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 factors; Reference-Dependent Utility; Pension Funds

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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 (Loomes and Sugden, 1982; 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 of loss aversion, risk aversion, and probability

[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).

weighting of 31 OECD countries are 1.74 (0.64)[2], 1.42 (0.13) and 0.78 (0.20), respectively.[3] The estimates of loss aversion and subjective probability weighting are similar to those reported by Wang et al. (2017) and Rieger et al. (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 (proxy of individual 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 GDPER. Our results support that wealthier investors suffer higher disutility from disappointing outcomes.

Our results also support that individualistic countries are more loss averse than collectivistic countries. This is consistent with the view that individualistic investors tend to

[2] Numbers in brackets represent standard deviations.

[3] When only equity and risk-free assets are considered for the optimal investment proportion in equity, losses below the reference point appear to be weighted approximately two to three times more than gains in the US and UK markets (Ang *et al.*, 2005; Fielding and Stracca, 2007; Hwang and Satchell, 2010). In general, our results with multiple asset classes show similar loss aversion worldwide.

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 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 such that important components in practice, e.g., decision making with a large dollar amount of investment, are tested (Hwang and Satchell, 2010). 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 Section 2, we propose our reference-dependent utility function and show how 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:[4]

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

[4] 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).

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), Barberis (2013), and Koszegi and Rabin (2007), 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 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; Barberis et al., 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).[5]

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

[5] Tversky and Kahneman (1992) suggest $v = 0.88$ and many studies use a piecewise linear value function ($v = 1$), e.g., Benartzi and Thaler (1995), Barberis *et al.* (2001), and Pagel (2015).

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) 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. Loss Aversion and 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 $0 < \delta \leq 1$. In essentials, 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 outcomes, $x^v w'(1 - F(x))$, 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 when the curvature parameter v is mild 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 $\alpha_1, \alpha_2, \dots, \alpha_n$ 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 $0 \leq \alpha_i \leq 1$ 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 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, we assume the gain-loss utility (the second component of Eq. (1)) to be additively separable across different asset classes as in Koszegi and Rabin (2007), and define gains and losses in each asset class, i.e., $r_i - \mu_i$.[6] Then, the expected reference-dependent utility in Eq. (1) appears as follows:

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

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:*

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

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

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

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:

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

[6] As Koszegi and Rabin (2006) and Koszegi and Rabin (2007) suggest, the psychological hypothesis that the dimensions by which people assess gains and losses are indeed separable. Moreover, if investment experience is thought of 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 sensation of gains and losses of an asset class can be considered separately from that of other asset classes.

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 can be avoided by including the expected wealth and allowing $v > 1$. However, 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 A, φ and δ for given values of v using the first order condition in Eq. (6) for each risky asset class i. Using the Generalized Method of Moments (GMM), we estimate the three parameters, i.e., 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 ($\mu_i - r_f$). 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 *others* (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 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 $\boldsymbol{y}_t = (r_{1t}, r_{2t}, r_{3t}, \alpha_{1t}, \alpha_{2t}, \alpha_{3t}, v)'$ 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

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

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 $h(\boldsymbol{\theta}, \boldsymbol{y}_t)$ is

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

where

$$h\big(\boldsymbol{\theta}, \boldsymbol{y}_t\big) = (\boldsymbol{r}_t - r_f\boldsymbol{e}) - \varphi v \boldsymbol{\alpha}_t^{v-1} \circ (A \circ \big(-\boldsymbol{I}_t^- \circ (\boldsymbol{r}_t - \bar{\boldsymbol{r}}_t)\big)^v \circ w'(\boldsymbol{e} - \boldsymbol{F}_t) - (\boldsymbol{I}_t^+ \circ (\boldsymbol{r}_t - \bar{\boldsymbol{r}}_t))^v \circ w'(\boldsymbol{F}_t)), \qquad (8)$$

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

$$g(\boldsymbol{\theta}; \boldsymbol{\mathcal{Y}}) \xrightarrow{p} \mathrm{E}(h(\boldsymbol{\theta}_0, \boldsymbol{\mathcal{Y}}_t)).$$

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

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

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

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

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 each *n* iteration, the estimate $\widehat{\boldsymbol{\theta}_n}$ is found using a popular machine learning method known as

Limited-memory BFGS.[7] Since $g(\boldsymbol{\theta};\boldsymbol{\mathcal{Y}})$ is not a globally convex function with a unique minimum, and so 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.[8] 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 OECD countries for the period from 2004 to 2015. Pension funds are widely used as a representative agent for asset allocation problems (Canner et al., 1997; Campbell and Viceira, 2002). We choose asset

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[7] 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).

[8] An alternative method would be the Bayesian estimation with informative priors, which is far more complicated. The robustness of our estimates are 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.

allocations of pension funds as the optimal weights α_i^*s, which reflect 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.[9]

3.1 Data

We collect asset allocations of pension funds across 31 countries for the period from 2004 to 2015. The number of countries and sampling period are restricted by the data availability of pension funds' asset allocations, returns and cultural measures we consider

[9] 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 mis-specification 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.

in this study.[10] The assets are 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.[11] 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,

[10] For example, countries that (e.g., Portugal, Luxemburg, Estonia and Netherland) hold large portions of foreign assets are excluded, because it is not possible to trace their investments in foreign assets in each asset class and replacing the foreign asset returns with their own domestic asset returns is not likely to be consistent with their realized returns.

[11] 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. We refer to 2004 as the starting year for our study, since the data availability before this year rapidly worsens.

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 -0.67, 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. Therefore, reducing investment in equities increases investment in bonds but not in other investments. Any change in the investment proportion of bonds negatively affects investment in equities and other investments. These results indicate that pension funds do not directly move investment from equities to other investments: bonds serve as a bridge between them.

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.[12] 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);[13] IBoxx Euro Corporate Bond Index for countries within the Eurozone (Finland, France, Germany, Greece, Italy, Slovenia and Spain);[14] and finally, BofA-Merrill Lynch Emerging Markets Corporate Plus Index for emerging markets (Mexico, Poland, Pakistan, South Africa, Thailand

[12] 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.

[13] The FTSE Euro Corporate Bond Index includes Euro-denominated issues from global corporate entities with all maturities from one-three years to more than 15 years. Each bond is classified under the Industry Classification Benchmark (ICB). The index constituents are investment grade debt with a minimum rating of BBB-.

[14] IBoxx Euro Corp. Bond Index is prepared and published by Markit, which is an ideal performance benchmark for fixed income research, asset allocation and performance evaluation. This index includes overall, rating and maturity indexes, with a split into financial and non-financial bonds, and rating and maturity sub-index for each.

and Turkey).[15] For the remaining countries (Australia, Canada, Chile, Israel, the United Kingdom 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.[16] These four return series

[15] The BofA-Merrill Lynch Emerging Markets Corporate Plus Index tracks the performance of US dollar- (USD) and Euro-denominated emerging markets' non-sovereign debt publicly issued within the major domestic and Eurobond markets. The index includes corporate and quasi-government debt of qualifying countries, but excludes sovereign and supranational debt. Other types of securities acceptable for inclusion in this index are: original-issue zero coupon bonds.

[16] The MSCI World Real Estate Price Index is a free-float-adjusted market capitalization index that consists of large and mid-cap equity REITs across 23 developed markets, which generate a majority of their revenue and income from real estate rental and leasing operations. With 101 constituents, it represents about 85% of the REIT universe in each country and all securities are classified in the REIT sector according to the Global Industry Classification Standard. Dow Johns Brookfield GLB INFRA is maintained collaboratively by S&P Dow Jones Indices and Brookfield Asset Management. It aims to measure the stock performance of companies worldwide whose primary business is the ownership and operation of (rather than service of) infrastructure assets. To be included in the indices,

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.

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a company must have more than 70% of estimated cash flows (based on publicly available information) derived from eight infrastructure sectors: airports, toll roads, ports, communications, electricity transmission & distribution, oil & gas storage & transportation, water and diversified. The S&P Listed Private Equity Index comprises the leading listed private equity companies that meet specific size, liquidity, exposure, and activity requirements. The index is designed to provide tradable exposure to the leading publicly listed companies that are active in the private equity space. The HFRI Fund of Funds Composite is a series of benchmarks designed to reflect hedge fund industry performance by constructing equally weighted composites of constituent funds, as reported by the hedge fund managers listed within the HFR Database. The HFRI range in breadth from the industry-level view of the HFRI Fund Weighted Composite Index, which encompasses over 2000 funds, to the increasingly specific level of the sub-strategy classifications.

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 over-optimism towards future returns (Markus and Kitayama, 1991; Van Den Steen, 2004; Chui et al., 2010).

We investigate cross-cultural variations of loss aversion we estimate using asset allocation in pension funds. Four primary cultural dimensions in Hofstede's culture measures (Hofstede, 2001) have been considered, including 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. Hsee and Weber (1999) show that investors in individualistic culture are known to be more loss averse because they have less social support. Chui et al. (2010) show that investors in more individualistic cultures tend to be more overconfident, increasing trading volume and volatility as well as momentum profits.

On the other hand, masculinity (MAS) represents the distribution of preferences to a competitive or corporative society. In masculinity societies which 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 (Barberis et al., 2001; 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. Lower PD refers that people strive to equalize the distribution of power and demand justification for inequalities of power. 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

As Eq. (5) shows, the optimal weights to 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 attitudes with respect to risks and losses as well as subjective weighting.

The parameters estimated in the presence of the performance of each asset class are reported in Table III. The numbers in brackets represent the standard errors of estimates. In general, the estimates based on asset allocation of pension funds are consistent with 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 ($\lambda = -0.11$) while Brazil (0.60), Greece (0.33) and Hungary (0.93) appear to be gain-oriented ($0 < \lambda < 1$). Since it is difficult to interpret loss-seeking behaviour, we exclude Iceland from further empirical tests, and the total number of countries are reduced to 30.[17]

[17] 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.

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.[18] 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 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

[18] 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, Kolm, Pachamanova and Focardi, 2007).

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.

For the 25 countries common in Wang et al. (2017) and our study[19], we find that the estimates of loss aversion are close to each other. The Spearman correlation coefficient between these two sets of loss aversion estimates is 0.44 and is statistically significant. Moreover, the mean (standard deviation) of loss aversion is 1.965 (0.381) while Wang et al. (2017) reported 2.012 (0.383). The subjective probability weighting parameters we estimate are also similar to those reported by Rieger et al. (2015). The Spearman rank correlation coefficient is 0.55 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

[19] Brazil, Greece, Hungary, Iceland, Pakistan and South Africa are not used due to missing data or loss-seeking.

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

We first 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 a proxy of wealth) (GDPER) as well as other control variables that represent the development of financial markets. The panel regression model can be expressed as:

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

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

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).

Regression results in Table IV show that loss aversion is higher in wealthier countries: the coefficient on GDPER is positive and significant at the 5% level. We also find that loss aversion is higher in the countries where their financial markets are more advanced. Positive coefficients on the regulatory efficiency (RE) and investment freedom (IF) suggest that loss aversion increases when financial markets 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. We answer this question using loss aversion estimated directly from asset allocations of pension fund managers who face similar investment objects and horizons across countries. To explore the question, we regress loss aversion on the following cultural dimensions:

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

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. Individualistic investors suffer more disutility from losses than collective investors. People from a more independent or over-confident 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 for the 30 countries we test in this study.

None of cultural dimensions can explain risk aversion or subjective probability weighing. 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 asset (RP_k) using the following regression equation:

$$RP_k = \beta_0 + \beta_1 PDI_k + \beta_2 MAS_k + \beta_3 INDV_k + \beta_4 UAI_k + \varepsilon_k.$$

As in panel B of Table V, a higher level of individualism increases proportions for risky assets, but the other three cultural dimension variables do not affect investment proportions in 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, 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[20]

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 by setting 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 25 countries we have in common with Wang et al. (2017), the Spearman' rank correlations are 0.41, 0.42 and 0.46 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 early findings with v = 1.1. Panel A shows that loss aversion increases with individual wealth (GDPER) for v = 1.25, 1.5 and 2.0. Other coefficients are also consistent with what we find with v = 1.1: loss aversion increases in the countries as their financial markets are advanced. Finally, results in Panel B confirms again that only individualism increases loss aversion while the other three cultural measures are not significant for different values of v.

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

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 show 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 (measureable uncertainty). 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 Investment	Risk-free
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%
UK	31.49%	24.70%	41.15%	2.66%
US	45.09%	21.67%	31.70%	1.54%
World average	21.84%	45.90%	23.63%	8.63%

B. Correlation Coefficients between Investment Proportions

	Total Risky Asset	Equities	Bonds	Other Investments
Equities	0.281			
Bonds	-0.047	**-0.541**		
Other Investments	0.315	0.037	**-0.677**	
Risk-free	**-1.000**	-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. Monthly price levels are obtained via DataStream and then converted into log-returns. 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%
UK	7.03%	16.64%	6.12%	4.83%	8.31%	22.64%	2.68%
US	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

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 average which represent standard deviations.

	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)

Table IV Loss Aversion with respect to Macroeconomic Variables

The estimated loss aversion in Table IV are regressed on various explanatory variables including: 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). Iceland are excluded for its negative loss aversion. The bold numbers represent significance at the 5% level. The numbers in brackets represent White heteroscedasticity robust standard errors.

Intercept	**-0.622**	(0.225)
CGDP	0.039	(0.039)
DGDP	**-0.229**	(0.087)
GDPER	**0.020**	(0.010)
IF	**0.005**	(0.001)
PSI	0.024	(0.026)
RE	**0.011**	(0.003)
R-squared	0.245	

Table V Loss Aversion and Cultural Dimensions

Panels A and B present regression results for the effects of cultural dimensions on the three risk parameters (natural logarithm of loss aversion, risk aversion, and probability weighting) and on the investment proportions in risky assets, respectively. IDV, MAS, PD and UA represent Hofstede's index of individualism, masculinity, power distance and uncertainty avoidance, respectively. Iceland are excluded for its negative loss aversion. The bold numbers represent significance at the 5% level. The numbers in brackets represent White heteroscedasticity robust standard errors.

A. The Effects of Cultural Dimensions on Investment Attitudes

	LN(LA)		LN(RA)		LN(Delta)	
C	0.476	(0.296)	**0.363**	(0.106)	-0.300	(0.207)
IDV	**0.650**	(0.306)	0.064	(0.101)	0.136	(0.210)
MAS	-0.175	(0.260)	-0.203	(0.097)	-0.015	(0.261)
PD	0.092	(0.386)	0.117	(0.116)	-0.126	(0.224)
UA	-0.408	(0.468)	-0.014	(0.069)	-0.018	(0.218)
R-squared	0.193		0.203		0.052	

B. The Effects of Cultural Dimensions on Investment Proportions

	Total Risky Asset		Equities		Bonds		Other Investments	
C	**0.878**	(0.056)	0.254	(0.167)	**0.715**	(0.174)	-0.091	(0.170)
IDV	**0.160**	(0.065)	0.107	(0.142)	**-0.357**	(0.153)	**0.410**	(0.149)
MAS	-0.003	(0.048)	0.052	(0.107)	**-0.296**	(0.135)	**0.241**	(0.117)
PD	0.007	(0.084)	0.221	(0.179)	-0.363	(0.210)	0.149	(0.200)
UA	-0.085	(0.090)	**-0.343**	(0.149)	**0.402**	(0.144)	-0.143	(0.165)
R-squared	0.264		0.276		0.355		0.337	

Table VI Robustness Tests

Panel A provides the results by regressing the re-estimated loss aversion on various explanatory variables: 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). Panel B provides the results by regressing the re-estimated loss aversion on four cultural measures. IDV, MAS, PD and UA represent Hofstede's index of individualism, masculinity, power distance and uncertainty avoidance, respectively. Iceland and Chile are excluded because of its negative or extreme large loss aversion. The bold numbers represent significance at the 5% level. The numbers in brackets represent White heteroscedasticity robust standard errors.

A. The Effects of Macroeconomic Variables on Loss Aversion

	v = 1.25		v = 1.5		v = 2.0	
Intercept	-0.216	(0.178)	0.109	(0.137)	0.004	(0.137)
CGDP	0.055	(0.030)	0.042	(0.027)	**0.059**	(0.025)
DGDP	-0.075	(0.047)	-0.014	(0.027)	0.015	(0.026)
GDPER	**0.024**	(0.009)	**0.015**	(0.007)	**0.016**	(0.007)
IF	**0.004**	(0.001)	**0.003**	(0.001)	**0.003**	(0.001)
PSI	0.029	(0.022)	**0.041**	(0.018)	0.037	(0.019)
RE	**0.005**	(0.002)	0.003	(0.002)	**0.005**	(0.002)
R-squared	0.285		0.247		0.289	

B. The Effects of Cultural Dimensions on Loss Aversion

	v = 1.25		v = 1.5		v = 2.0	
C	0.481	(0.281)	0.524	(0.271)	0.532	(0.269)
IDV	**0.599**	(0.214)	**0.485**	(0.222)	**0.529**	(0.213)
MAS	-0.164	(0.223)	-0.208	(0.172)	-0.130	(0.188)
PD	-0.009	(0.332)	0.077	(0.264)	0.061	(0.253)
UA	-0.233	(0.392)	-0.118	(0.245)	-0.139	(0.250)
R-squared	0.247		0.211		0.230	