EXPLORING THE BENEFITS OF INTERNATIONAL GOVERNMENT BOND PORTFOLIO DIVERSIFICATION STRATEGIES

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ABSTRACT

We use the Bayesian approach of Wang(1998) to examine the diversification benefits of investing in international government bonds. We find that no short selling constraints substantially reduce but do not eliminate the diversification benefits when only investing in G7 government bonds with different maturities. There are significant diversification benefits when using the G7 bonds, an inflation-linked bond index, and emerging market bonds even in the presence of no short selling constraints. The superior performance is driven by the emerging markets bonds. We also find that the diversification benefits vary across different economic states.

I Introduction

Ever since the seminal studies of Grubel(1968) and Solnik(1974), there has been a strong case for international portfolio diversification. The benefits of international diversification have been questioned in recent years due to increased correlations over time especially in developed markets (Goetzmann, Li and Rouwenhorst(2005)). A recent study by Hodrick and Zhang(2014) re-examine the benefits of international diversification in developed equity markets using a variety of different measures and finds that significant international diversification benefits in developed equity markets remains.

Much of the empirical literature on international diversification focuses on equity portfolios. There is a much smaller literature looking at the diversification benefits of bond portfolios. This fact is perhaps surprising given the size of international bond markets. As of March 2015, the amount outstanding of general government international debt securities across all countries is $1,563.4 billion (Bank of International Settlements). Levy and Lerman(1988) find significant diversification benefits for U.S. investors in developed market bond portfolios between 1960 and 1980. The benefits are larger than from international stock portfolios. Eun and Resnick(1994) and Glen and Jorion(1993) find significant benefits of investing in international government bond indexes, especially when currency hedged.

Hansson, Liljeblom and Loflund(2009) examine the benefits of international bond portfolio strategies from a U.S. and a non-U.S. perspective[1]. They find that there are no significant benefits of investing in developed market government bond portfolios, even when using currency hedging. Using emerging market bond portfolios does lead to significant

[1] Studies of international diversification are dependent on the currency chosen. Hentschel Kang and Long(2002) use the numeraire portfolio approach of Long(1990) to evaluate the diversification benefits of investing in zero-coupon bonds in the U.S., U.K., and Germany, which is invariant to the currency chosen.

benefits but is largely eliminated when investors face no short selling constraints. When international corporate bond portfolios are included in the investment universe, there are significant benefits when the corporate bonds are hedged. Liu(2016) extends the results of Hansson et al(2009) and finds substantial benefits of investing in international corporate bonds. Briere, Mignon, Oosterlinck and Szafarz(2016) take a central bank perspective and examine the benefits of investing in short-term developed government bonds and U.S. non-bond assets such as mortgage backed securities, domestic bonds, and equities. Briere et al (2016) find that U.S. non-bond assets are important to increase the portfolio average return. The optimal short-term developed market bonds are useful for reducing portfolio volatility.

We use the Bayesian approach of Wang(1998) to examine the diversification benefits of international government bonds from a U.S. perspective. Our study focuses on two main issues. First, we examine the diversification benefits provided by three types of international government bonds that has not been fully addressed by the prior literature. We consider the benefits of longer maturity G7 government bonds, a global inflation-linked bond index, and emerging markets (EM) bonds based on geographical location and credit rating. We evaluate the diversification benefits as the increase in Certainty Equivalent Return (CER) performance[2] for a mean-variance investor of adding the international government bonds to a benchmark investment universe. We consider both unconstrained portfolio strategies, and constrained portfolio strategies, where there are no short selling constraints[3].

Second, we examine if the diversification benefits of international government bonds varies across different economic states. We use the dummy variable approach of a given

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[2] We also consider performance measures based on Value at Risk (VAR) and Conditional VAR measures developed by Alexander and Baptista(2003).

[3] We also examine the impact of a combined upper bound constraint on the emerging market bonds.

lagged information variable of Ferson and Qian(2004) and Ferson, Hnery and Kisgen(2006) to identify the economic states. Since the short rate is used in most bond pricing models, we use the lagged one-month U.S. Treasury Bill as the information variable. The dummy variable approach allows us to identify months where the lagged Treasury Bill return is lower than normal, normal, and higher than normal. The attraction of the dummy variable approach is that it allocates each month to one of three states using only information prior to that month, rather than ex post indicators such as the NBER recession states.

There are three main findings in our study. First, when only investing in G7 government bond portfolios, no short selling constraints substantially reduces the magnitude but does not eliminate the diversification benefits of the G7 government bonds. Second, when investing in the three groups of international government bonds, there are significant diversification benefits from constrained portfolio strategies. The superior performance is driven by emerging market bonds. Third, the diversification benefits of international government bonds vary across economic states. The strategies deliver their best performance when the lagged one-month U.S. Treasury Bill return is lower than normal. Our results suggest that there are significant diversification benefits of investing in international government bonds.

Our study makes two main contributions to the literature. First, we extend the prior evidence of Hansson et al(2009), Liu(2016), and Briere et al(2016) by examining the benefits of different classes of international government bonds such as long-term G7 government bonds, an inflation-linked bond, and EM bonds sorted by geographical location and credit rating. Our study differs from Hansson et al(2009) and Briere et al(2016) by using the Bayesian approach of Wang(1998) to estimate the magnitude of the diversification benefits and conduct statistical significance. We complement the recent study of Liu(2016) by using the Bayesian approach to test the diversification benefits of international government bonds rather than international corporate bonds. Second, we extend the prior evidence of Levy and Lerman(1988), Hansson et al(2009), and Liu(2016) among others by using the dummy variable approach of Ferson and Qian(2004) and Ferson et al(2006) to evaluate the diversification benefits across economic states. We complement Briere et al(2016) who evaluate the diversification benefits in rising interest rate states. We differ from Briere et al by identifying states ex ante rather than ex post. We also apply the dummy variable approach to a different context from conditional mutual fund performance as in Ferson and Qian(2004) and Ferson et al(2006).

The paper is organized as follows. Section II presents the research method used in our study. Section III describes the data. Section IV reports the empirical results and the final section concludes.

II Research Method

We use the mean-variance approach to examine the diversification benefits of the international government bond portfolio strategies[4]. The mean-variance approach of Markowitz(1952) assumes that investors select a (N,1) vector of risky assets to:

$$\text{Max } x'u - (\gamma/2)x'Vx \tag{1}$$

where u is a (N,1) vector of expected excess returns, V is a (N,N) covariance matrix of excess returns, and γ is the risk aversion level of the investor. The framework in (1) assumes that the remainder of the portfolio is invested in the risk-free asset (x_f) such that $x'e + x_f = 1$, where e is a (N,1) vector of ones. We can include additional constraints to equation (1) such as no short selling ($x_i \geq 0$, i=1,…,N).

[4] A partial list of studies that evaluate the benefits of international diversification using the mean-variance approach include Bekaert and Urias(1996), Li et al(2003), Ehling and Ramos(2006), Eiling, Gerard, Hillion and de Roon(2012), Hodrick and Zhang(2014), Briere et al(2016), and Liu(2016) among others.

We conduct our analysis from a U.S. perspective and the domestic investment universe is given by the one-month Treasury Bill and the excess returns of a U.S. domestic government bond index. We consider the diversification benefits of adding three classes of international government bond portfolios to the domestic investment universe:

1. G7 government bond indexes of different maturities.

2. Inflation linked bond – this index is a global government inflation linked bond index.

3. Emerging market bonds – this includes both regional bond indexes and country rating bond indexes.

A number of alternative measures can be used to evaluate the diversification benefits from a mean-variance perspective such as Kandel, McCulloch and Stambaugh(1995), Wang(1998), and Li et al(2003). We measure the diversification benefits using the mean-variance objective function in (1) as the CER performance. The benefits are given as the increase in the CER performance of adding the international government bonds to the domestic investment universe as:

$$DCER = (x'u - (\gamma/2)x'Vx) - (x_b'u - (\gamma/2)x_b'Vx_b) \quad (2)$$

where x_b is a (N,1) vector of weights in the benchmark portfolio which is the optimal weight in the benchmark strategy and the remaining (N-1) cells are zero. The DCER measure in equation (2) is the increase in CER performance[5] between holding the optimal portfolio in the N risky assets and the optimal benchmark portfolio. If there are no diversification benefits in holding the optimal international government bond portfolio, we expect DCER = 0.

[5] The CER performance measure is commonly used to evaluate the performance of mean-variance trading strategies such as Kan and Zhou(2007), DeMiguel, Garlappi and Uppal(2009), Tu and Zhou(2011), and Kan, Wang and Zhou(2017). In contrast to the Sharpe(1966) performance measure, the CER performance depends upon the level of risk aversion.

We can generalize the DCER measure in equation (2) to also compare the difference in CER performance between two optimal bond portfolios to capture the marginal benefit of adding specific bond indexes to the investment universe. We estimate the DCER measure using two levels of risk aversion, where γ = 1, and 3 as in Tu and Zhou(2011). When including just the G7 government bonds, we consider both unconstrained portfolio strategies and constrained portfolio strategies, where no short selling is allowed in the risky assets and the one-month Treasury Bill. When we include all bonds, we consider two constrained portfolio strategies. First, we impose no short selling constraints in the risky assets and the one-month Treasury Bill. Second, we add a combined upper bound constraint of 20% to the emerging market bonds.

We use the Bayesian approach of Wang(1998) and Li et al(2003) to estimate the increase in CER performance (DCER) and evaluate statistical significance[6]. An alternative approach to examine the diversification benefits would be to use classical tests of mean-variance efficiency and spanning. Kan and Zhou(2012) provide a review of different mean-variance spanning tests, when the only constraint is the budget constraint. De Roon, Nijman and Werker(2001), Basak, Jagannathan and Sun(2002), and Briere, Drut, Mignon, Oosterlinck and Szafarz(2013) develop asympototic mean-variance spanning and efficiency tests that allows for no short selling constraints.

Li et al(2003) point out that the Bayesian approach has a number of advantages over the asymptotic tests. First, the uncertainty of finite samples is included in the posterior distribution. Second, the Bayesian approach is easier to implement and can include a wide range of portfolio constraints without any additional difficulty and different performance

[6] Recent applications of the Bayesian approach include Hodrick and Zhang(2014) and Liu(2016).

measures can be used. Third, the asymptotic tests rely on a linear approximation to a nonlinear function but the Bayesian approach uses the exact nonlinear function.

The analysis assumes that the N asset excess returns have a multivariate normal distribution[7]. We assume a non-informative prior about the expected excess returns u and the covariance matrix V. Define u_s and V_s as the sample moments of the expected excess returns and covariance matrix, and R as the (T,N) matrix of excess returns on the N assets. The posterior probability density function is given by:

$$p(u,V|R) = p(u|V,u_s,T) \bullet p(V|V_s,T) \tag{3}$$

where $p(u|V,u_s,T)$ is the conditional distribution of a multivariate normal $(u_s,(1/T)V)$ distribution and $p(V|V_s,T)$ is the marginal posterior distribution that has an inverse Wishart(TV, T-1) distribution (Zellner, 1971)).

To approximate the posterior distribution of the DCER measure, we use the Monte Carlo method of Wang(1998). We use the following four-step approach. First, a random V matrix is drawn from an inverse Wishart $(TV_s,T-1)$ distribution. Second, a random u vector is drawn from a multivariate normal $(u_s,(1/T)V)$ distribution. Third, given the u and V from steps 1 and 2, the DCER measure from equation (2) is estimated. Fourth, steps 1 to 3 are repeated 1,000 times to generate the approximate posterior distribution of the DCER measure.

The posterior distribution of the DCER measure is then used to assess the size of the diversification benefits and the statistical significance of these benefits. The average value from the posterior distribution of the DCER measure provides the average diversification

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[7] We can view the normality assumption as a working approximation to monthly excess returns. In addition, optimal portfolios of mean-variance utility functions are often close to other utility functions over short horizons (Kroll, Levy and Markowitz(1984), Grauer and Hakansson(1993), and Best and Grauer(2011)).

benefits in terms of the increase in CER performance. The values of the 5^{th} percentile of the posterior distribution of the DCER measure provides a statistical test of the average DCER = 0 (Hodrick and Zhang(2014)). If the optimal bond portfolios provide significant diversification benefits, we expect to find a significant positive average DCER measure.

The Monte Carlo simulation also gives the approximate posterior distribution of the optimal weights in the bond portfolio strategies. Britten-Jones(1999) and Kan and Smith(2008) derive the sampling distribution of the optimal mean-variance portfolio weights when there are no portfolio constraints. The Bayesian approach provides an approximate posterior distribution of the optimal weights when there are portfolio constraints. We can use the posterior distribution to examine if the average weights in the optimal portfolios are more than two standard errors from zero (Li et al(2003)).

The analysis so far provides a measure of diversification benefits across the whole sample. To examine the conditional diversification benefits, we use the dummy variable approach of Ferson and Qian(2004) and Ferson et al(2006) to allocate each month into one of three economic states using a lagged information variable z_{t-1}[8], where z_{t-1} is the value of the lagged information variable at time t-1. We then use the Bayesian approach to evaluate the diversification benefits of the international government bond portfolio strategies in each state. The attraction of the dummy variable approach is that it is straightforward to implement and the states can be identified ex ante by only using data prior to each month[9]. Ferson et al(2006) point out that another benefit of the dummy variable approach is that it mitigates the spurious regression bias of Ferson, Sarkissian and Simin(2003) of lagged information variables which have a high first-order autocorrelation.

[8] An alternative approach could be the regime switching method of Ang and Bekaert(2004).

[9] An alternative approach is followed by Briere et al(2016) who identify months of rising interest rates, but this approach can only be identified ex post.

We identify the states as follows. First, we calculate x_{t-1} as z_{t-1} minus the past average value of z_{t-1} over the prior sixty months. Second, we also calculate the standard deviation of z_{t-1} ($\sigma(z_{t-1})$) over the prior sixty months. Third, given the values of $x_{t-1}/\sigma(z_{t-1})$, we construct three dummy variables. If $x_{t-1}/\sigma(z_{t-1}) > 1$, D_{high} equals one, and D_{low} and D_{normal} equal zero. If $x_{t-1}/\sigma(z_{t-1}) < -1$, D_{low} equals one, and D_{normal} and D_{high} equal zero. When $-1 \leq x_{t-1}/\sigma(z_{t-1}) \leq 1$, D_{normal} equals one, and D_{low} and D_{normal} equal zero. The three dummy variables capture when the lagged information variable is lower than normal, normal, and higher than normal.

Using the CER performance to evaluate the diversification benefits is the relevant performance measure for mean-variance investors. However one criticism of using variance as a risk measure is that it does not adequately capture the tail risk of a portfolio strategy[10]. Value at Risk (VAR) and Conditional VAR (VAR) measures have been proposed to estimate the tail risk of the portfolio[11]. Alexander and Baptista(2003) propose a Sharpe(1966) type performance measure to evaluate performance based on mean and VAR. They also note that can adapt to using CVAR. Since we assume multivariate normality, we use their mean/VAR and mean/CVAR measure under this assumption (see equation (11) in the Alexander and Baptista(2003) study). Using these measures, we can evaluate whether there is a significant increase in mean/VAR or mean/CVAR performance of adding international government bonds to the domestic investment universe by the Bayesian approach[12].

III Data

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10 We thank the reviewer and the Editor for encouraging us to examine this issue.

11 See Alexander(2009) for a review of modern risk management.

12 We do not consider the impact of using portfolio constraints based on VAR or CVAR in the mean-variance optimization, as in Alexander and Baptista(2004) and Alexander, Baptista and Yan(2007) among others, but is an interesting extension for future research.

We adopt a U.S. perspective to evaluate the diversification benefits of international government bond portfolios. Our domestic investment universe is the one-month U.S. Treasury Bill returns and the excess returns of the U.S. domestic bond index. We use the Bank of America U.S. Treasury Master index as the domestic bond index. The one-month Treasury Bill return is collected from Ken French's web site and the Treasury Master index comes from Thompson Financial Datastream.

We consider adding three groups of international government bonds to the domestic investment universe. We use the Bank of America Merrill Lynch international government bond indexes collected from Datastream and the returns are in U.S. dollars and currency unhedged[13]. The groups include:

1. G7 government bonds

This group includes four G7 government bond indexes with maturities of 1-5 years, 5-7 years (G7 5-7yr), 7-10 years (G7 7-10yr), and 10+ years (G7 10yr+). The sample period for the G7 bonds is January 1986 and September 2016.

2. Inflation-linked bonds

This group includes the Global government inflation-linked bond index (IL). This bond index is available between January 1998 and September 2016.

3. Emerging markets

This group includes three emerging markets bond indexes based on regions and three emerging markets bond indexes based on country rating. The regional indexes include Asia (EM Asia), Europe/Middle East/Africa (EM EU/ME/Afr), and Latin America (EM LA). The three country rating bond indexes include B, BB, and BBB (EM B, EM BB, and EM BBB)

[13] Currency hedging tends to have a positive impact on the performance of international bond portfolios such as Eun and Resnick(1994), Glen and Jorion(1994), Hansson et al(2009), and Liu(2016).

ratings. The emerging markets bond indexes are available between January 2005 and September 2016.

Table 1 reports summary statistics of the monthly excess returns of the bond indexes over their respective sample periods. The summary statistics include the mean, standard deviation, minimum, and maximum values (%). Table 2 reports the correlations between the bond indexes over their respective sample periods.

Table 1 here

Table 2 here

Table 1 shows that there is a wide spread in the average excess returns of the bond indexes. For the G7 government bond indexes, there is an increase in both the mean and volatility as we move to the longer maturity bonds. The average excess returns among the six emerging market bond indexes range between 0.495% (EM-BBB) and 0.787% (EM-BB). The EM B bond index has the highest volatility among the six emerging market bond indexes and the widest range in minimum and maximum monthly excess returns. The volatility of the bond portfolios are considerably lower than the corresponding international equity portfolios.

Table 2 shows that the G7 government bonds have the highest correlation with the domestic bond index. In contrast, the EM bond indexes tend to have small correlations with the domestic bond index. The correlations within a given group of bonds tend to have a high positive correlation with one another as reflected in the G7 government bonds and the EM bonds. The EM bonds tend to have smaller correlations with the G7 bonds. The patterns in correlations suggest that there might be significant diversification benefits of investing in international government bond portfolios.

Our study uses the dummy variable approach of Ferson and Qian(2004) and Ferson et al(2006) with the lagged one-month U.S. Treasury Bill return as z_{t-1}. Studies which use a short term interest rate in international asset pricing studies include Harvey(1991), Harvey, Solnik and Zhou(2002), and Zhang(2006) among others. Table 3 reports the mean and standard deviation of the excess bond index returns across the three economic states. Ferson et al(2006) point out that we can estimate the standard error for the difference in mean excess returns in high and low states as $0.05\sigma(hi)[1+(\sigma(lo)/\sigma(hi))^2]^{1/2}$, where $\sigma(lo)$ and $\sigma(hi)$ are the standard deviation of bond excess returns in low and high states.

Table 3 here

Table 3 shows that the international government bonds exhibit substantial variation in mean and volatility across economic states. In contrast, there is little variation in the mean and volatility of the domestic bond index across the three states. The null hypothesis of no significant difference in mean excess returns between the High and Low states cannot be rejected for the domestic bond index. The average excess returns for the international government bonds are highest in the Low state and lowest in the Normal state. In most cases, the volatility of international government bonds is highest in the Low state but the differences in volatility across the three states are more marginal.

The EM bonds exhibit the greatest variation in the mean and volatility of excess returns across the three states. The EM-B bond index has the largest spread in the mean excess returns across the three states. The differences in mean excess returns of the High and Low states are significant for all the international government bonds, except the G7 10+yr index. Table 3 suggests that there is significant variation in the mean and volatility of the international government bonds across different economic states. The higher mean excess returns in the Low state suggests that the diversification benefits of the international government bonds might be largest for the Low state.

IV Empirical Results

We begin our analysis by examining the diversification benefits of investing in G7 government bond portfolios. We add to the domestic investment universe, the four G7 government bond indexes with different maturities. Panels A and B of Table 4 report summary statistics of the posterior distribution of the DCER measure (%) for the unconstrained (panel A) and constrained (panel B) portfolio strategies. Panels C and D include the mean and standard deviation of the posterior distribution of the optimal portfolio weights in the unconstrained (panel C) and constrained (panel D) portfolio strategies.

Table 4 here

Panel A of Table 4 shows that there are significant diversification benefits of investing in the G7 government bond portfolios using the unconstrained portfolio strategies. The mean DCER measures at the two levels of risk aversion are large in economic terms and both are significant at the 5% percentile. In the optimal portfolios in panel C of Table 4 underlying the increase in CER performance, shows that there are substantial short positions in the G7 1-5yr and G7 7-10yr bond indexes and large long positions in the Market and G7 5-7yr indexes. The extreme weights in the unconstrained mean-variance optimal portfolios is common when using sample mean-variance portfolios (Michaud(1989)). There is substantial volatility in the optimal portfolio weights and so none of the average weights are more than two standard deviations from zero. The large volatility in the optimal weights stems from the large estimation risk in sample mean-variance portfolios and is similar to Britten-Jones(1999) in international equity portfolios.

Imposing no short selling constraints leads to a sharp drop in the mean and volatility of the DCER measure in panel B of Table 4. This pattern is similar to Wang(1998) and Li et al(2003) and is due to the lower estimation risk when short selling constraints are imposed (Frost and Savarino(1988) and Jagannathan and Ma(2003))[14]. The mean DCER measure is significant at the 5% percentile when $\gamma = 1$ but is on the borderline of statistical significance when $\gamma = 3$. The superior performance of the constrained portfolio strategies in panel B is driven by the large positive average weight on the G7 10+yr index in panel D. The average weight on the G7 10+yr bond index is more than two standard deviations from zero.

Table 4 shows that there are significant diversification benefits of investing in G7 government bonds even in the presence of no short selling constraints. For the constrained portfolio strategies, the benefits are driven by the longest maturity G7 government bonds. Our results differ from Hansson et al(2009) who find no significant benefits of investing in eleven developed market bond indexes, even for unconstrained portfolio strategies. The difference likely stems from a different sample period and the choice of test assets to add to the benchmark investment universe. We use G7 bonds of different maturities rather than the individual developed market bond indexes. Our results also differ from Briere et al(2016). Briere et al find that adding G4 developed market bonds to the domestic investment universe of U.S. government bonds neither significantly increases expected returns nor reduce portfolio volatility. Our results again stand in sharp contrast due to the G7 bonds with longer maturities.

[14] Basak et al(2002) find that the standard error of their mean-variance inefficiency measure increases when no short selling constraints are imposed. Basak et al point out that this occurs because the linear approximation of a nonlinear function is less reliable when there are no short selling constraints.

We next examine whether the diversification benefits of investing in the G7 government bond portfolios varies across economic states. Table 5 reports the summary statistics of the posterior distribution of the DCER measure across the Low (panel A), Normal (panel B), and High (panel C) states. To conserve space, we do not report the mean and volatility of the optimal weights but will discuss in the text.

Table 5 here

Table 5 shows that the diversification benefits of investing in the G7 government bond indexes varies across the economic states. The performance is strongest in the Low state and weakest in the Normal state. Across all three states, there are large significant mean DCER measures using the unconstrained portfolio strategies. The optimal portfolios in the unconstrained strategies have extreme average weights and are highly volatile. None of the average weights in the optimal unconstrained portfolios are more than two standard deviations from zero.

When imposing no short selling constraints, there is a huge drop in the mean and volatility of the DCER measures. In the Normal state, the mean DCER measures are tiny at 0.042% ($\gamma = 3$), and 0.06% ($\gamma = 1$) and both are insignificant at the 5% percentile. In the High economic state, the mean DCER measures are high relative to the Normal state but the mean DCER measures for both strategies are not significant at the 5% percentile. This finding suggests that no short selling constraints eliminate the diversification benefits of investing in G7 government bond portfolios in Normal and High states.

It is only in the Low economic state, that the constrained portfolio strategies have significant diversification benefits. The mean DCER measures for the two levels of risk aversion are large in economic terms and both are significant at the 5% percentile. In the optimal unconstrained portfolios, there are positive average weights on the G7 5-7yr, G7 7-10yr, and G7 10+yr bonds but none are more than two standard deviations from zero. In the constrained portfolio strategies, it is only for the G7 10+yr bond index in the High state that has a large positive average weight more than two standard deviations from zero. The superior performance in the Low state is driven by large positive average weights on the G7 7-10yr and 10+yr bond indexes but the average weights are not more than two standard deviations from zero.

Table 5 shows that the diversification benefits of investing in G7 government bond indexes varies across economic states. It is only in the Low state, that the optimal constrained portfolios deliver significant diversification benefits. We next examine the diversification benefits of adding all three groups of bonds to the domestic investment universe between January 2005 and September 2016. We only report the results for the constrained portfolio strategies using the two models of portfolio constraints. Panels A and B of Table 6 report the summary statistics of the posterior distribution of the DCER measure for the constrained portfolio strategies under the two models of portfolio constraints. Panels C and D report the mean and standard deviation of the posterior distribution of the optimal portfolio weights under the two models of portfolio constraints.

Table 6 here

Panel A of Table 6 shows that there are significant diversification benefits of investing in all the international bond indexes, when only no short selling constraints are imposed on the optimal portfolio strategies. The mean DCER measures at 0.449% (γ=3) and 0.505% (γ=1) are large in economic terms and both are significant at the 5% percentile. Panel C shows that this superior performance is driven by the EM-BB bond index. There is little diversification in the optimal portfolio weights in panel C. The average weight on the EM-BB bond index is close to one and is more than two standard deviations from zero.

Imposing the combined upper bound constraint of 20% on the EM bonds leads to a substantial reduction in the mean and volatility of the DCER measures. However the mean DCER measures remains significant at the 5% percentile for both levels of risk aversion. The optimal weights in panel D show that the EM-BB bond index has the largest average weight among the EM bond indexes and is more than two standard deviations from zero. The largest average weight is now given by the G7 10+yr bond index with smaller average weights in the Market and IL bond index. Neither of the average weights in the Market and IL bond indexes are more than two standard deviations from zero. The average weight on the G7 10+yr index is more than two standard deviations from zero when $\gamma = 1$ and borderline when $\gamma = 3$.

Table 6 shows that there are significant diversification benefits of investing in the three groups of international government bonds. The superior performance is driven by the EM bonds. This finding is stronger than in Hansson et al(2009), where the diversification benefits of investing in EM bonds depends on the benchmark used when investors face no short selling constraints. The results could differ due to the different time periods and different empirical methods. Hansson et al use the asymptotic test of De Roon et al(2001). Li et al(2003) argue that the Bayesian results are clearer as the uncertainty in finite samples are incorporated into the posterior distribution and the exact nonlinear function is used rather than a first-order approximation in the asymptotic test.

We next formally examine the incremental contribution of adding each group of bonds to the investment universe. We begin by adding the G7 bonds to the domestic investment universe and then consecutively add the inflation-linked bond index, and the EM bonds. Table 7 reports summary statistics of posterior distribution of the DCER measure that captures the incremental contribution of the G7 and inflation-linked bond indexes in panel A.

Panel B reports the incremental contribution of the EM bonds for the two models of portfolio constraints.

Table 7 here

Panel A of Table 7 shows that neither the G7 government bonds nor the inflation-linked bond index make a significant incremental contribution to the CER performance when added to the investment universe in the presence of no short selling constraints. The mean DCER measures are small and none are significant at the 5% percentile. In contrast, panel B of Table 7 shows that the EM bonds do make a significant incremental contribution in CER performance under both models of portfolio constraints. When the investor only faces no short selling constraints, the mean DCER measures are large in economic terms and significant at the 5% percentile. Adding the combined upper bound constraint, leads to a sharp drop in the mean and volatility of the DCER measures. However the mean DCER measures remain significant at the 5% percentile. This finding suggests that the EM bonds are the driving force behind the diversification benefits of the international government bond portfolio strategies.

We next examine whether the diversification benefits varies across economic states using all three groups of bonds between January 2005 and September 2016. We use both models of portfolio constraints. Table 8 reports the summary statistics of the posterior distribution of the DCER measure in Low (panel A), Normal (panel B), and High (panel C) economic states.

Table 8 here

Table 8 shows that the diversification benefits of investing in international government bonds varies across economic states. The diversification benefits are strongest in the Low state and weakest in the Normal state. The mean DCER measures are massive in the Low state and significant at the 5% percentile. Even with the combined upper bound constraint of the EM bonds, the diversification benefits are large. In the High state, the diversification benefits are also highly significant. The mean DCER measures are large in economic terms and significant at the 5% percentile. In contrast, for the Normal state there are no diversification benefits of investing in international government bonds. The mean DCER measures are small and none are significant at the 5% percentile. The results in Table 8 suggest that the constrained portfolio strategies in international government bonds are substantial in states of the world when the lagged one-month U.S. Treasury Bill return is lower and higher than normal.

The final issue we examine is whether the mean-variance strategies deliver significant diversification benefits using mean/VAR and mean/CVAR performance measures. We repeat the tests in Tables 6 and 8 for the constrained portfolio strategies. Table 9 reports summary statistics of the posterior distribution of the alternative performance measures. The results are reported for the January 2005 and September 2016 period (panel A) and for the Low (panel B) and High (panel C) states. We only include the results for the model 1 portfolio constraints as the results are similar when using the combined upper bound constraint on the emerging market bonds. We set the confidence level at t=0.95 and t=0.99 for estimating the mean/VAR and mean/CVAR performance measures.

Table 9 here

Panel A of Table 9 shows that the diversification benefits of the international government bonds disappears when using the alternative performance measures across the January 2005 and September 2016 period. The average mean/VAR and mean/CVAR measures are small and none are significant at the 5% percentile. There is little difference between the mean/VAR and mean/CVAR measures. Panel A suggests that the superior CER performance in Table 6 comes at the expense of higher VAR and CVAR, which offsets the increase in mean excess returns of investing in the international government bonds.

Panels B and C of Table 9 show that the international government bonds continue to deliver significant diversification benefits in the Low and High states using the alternative performance measures. All of the average mean/VAR and mean/CVAR measures are economically large and significant at the 5% percentile. The magnitude of the benefits is larger in the Low state compared to the High state. Likewise the average mean/VAR measures are larger than the mean/CVAR measures since a portfolio CVAR is higher than the VAR. The results suggests that the diversification benefits in panels A and C in Table 8 are robust to the use of alternative performance measures.

V Conclusions

This study uses the Bayesian approach of Wang(1998) and Li et al(2003) to examine the diversification benefits provided by three groups of international government bonds and whether these benefits vary across economic states. There are three main findings in our study. First, when investing only in G7 government bonds, there are substantial diversification benefits using unconstrained portfolio strategies. Imposing no short selling constraints leads to a substantial reduction in the magnitude of the benefits but does not eliminate them. The superior performance is driven the longest maturity G7 bond index. This finding differs from Hansson et al(2009) and Briere et al(2016) who find little benefit of investing in developed market government bonds when the domestic investment universe is U.S. government bonds.

Second, when investing across all three groups of bonds, there are significant diversification benefits using constrained portfolio strategies using the CER measure. This result holds even when investors face a combined upper bound constraint of 20% in EM bonds. The superior performance is driven by the EM bonds, especially the EM-BB index. This finding is stronger than that observed in Hansson et al(2009). The finding complements the results in Li et al(2003) of the diversification benefits of investing in EM equity markets even in the presence of short selling constraints. The significant diversification benefits disappear using the alternative mean/VAR and mean/CVAR measures, which suggests that the increase in the portfolio VAR or CVAR offsets the increase in mean excess returns when investing in international government bonds.

Third, we find that the diversification benefits of international government bond strategies varies across economic states. This result holds whether investing only in the G7 government bonds or in all three groups of bonds. The benefits are strongest in the Low state and poorest in the Normal state. For the constrained portfolio strategies in all international government bonds, there are large and significant diversification benefits when the lagged one-month Tresaury Bill return is both lower and higher than normal. These benefits remain significant using the mean/VAR and mean/CVAR measures. This result suggests that the lagged one-month Treasury Bill return has significant predictive ability of the diversification benefits of international government bond portfolios.

Our results suggest that there are significant diversification benefits of investing in international government bonds, especially when the lagged U.S. Treasury Bill return is lower than normal. The superior performance is driven by the EM bonds. Our study has focused on the diversification benefits of international government bonds. An interesting extension to our study would be to look at the diversification benefits of alternative asset classes such as in Hansson et al(2009), Liu(2016), and Briere et al(2016). We have used the dummy variable approach of Ferson and Qian(2004) and Ferson et al(2006) to capture different economic states. An alternative approach would be to use the regime switching method of Ang and Bekaert(2004). We have considered the use of VAR and CVAR performance measures of Alexander and Baptists(2003). It would be of interest to consider the use of VAR and CVAR portfolio constraints as in Alexander and Baptista(2004) and Alexander, Baptista and Yan(2007). Alternatively using a mean-VAR or mean-CVAR portfolio optimization could be explored to evaluate diversification benefits. We leave these issues to future research.

Table 1 Summary Statistics of Bond Indexes

Bond	Mean	Standard Deviation	Minimum	Maximum
Market	0.260	1.303	-4.307	5.324
G7 1-5yr	0.195	1.484	-4.219	5.102
G7 5-7yr	0.328	2.127	-5.907	8.448
G7 7-10yr	0.376	2.467	-6.332	8.346
G7 10+yr	0.461	2.508	-6.843	9.295
IL	0.367	2.131	-11.998	7.722
EM-Asia	0.707	2.815	-17.527	14.129
EM-EU/ME/Afr	0.553	2.289	-15.551	7.183
EM-LA	0.580	2.742	-16.371	8.979
EM-B	0.523	3.759	-25.961	9.883
EM-BB	0.787	2.619	-17.795	13.037
EM-BBB	0.495	2.191	-11.123	10.038

The table reports summary statistics of monthly excess returns (%) of the different international government bond indexes. The summary statistics includes the mean, standard deviation, minimum, and maximum of monthly excess returns. The Market is the U.S. Treasury Master bond index. G7 1-5yr, G7 5-7yr, G7 7-10yr, and G7 10yr+ are the G7 government bond indexes with maturities of 1-5 years, 5-7 years, 7-10 years, and 10+ years. The sample period for the Market and G7 bonds is January 1986 and September 2016. IL is the global government inflation-linked bond index and the data covers the January 1998 and September 2016. The final six rows are emerging market (EM) bond indexes. The first three rows are regional sovereign bond indexes for Asia, Europe/Middle East/Africa (EU/ME/Afr), and Latin America (LA). The final three rows are sovereign bond indexes based on country ratings of B, BB, and BBB. The data for the EM bond indexes covers the January 2005 and September 2016.

Table 2 Correlations of Bond Indexes

	Market	G7 1-5yr	G7 5-7yr	G7 7-10yr	G7 10+yr	IL	EM-Asia	EM-EU/ME/Afr	EM-LA	EM-B	EM-BB
G7 1-5yr	0.470										
G7 5-7yr	0.523	0.958									
G7 7-10yr	0.537	0.939	0.981								
G7 10+yr	0.836	0.736	0.771	0.797							
IL	0.458	0.675	0.668	0.669	0.715						
EM-Asia	0.257	0.260	0.303	0.334	0.433	0.680					
EM-EU/ME/Afr	0.174	0.278	0.299	0.320	0.357	0.722	0.872				
EM-LA	0.228	0.315	0.334	0.383	0.449	0.704	0.856	0.871			
EM-B	-0.133	0.084	0.054	0.084	0.104	0.555	0.648	0.797	0.808		
EM-BB	0.279	0.275	0.314	0.349	0.442	0.686	0.931	0.928	0.909	0.701	
EM-BBB	0.414	0.409	0.468	0.505	0.577	0.761	0.899	0.896	0.920	0.635	0.914

The table reports correlations of the different international government bond indexes across the relevant sample periods. The Market is the U.S. Treasury Master bond index. G7 1-5yr, G7 5-7yr, G7 7-10yr, and G7 10yr+ are the G7 government bond indexes with maturities of 1-5 years, 5-7 years, 7-10 years, and 10+ years. The sample period for the Market and G7 bonds is January 1986 and September 2016. IL is the global government inflation-linked bond index and the data covers the January 1998 and September 2016. The final six rows are emerging market (EM) bond indexes. The first three rows are regional sovereign bond indexes for Asia, Europe/Middle East/Africa (EU/ME/Afr), and Latin America (LA). The final three rows are sovereign bond indexes based on country ratings of B, BB, and BBB. The data for the EM bond indexes covers the January 2005 and September 2016.

Table 3 Summary Statistics of Bond Indexes in Different Economic States

Bond	Low		Normal		High	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Market	0.356	1.625	0.188	1.125	0.285	1.046
G7 1-5yr	0.538	1.697	-0.024	1.341	0.166	1.312
G7 5-7yr	0.759	2.344	0.087	2.040	0.181	1.790
G7 7-10yr	0.797	2.805	0.119	2.324	0.297	2.036
G7 10+yr	0.741	3.117	0.233	2.061	0.585	2.322
IL	0.866	2.486	0.053	2.038	0.410	1.543
EM-Asia	1.988	3.312	0.248	2.895	0.817	1.581
EM-EU/ME/Afr	1.702	2.408	0.251	2.472	0.359	1.118
EM-LA	1.713	2.544	0.086	2.924	0.915	2.043
EM-B	2.420	3.717	-0.099	4.080	0.538	2.039
EM-BB	1.867	2.976	0.433	2.735	0.793	1.580
EM-BBB	1.431	2.499	0.207	2.249	0.450	1.463

The table reports the mean and standard deviation (Std Dev) of monthly excess returns (%) of different bond indexes across three economic states. The three states are when the lagged one-month U.S. Treasury Bill return is lower than normal (Low), normal, and higher than normal (High). The Mkt is the U.S. Treasury Master bond index. G7 1-5yr, G7 5-7yr, G7 7-10yr, and G7 10yr+ are the G7 government bond indexes with maturities of 1-5 years, 5-7 years, 7-10 years, and 10+ years. The sample period for the Mkt and G7 bonds is January 1986 and September 2016. IL is the global government inflation-linked bond index and the data covers the January 1998 and September 2016. The final six rows are emerging market (EM) bond indexes. The first three rows are regional sovereign bond indexes for Asia, Europe/Middle East/Africa (EU/ME/Afr), and Latin America (LA). The final three rows are sovereign bond indexes based on country ratings of B, BB, and BBB. The data for the EM bond indexes covers the January 2005 and September 2016.

Table 4 Posterior Distribution of the DCER Measure: G7 Government Bonds

Panel A:				
Unconstrained	Mean	Std Dev	5%	Median
γ=1	0.827	0.565	0.161	0.714
γ=3	0.275	0.188	0.053	0.238
Panel B:				
Constrained	Mean	Std Dev	5%	Median
γ=1	0.181	0.087	0.036	0.180
γ=3	0.138	0.083	0.006	0.135
Panel C:				
Unconstrained	γ=1		γ=3	
	Mean	Std Dev	Mean	Std Dev
Market	13.109	8.315	4.369	2.771
G7 1-5yr	-9.148	12.858	-3.049	4.286
G7 5-7yr	13.615	16.109	4.538	5.369
G7 7-10yr	-3.317	12.387	-1.105	4.129
G7 10+yr	-0.660	5.977	-0.220	1.992
Panel D:				
Constrained	γ=1		γ=3	
	Mean	Std Dev	Mean	Std Dev
Market	0.020	0.133	0.072	0.216
G7 1-5yr	0	0	0.000	0.019
G7 5-7yr	0.006	0.070	0.019	0.108
G7 7-10yr	0.140	0.331	0.137	0.294
G7 10+yr	0.832	0.352	0.770	0.356

Panels A and B of the table report summary statistics of the posterior distribution of the DCER measure (%) for the unconstrained (panel A) and constrained (panel B) portfolio strategies. In the constrained portfolio strategies, no short selling is allowed in the risky assets and the one-month Treasury Bill. The summary statistics include the mean, standard deviation (Std Dev), fifth percentile (5%), and median. The domestic investment universe consists of the one-month U.S. Treasury Bill return, and the excess returns of the U.S. bond index (Market). The DCER measure is calculated by adding four G7 government bond indexes with different maturities (G7 1-5yr, G7 5-7yr, G7 7-10yr, and G7 10+yr) to the domestic investment universe. The sample period covers January 1986 and September 2016. Panels C and D report the mean and standard deviation of the posterior distribution of the optimal weights for the unconstrained (panel C) and constrained (panel D) portfolio strategies. The risk aversion (γ) of the investor is set equal to 1 and 3.

Table 5 Posterior Distribution of the DCER Measure Across Different Economic States: G7 Government Bonds

Panel A:				
Low				
Unconstrained	Mean	Std Dev	5%	Median
γ=1	6.331	3.117	2.127	5.964
γ=3	2.110	1.039	0.709	1.988
Constrained				
γ=1	0.470	0.181	0.168	0.464
γ=3	0.417	0.177	0.123	0.412
Panel B:				
Normal				
Unconstrained	Mean	Std Dev	5%	Median
γ=1	2.728	1.528	0.715	2.516
γ=3	0.909	0.509	0.238	0.838
Constrained				
γ=1	0.060	0.072	0	0.038
γ=3	0.042	0.061	0	0.012
Panel C:				
High				
Unconstrained	Mean	Std Dev	5%	Median
γ=1	7.681	4.473	1.666	6.831
γ=3	2.560	1.491	0.555	2.277
Constrained				
γ=1	0.284	0.189	0	0.283
γ=3	0.243	0.180	0	0.241

The table reports summary statistics of the posterior distribution of the DCER measure (%) across different economic states. The summary statistics include the mean, standard deviation (Std Dev), fifth percentile (5%), and median. The economic states are when the lagged one-month U.S. Treasury Bill return is lower than normal (Low, panel A), Normal (panel B), and higher than normal (High, panel C). The domestic investment universe consists of the one-month U.S. Treasury Bill return, and the excess returns of the U.S. bond index (Market). The DCER measure is calculated by adding four G7 government bond indexes with different maturities (G7 1-5yr, G7 5-7yr, G7 7-10yr, and G7 10+yr) to the domestic investment universe. The sample period covers January 1986 and September 2016. The results are reported for the unconstrained portfolio strategies and the constrained portfolio strategies, where no short selling is allowed in the risky assets or the Treasury Bill. The risk aversion (γ) of the investor is set equal to 1 and 3.

Table 6 Posterior Distribution of the DCER Measure: All Bonds

Panel A:				
Model 1	Mean	Std Dev	5%	Median
γ=1	0.505	0.133	0.280	0.505
γ=3	0.449	0.132	0.224	0.450
Panel B:				
Model 2	Mean	Std Dev	5%	Median
γ=1	0.213	0.079	0.090	0.210
γ=3	0.179	0.072	0.078	0.172
Panel C:				
Model 1	γ=1		γ=3	
	Mean	Std Dev	Mean	Std Dev
Market	0.000	0.014	0.000	0.023
G7 1-5yr	0	0	0	0
G7 5-7yr	0	0	0	0
G7 7-10yr	0	0	0	0
G7 10+yr	0.001	0.032	0.005	0.040919
IL	0	0	0	0
EM-Asia	0.054	0.216	0.038	0.171
EM-EU/ME/Afr	0	0	0	0
EM-LA	0.001	0.031	0.001	0.031
EM-B	0.014	0.100	0.005	0.045
EM-BB	0.927	0.239	0.948	0.183
EM-BBB	0	0	0	0
Panel D:				
Model 2	γ=1		γ=3	
	Mean	Std Dev	Mean	Std Dev
Market	0.061	0.202	0.144	0.272
G7 1-5yr	0	0	0	0
G7 5-7yr	0.000	0.015	0.000	0.025
G7 7-10yr	0.002	0.038	0.004	0.051
G7 10+yr	0.670	0.282	0.581	0.313
IL	0.066	0.210	0.068	0.186
EM-Asia	0.011	0.046	0.009	0.042
EM-EU/ME/Afr	0	0	0	0
EM-LA	0	0	0	0
EM-B	0.006	0.033	0.007	0.035
EM-BB	0.181	0.057	0.182	0.054
EM-BBB	0	0	0	0

Panels A and B of the table report the summary statistics of the posterior distribution of the DCER measure (%) for the constrained portfolio strategies under the two models of portfolio constraints. The summary statistics include the mean, standard deviation (Std Dev), fifth percentile (5%), and median. Model 1 of portfolio constraints is where no short selling is allowed in the risky assets and Treasury Bill. Model 2 adds a combined upper bound constraint of 20% in the emerging market (EM) bonds. Panels C and D report the mean and standard deviation from the posterior distribution of the optimal portfolio weights. The domestic investment universe consists of the one-month U.S. Treasury Bill return, and the excess returns of the U.S. bond index (Market). The DCER measures are calculated by adding four G7 government bond indexes with different maturities (G7 1-5yr, G7 5-7yr, G7 7-10yr, and G7 10+yr), a global inflation-linked (IL) bond index, and six EM bond indexes (EM-Asia, EM-EU/ME/Afr, EM-LA, EM-B, EM-BB, EM-BBB). The sample period is January 2005 and September 2016. The risk aversion (γ) of the investor is set equal to 1 and 3.

Table 7 Posterior Distribution of the Incremental DCER Measures: All Bonds

Panel A:				
G7	Mean	Std Dev	5%	Median
γ=1	0.126	0.082	0	0.122
γ=3	0.084	0.072	0	0.071
IL				
γ=1	0.004	0.019	0	0
γ=3	0.005	0.019	0	0
Panel B:				
EM-model 1	Mean	Std Dev	5%	Median
γ=1	0.374	0.130	0.153	0.372
γ=3	0.359	0.126	0.143	0.359
EM-model 2				
γ=1	0.080	0.025	0.036	0.080
γ=3	0.088	0.024	0.046	0.088

The table reports the summary statistics of the posterior distribution of the incremental DCER measures between January 2005 and September 2016. The summary statistics include the mean, standard deviation (Std Dev), fifth percentile (5%), and median. The domestic investment universe consists of the one-month U.S. Treasury Bill return, and the excess returns of the U.S. bond index (Market). The incremental DCER measures are calculated in panel A by first adding the G7 government bonds to the domestic universe, and then consecutively adding the global inflation-linked (IL) bonds, and the emerging market (EM) bonds in panel B. Model 1 of portfolio constraints is where no short selling is allowed in the risky assets and Treasury Bill. Model 2 adds a combined upper bound constraint of 20% in the emerging market (EM) bonds. The risk aversion (γ) of the investor is set equal to 1 and 3.

Table 8 Posterior Distribution of the DCER Measure Across Economic States: All Bonds

Panel A:				
Low	Mean	Std Dev	5%	Median
Model 1 γ=1	1.979	0.229	1.609	1.968
γ=3	1.884	0.220	1.535	1.870
Model 2 γ=1	0.808	0.121	0.612	0.806
γ=3	0.770	0.122	0.576	0.769
Panel B:				
Normal	Mean	Std Dev	5%	Median
Model 1 γ=1	0.168	0.125	0	0.160
γ=3	0.121	0.107	0	0.096
Model 2 γ=1	0.039	0.028	0	0.038
γ=3	0.038	0.027	0	0.037
Panel C:				
High	Mean	Std Dev	5%	Median
Model 1 γ=1	0.735	0.090	0.594	0.737
γ=3	0.704	0.089	0.562	0.704
Model 2 γ=1	0.583	0.079	0.457	0.582
γ=3	0.543	0.078	0.419	0.542

The table reports the summary statistics of the posterior distribution of the DCER measures across three economic states between January 2005 and September 2016. The summary statistics include the mean, standard deviation (Std Dev), fifth percentile (5%), and median. The economic states are when the lagged one-month U.S. Treasury Bill return is lower than normal (Low, panel A), Normal (panel B), and higher than normal (High, panel C). The domestic investment universe consists of the one-month U.S. Treasury Bill return, and the excess returns of the U.S. bond index (Market). The DCER measures are calculated by adding four G7 government bond indexes with different maturities (G7 1-5yr, G7 5-7yr, G7 7-10yr, and G7 10+yr), a global inflation-linked (IL) bond index, and six EM bond indexes (EM-Asia, EM-EU/ME/Afr, EM-LA, EM-B, EM-BB, EM-BBB). Model 1 of portfolio constraints is where no short selling is allowed in the risky assets and Treasury Bill. Model 2 adds a combined upper bound constraint of 20% in the emerging market (EM) bonds. The risk aversion (γ) of the investor is set equal to 1 and 3.

Table 9 Posterior Distribution of Alternative Performance Measures: All Bonds

Panel A: All	Mean	Std Dev	5%	Median
Mean/VAR				
γ=1.t=0.95	0.074	0.052	-0.011	0.076
γ=3	0.076	0.052	-0.008	0.077
γ=1, t=0.99	0.047	0.033	-0.007	0.048
γ=3	0.048	0.033	-0.005	0.049
Mean/CVAR	Mean	Std Dev	5%	Median
γ=1,t=0.95	0.055	0.038	-0.008	0.056
γ=3	0.056	0.038	-0.006	0.057
γ=1, t=0.99	0.040	0.028	-0.006	0.041
γ=3	0.040	0.028	-0.004	0.041
Panel B: Low	Mean	Std Dev	5%	Median
Mean/VAR				
γ=1.t=0.95	0.540	0.124	0.370	0.524
γ=3	0.605	0.147	0.416	0.578
γ=1, t=0.99	0.302	0.061	0.213	0.295
γ=3	0.332	0.067	0.236	0.324
Mean/CVAR	Mean	Std Dev	5%	Median
γ=1,t=0.95	0.364	0.076	0.255	0.356
γ=3	0.403	0.085	0.283	0.390
γ=1, t=0.99	0.247	0.049	0.174	0.241
γ=3	0.271	0.052	0.195	0.265
Panel C: High	Mean	Std Dev	5%	Median
Mean/VAR				
γ=1.t=0.95	0.266	0.070	0.157	0.260
γ=3	0.278	0.069	0.179	0.271
γ=1, t=0.99	0.162	0.041	0.097	0.160
γ=3	0.169	0.040	0.110	0.166
Mean/CVAR	Mean	Std Dev	5%	Median
γ=1,t=0.95	0.191	0.049	0.114	0.189
γ=3	0.199	0.048	0.129	0.195
γ=1, t=0.99	0.135	0.034	0.081	0.134
γ=3	0.141	0.033	0.092	0.138

The table reports the posterior distribution of two alternative performance measures for the constrained portfolio strategies, where no short selling is allowed in the risky assets or the Treasury Bill. The summary statistics include the mean, standard deviation (Std Dev), fifth percentile (5%), and median. The alternative performance measures are the Mean/VAR and Mean/CVAR measures of Alexander and Baptista(2003) using two confidence levels (t) of 0.95 and 0.99. The domestic investment universe consists of the one-month U.S. Treasury Bill return and the excess returns on the U.S. bond index. The incremental Mean/VAR and Mean/CVAR measures are calculated by adding the G7 government bonds, the global inflation-linked bond index, and the emerging market bonds to the domestic investment universe. Panel A reports the results for the January 2005 and September 2016 period (All), and panel B (Low) (panel C, High) reports the results when the lag one-month Treasury Bill return is lower than normal (higher) during this period. The risk aversion (γ) of the investor is set equal to 1 and 3.

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