%	58.31%	14.90%	13.57%
Sweden	20.88%	58.99%	15.70%	4.43%
Switzerland	17.25%	24.85%	48.98%	8.92%
Thailand	12.27%	67.27%	4.17%	16.29%
Turkey	11.99%	57.09%	13.82%	17.10%
United Kingdom	31.49%	24.70%	41.15%	2.66%
United States	45.09%	21.67%	31.70%	1.54%
World average	21.84%	45.90%	23.63%	8.63%

B. Correlation Coefficients between Investment Proportions

	Equities	Bonds	Other Investments
Bonds	-0.541		
Other Investments	0.037	-0.677	
Risk-free Asset	-0.286	0.049	-0.313

Table II Summary Statistics of Annual Asset Returns

Equity returns are measured by the composite index of the major stock exchange in each country. Bond returns are calculated with equal weights on the total returns of government and corporate bonds. Performance of other investments consists of four major assets on equal weights: real estates, infrastructure, hedge funds, and private equities. Four global indexes are utilized as the return proxies, which includes MSCI World Real Estate, Dow Johns Brookfield GLB INFRA, S&P Listed Private Equity and HFRI Fund of Funds Composite. Finally, risk-free rates equal to 30-day T-bill rates. If T-bill returns are not available, 30-day interbank rates or repo-rates are applied instead. The numbers in the round brackets are standard deviations of annual returns. The sampling period is 12 years from 2004 to 2015.

	Equity mean	Equity S.D.	Bond mean	Bond S.D.	Other mean	Other S.D.	Risk-free
Australia	8.34%	21.46%	5.55%	6.44%	9.07%	22.28%	4.53%
Austria	5.25%	37.17%	5.29%	4.98%	8.40%	22.93%	1.55%
Belgium	10.52%	32.47%	5.48%	5.81%	8.40%	22.93%	1.55%
Brazil	10.20%	29.16%	5.62%	5.43%	8.84%	22.08%	12.13%
Canada	6.75%	18.07%	5.35%	3.38%	8.61%	22.51%	1.65%
Chile	8.89%	17.99%	9.34%	13.63%	8.49%	21.91%	0.34%
Czech Republic	10.67%	25.38%	8.24%	16.03%	8.60%	23.16%	1.46%
Denmark	12.64%	28.40%	5.82%	4.86%	8.41%	22.89%	1.77%
Finland	6.71%	29.87%	5.16%	4.64%	8.40%	22.93%	1.55%
France	7.31%	21.81%	5.27%	4.88%	8.40%	22.93%	1.55%
Germany	8.39%	21.47%	5.15%	4.27%	8.40%	22.93%	1.55%
Greece	-14.45%	45.41%	2.96%	20.17%	8.40%	22.93%	1.55%
Hong Kong	8.12%	29.61%	4.27%	2.67%	7.57%	23.34%	1.28%
Hungary	6.99%	34.47%	7.56%	8.61%	9.04%	22.66%	6.42%
Iceland	-8.40%	70.19%	4.67%	2.78%	8.68%	20.60%	8.50%
Israel	6.63%	28.12%	5.16%	4.89%	8.17%	22.93%	2.65%
Italy	4.05%	24.90%	5.66%	6.66%	8.40%	22.93%	1.55%
Japan	5.21%	24.91%	4.30%	3.20%	7.38%	24.21%	0.15%
Mexico	15.56%	19.35%	7.58%	6.00%	8.74%	22.31%	5.56%
Norway	10.14%	30.20%	5.84%	4.82%	8.62%	22.27%	2.64%
Pakistan	14.79%	38.73%	8.78%	5.70%	7.67%	23.00%	9.32%
Poland	6.42%	26.20%	6.66%	6.49%	9.20%	22.64%	4.07%
Slovenia	0.67%	40.53%	4.39%	2.98%	8.40%	22.93%	1.55%
South Africa	14.96%	16.62%	6.87%	5.54%	9.28%	21.99%	7.11%
Spain	6.67%	21.16%	5.50%	5.37%	8.40%	22.93%	1.55%
Sweden	11.39%	24.43%	5.76%	5.40%	8.75%	22.78%	1.53%
Switzerland	7.22%	18.19%	5.09%	4.29%	8.23%	23.27%	0.45%
Thailand	7.80%	30.65%	0.23%	17.56%	7.99%	23.22%	2.70%
Turkey	11.24%	38.82%	8.87%	5.17%	8.70%	21.93%	11.09%
United Kingdom	7.03%	16.64%	6.12%	4.83%	8.31%	22.64%	2.68%
United States	7.39%	18.96%	5.25%	4.75%	7.56%	23.31%	1.29%
World average	7.26%	28.43%	5.74%	6.52%	8.44%	22.72%	3.33%

Table III Investors' Preferences

Panel A lists investors' preferences for each country (region) estimated using GMM with annual data 2004-2015. Numbers in brackets are standard errors of estimates except for those in the World average which represent standard deviations. Panel B and C compare our estimates of loss aversion and subjective probability weight that are in common with Wang *et al.* (2017) and Rieger *et al.* (2015), respectively.

A. Estimated Loss Aversion, Risk Aversion and Subjective Weighting

	Loss Aversion (A)		Risk Aversion (Phi)		Subjective Weighting (Delta)	
Australia	1.651	(0.009)	1.210	(0.005)	0.771	(0.010)
Austria	1.819	(0.005)	1.158	(0.004)	0.792	(0.007)
Belgium	1.809	(0.006)	1.438	(0.004)	0.698	(0.010)
Brazil	0.603	(0.021)	1.494	(0.005)	0.807	(0.008)
Canada	1.940	(0.017)	1.459	(0.010)	0.754	(0.027)
Chile	2.040	(0.010)	1.520	(0.010)	0.503	(0.013)
Czech Republic	1.968	(0.008)	1.477	(0.006)	0.808	(0.011)
Denmark	2.205	(0.007)	1.504	(0.005)	0.861	(0.015)
Finland	2.222	(0.008)	1.595	(0.007)	0.985	(0.009)
France	2.050	(0.007)	1.534	(0.005)	0.915	(0.008)
Germany	1.903	(0.006)	1.431	(0.004)	0.717	(0.009)
Greece	0.331	(0.045)	1.460	(0.031)	0.903	(0.035)
Hong Kong	2.168	(0.009)	1.384	(0.007)	0.589	(0.020)
Hungary	0.925	(0.007)	1.008	(0.001)	0.534	(0.001)
Iceland	-0.112	(0.075)	1.441	(0.031)	1.551	(0.044)
Israel	1.914	(0.005)	1.442	(0.003)	0.705	(0.008)
Italy	3.348	(0.004)	1.415	(0.006)	0.703	(0.012)
Japan	1.932	(0.004)	1.441	(0.003)	0.714	(0.009)
Mexico	1.644	(0.016)	1.563	(0.008)	0.988	(0.016)
Norway	1.953	(0.011)	1.468	(0.007)	0.779	(0.016)
Pakistan	1.198	(0.042)	1.501	(0.006)	0.946	(0.030)
Poland	2.317	(0.008)	1.184	(0.007)	0.669	(0.024)
Slovenia	1.828	(0.006)	1.383	(0.003)	0.349	(0.009)
South Africa	1.840	(0.013)	1.388	(0.008)	0.645	(0.018)
Spain	1.952	(0.011)	1.467	(0.007)	0.784	(0.015)
Sweden	2.032	(0.011)	1.520	(0.007)	0.893	(0.015)
Switzerland	1.957	(0.010)	1.471	(0.007)	0.779	(0.017)
Thailand	1.638	(0.018)	1.193	(0.010)	0.663	(0.018)
Turkey	1.027	(0.021)	1.457	(0.001)	0.857	(0.003)
United Kingdom	1.889	(0.009)	1.421	(0.006)	0.690	(0.014)
United States	1.942	(0.011)	1.459	(0.007)	0.758	(0.018)
World average	1.740	(0.644)	1.416	(0.131)	0.778	(0.200)

B. Comparison of Loss Aversion between our study and Wang et al. (2017)

	Our Estimates	Wang *et al.* (2017)
Average	1.866	2.011
S.D.	0.518	0.368
Spearman Correlation	0.38*	
Number of Countries	27	

*. Correlation is significant at the 0.05 level (2-tailed).

C. Comparison of Subjective Weighting between our study and Rieger *et al.* (2011)

	Our Estimates	Rieger *et al.* (2011)
Average	0.737	0.525
S.D.	0.094	0.109
Spearman Correlation	0.54*	
Number of Countries	21	

*. Correlation is significant at the 0.05 level (2-tailed).

Table IV Loss Aversion with respect to Macroeconomic Variables

The table reports the results of panel regression. The dependent variable is the natural logarithm of estimated loss aversion. Control variables include the scale of financial recourses (credit to private sector, as the % of GDP, CGDP); government's debt ratio (debt to GDP ratio, DGDP); the individual wealth level (GDP per Capita, GDPER); investment freedom index (published by the heritage foundation, IF); political stability issued by the World Bank (PSI) and regulatory efficiency (published by the heritage foundation, RE). Bold numbers represent significance at the 5% level. Numbers in brackets represent white heteroscedasticity robust standard errors. Variance inflation factors (VIF) are checked simultaneously to ensure all control variables are free of multicollinearity issues. N represents the number of samples applied in regressions.

	(1)	(2)	(3)	(4)	(5)	(6)
GDPER	**0.071**	**0.056**	**0.056**	**0.032**	**0.023**	**0.020**
	(0.008)	(0.008)	(0.009)	(0.008)	(0.010)	(0.010)
CGDP		**0.115**	**0.144**	**0.124**	**0.122**	0.039
		(0.027)	(0.025)	(0.025)	(0.025)	(0.039)
DGDP			**-0.264**	**-0.240**	**-0.237**	**-0.229**
			(0.095)	(0.093)	(0.092)	(0.087)
IF				**0.007**	**0.006**	**0.005**
				(0.001)	(0.001)	(0.001)
PSI					0.043	0.024
					(0.025)	(0.026)
RE						**0.011**
						(0.003)
constant	**0.291**	**0.222**	**0.357**	-0.051	0.009	**-0.622**
	(0.042)	(0.049)	(0.051)	(0.100)	(0.123)	(0.225)
R-squared	0.119	0.133	0.186	0.232	0.237	0.257
N	360	360	360	360	360	360

Table V Loss Aversion and Cultural Dimensions

Panel A presents regression results of the natural logarithm of loss aversion on various control variables: GDP per capita (GDPER), Hofstede's index of individualism (IDV); masculinity (MAS); power distance (PD) and uncertainty avoidance (UA). Iceland are excluded in Panel A for its negative loss aversion. Panel B reports regression results for the two other preference parameters in (natural logarithm of Phi and Delta) on Hofstede's cultural measures. Panels C shows if investment proportions in different asset classes are affected by cultural dimensions. PD is not used as an explanatory variable because it is not significant in our preliminary tests. Bold numbers represent significance at the 5% level. Numbers in brackets represent white heteroscedasticity robust standard errors. Variance inflation factors (VIF) are checked simultaneously to ensure all control variables are free of multicollinearity issues. N represents the number of samples applied in regressions.

A. Loss Aversion with respect to Cultural Dimensions

	(1)	(2)	(3)	(4)	(5)
IDV	**0.756**	**0.508**	**0.598**	**0.604**	**0.526**
	(0.157)	(0.184)	(0.188)	(0.230)	(0.238)
GDPER		0.040	0.029	0.030	0.027
		(0.025)	(0.025)	(0.017)	(0.016)
MAS			-0.227	-0.227	-0.124
			(0.123)	(0.125)	(0.110)
PD				0.028	0.185
				(0.286)	(0.300)
UA					-0.395
					(0.285)
constant	0.096	0.106	**0.208**	0.187	0.378
	(0.113)	(0.116)	(0.089)	(0.204)	(0.208)
R-squared	0.145	0.165	0.176	0.176	0.200
N	30	30	30	30	30

B. The Effects of Cultural Dimensions on Investment Attitudes

	LN(Phi)		LN(Delta)	
IDV	0.063	(0.103)	0.136	(0.214)
MAS	-0.203	(0.113)	-0.015	(0.274)
PD	0.117	(0.105)	-0.126	(0.209)
UA	-0.014	(0.072)	-0.018	(0.237)
constant	**0.363**	(0.105)	-0.300	(0.185)
R-squared	0.203		0.052	
N	30		30	

C. The Effects of Cultural Dimensions on Investment Proportions

	Total Risky Asset		Equities		Bonds		Other Investments	
IDV	**0.158**	(0.054)	0.032	(0.079)	**-0.233**	(0.091)	**0.359**	(0.049)
MAS	-0.003	(0.036)	0.054	(0.059)	**-0.298**	(0.116)	**0.242**	(0.105)
UA	**-0.083**	(0.026)	**-0.278**	(0.078)	**0.295**	(0.138)	-0.100	(0.119)
constant	**0.882**	(0.054)	**0.360**	(0.102)	**0.542**	(0.091)	-0.020	(0.050)
R-squared	0.264		0.218		0.290		0.323	
N	30		30		30		30	

Table VI Robustness Tests

Panel A reports the results of regressing the log-loss aversion on GDP per Capita (GDPER) when the loss aversion parameters are estimated with three different values of *v*. The control variables include the scale of financial recourses (credit to private sector, as the % of GDP, CGDP); government's debt ratio (debt to GDP ratio, DGDP); investment freedom index (published by the heritage foundation, IF) and regulatory efficiency (published by the heritage foundation, RE). The coefficients on these control variables are not reported. In Panel B, loss aversion parameters are regressed only on the individualism (IDV) and wealth (GDPER). In both two panels, Iceland and Chile are excluded because of its negative or extreme large loss aversion. Bold numbers represent significance at the 5% level. Numbers in brackets represent white heteroscedasticity robust standard errors. Variance inflation factors (VIF) are checked simultaneously to ensure all control variables are free of multicollinearity issues. N represents the number of samples applied in regressions.

A. The Effects of Macroeconomic Variables on Loss Aversion

	v = 1.25		v = 1.5		v = 2.0	
GDPER	**0.030**	(0.006)	**0.023**	(0.005)	**0.023**	(0.005)
Control variables	Yes		Yes		Yes	
R-squared	0.282		0.236		0.292	
N	348		348		348	

B. The Effects of Cultural Dimensions on Loss Aversion

	v = 1.25		v = 1.5		v = 2.0	
IDV	**0.406**	(0.214)	**0.261**	(0.120)	**0.038**	(0.110)
GDPER	0.046	(0.223)	0.037	(0.018)	**0.039**	(0.019)
constant	0.195	(0.281)	**0.381**	(0.072)	**0.398**	(0.066)
R-squared	0.249		0.212		0.255	
N	29		29		29	