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ORIGINAL ARTICLE

Is portfolio diversification still effective: evidence spanning three crises from the perspective of U.S. investors

Rong Huang[1] · **Dimos Kambouroudis**[1] · **David G. McMillan**[1]

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Abstract
This paper uses over twenty years of data to examine diversification benefits for U.S. investors through assessing different portfolio opportunities, including a stock (60%)-bond (40%) portfolio, an internationally diversified stock portfolio, and a cross-asset diversified portfolio compared with investing only in the U.S. stock market. Our dataset consists of three stock indices (S&P 500, MSCI EAFE, and MSCI EM) and three assets (Gold, Oil, and Bonds). Portfolios are built using both equal- and mean-variance efficient-weights and are compared primarily using the Sharpe ratio. The results indicate that before 2009, U.S. investors could benefit from an internationally diversified stock portfolio. However, since 2009, this international stock portfolio is less likely to benefit U.S. investors. In contrast, the cross-asset diversified portfolio does provide greater benefit and outperforms the U.S only, the stock–bond portfolio, and the international stock portfolio over different time periods. Of note, the mean-variance efficient portfolio weighting outperforms the equal-weighted portfolio. Overall, a portfolio consisting of the S&P500 Index, gold, oil, and U.S. 10-year Treasury Note is the preferred option for U.S. investors.

Keywords Stocks · Diversification · International · Cross-assets

JEL Classification C22 · G12

Introduction

Modern Portfolio Theory (MPT; Markowitz 1952) is designed to aid investors in allocating their wealth among alternative assets to maximize their return within an acceptable level of risk (Elton and Gruber 1997; Rubinstein 2002). A key component of MPT theory is diversification. With recent events from the global financial crisis to the COVID-19 health crisis, the diversification benefits of international investment portfolios are again a subject of discussion by investors, policymakers, and researchers. With the belief of a positive trade-off between return and risk, investors choose the best combination of these based on their assessment of individual risk tolerance to obtain a preferred portfolio. However, the extent to which risk can be reduced depends on the correlation between securities returns. For example, if the return correlation between assets is zero, then firm-specific risk can be eliminated (Levy and Sarnat 1970; Brown and Kapadia 2007). While most investors are well versed with the saying of 'not putting all their eggs in the same basket', how to allocate these eggs remains a focus of research by academics and investors. This paper seeks to investigate the diversification benefits of portfolio choices for U.S. investors across three major crisis periods and the apparent dominance of the U.S. market. Specifically, we examine three portfolio options, including a stock-bond portfolio, an internationally diversified stock portfolio, and a cross-asset diversified portfolio, against a U.S. only portfolio, to determine whether diversification benefit U.S. investors.

Existing literature (e.g., Longin and Solnik 1995; Forbes and Rigobon 2002; Morana and Beltratti 2008) shows that correlations between national stock markets have been increasing in recent years. Karolyi and Stulz (1996) argue that increasing correlations are detrimental to the benefits of international diversification and increase shock transmission between markets, a view that is supported by further empirical evidence (e.g., Longin and Solnik 1995; Driessen and

✉ David G. McMillan
david.mcmillan@stir.ac.uk

[1] Division of Accounting and Finance, University of Stirling, Stirling, UK

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Laeven 2007; Koch and Koch 1991).[1] De Roon et al. (2001) find that once transaction costs and short-selling restrictions are taken into account, the international diversification gains for U.S. investors are small. Conversely, some literature (e.g., Hatemi-J and Roca 2006; Gilmore and McManus 2002) shows that although the correlation between stock markets across countries increases over time, as long as investors can measure this correlation and combine them into an optimal investment portfolio, then the potential for international portfolio diversification remains. Given the dominance of the U.S. economy and its stock market, the question arises as to whether U.S. investors benefit from diversifying their portfolios, either internationally or across asset types.

In considering this question, we compare the performance of different portfolios over the sample period of January 1995-December 2021. We build three portfolios, a stock (60%)-bond (40%) portfolio, an internationally diversified stock portfolio, and a cross-asset diversified portfolio, to compare against a U.S. only position. From these portfolios, we consider which would be more beneficial to U.S. investors. In building the two diversified portfolios, we consider both equal and mean-variance efficient (optimized) weights.

For the U.S. portfolio, we use the Standard & Poor's 500 (S&P500) index as a representative indicator of the U.S. stock market. The 60-40 stock-bond portfolio has a long history and is typically recommended by, for example, pension funds to reduce risk as bonds tend to rise during periods of stock market decline (Ziemba 2013). Therefore, we build such a portfolio consisting of the S&P500 Index and U.S. 10-year Treasury Note. The principal of international diversification suggests that if international stock markets do not correlate perfectly, investors can benefit from a diversified portfolio (Li et al. 2003). As such, we build a representative international portfolio consisting of the S&P500, the MSCI EAFE (Europe, Australasia, and the Far East) index, and the MSCI EM (emerging markets) index. The MSCI EAFE index (henceforth EAFE) and MSCI EM index (henceforth EM) represent developed (excluding U.S.) and emerging countries, respectively. Alternatively, investors can diversify across assets, in addition to bonds, notably this includes commodities, such as gold and oil. Some literature (e.g., Capie et al. 2005; Baur and McDermott 2010; McCown and Zimmerman 2006) finds that gold not only protects investors from inflation but also has hedging properties. Hammoudeh et al. (2011, 2013) find that when oil is combined with precious metals in a diversified portfolio, it has the property of increasing returns and reducing risk. Therefore, we build a portfolio consisting of the S&P500, gold, oil, and bonds.

In examining the potential diversification benefits, we consider differences across both crisis and non-crisis periods. Empirical evidence (e.g., Bertero and Mayer 1990; Butler and Joaquin 2002; King and Wadhwani 1990; Solnik et al. 1996; Guidi and Ugur 2014; Roll 1988) suggests that the correlation between stock markets in crisis periods is higher than in non-crisis periods. This leads to a consideration of whether any diversification benefits may disappear when investors need it most. Therefore, we examine the performance of diversified portfolios over the financial and economic crises of the dot-com bubble and Great Recession and the health crisis of COVID-19. This also allows an examination of the effects of different types of crises on financial markets.

Our main findings are as follows. Since 2009, compared with the EAFE Index and the EM Index, the S&P500 Index is the best performer, with a higher average monthly real return and a higher Sharpe ratio. In regard of portfolio performance, the cross-asset diversified portfolio consisting of the S&P500 Index, gold, oil, and U.S. 10-year Treasury Note offers substantial diversification benefits for U.S. investors, regardless of whether investors choose the equal-weighted or optimized-diversified portfolio. The cross-asset diversified portfolio outperforms not only the U.S. index but also the stock-bond portfolio and the international stock diversified portfolio. Prior to 2009, U.S. investors could benefit from an internationally diversified stock portfolio consisting of the S&P500 index and EM index. However, after 2009, a U.S. only portfolio outperforms the internationally diversified one. This arises not only because, of the three stock markets, the S&P500 Index has been the best performer but also as the correlation between the international stock markets has been increasing over time and so, eliminating the benefits of diversification. Compared with the dot-com crisis and the Great Recession, the COVID-19 health crisis did not have an evident impact on the return of the four portfolios, although it increased the volatility of each variable.

This paper expands the existing literature by considering the performance of both an internationally diversified stock portfolio and a cross-asset portfolio, together with a traditional stock-bond portfolio against a U.S. stock only portfolio. Notably, the analysis considers the effect of three different crisis periods. It is hoped that these results will be of interest to academics, investors, and policymakers interested in portfolio building and cross-market information transmission.

[1] In understanding the increase in correlations, Stulz (2005) notes the liberalization of trade in financial assets (financial globalization) as trade barriers have been reduced. In the same vein, Broner et al. (2013) and Davis and Van Wincoop (2018) find that the correlation between capital inflows and outflows have increased since the 1980s. Burger and Warnock (2003) also note an increase in correlations in the bond market for countries with a more open capital account. Obstfeld et al. (2004) comment that this financial globalization is more apparent between developed countries.

Literature review

We think of diversification within portfolios as beginning with Markowitz (1952). Rational, risk-averse investors realize that not all investments simultaneously perform well (indeed, some may never perform well). Moreover, since no one can accurately predict which investments will perform and which will not, investors can minimize investment risk by spreading their investments across a broad range of assets to form a diversified portfolio.

Three broad aspects of portfolio diversification can be considered. Diversification of the investment industry (e.g., Moerman 2008; Balli et al. 2013; Meric and Meric 1989), where investors should diversify across industries (or sectors), notably where profit levels are negatively correlated. As such, the rise and fall of various securities in the portfolio offset each other. Diversification of investment tools (e.g., McDonald and Solnik, 1977; Lean and Wong 2015; Guesmi et al. 2019). Investors should spread their funds across various investment tools such as stocks, bonds, funds, bank deposits, and so forth. This can include diversification across securities of different maturity. Different types of securities have different maturities. Investors can arrange the maturity structure of their investment in order to achieve a high degree of uniformity in profitability, liquidity, and risk. Diversification of investment areas (e.g., Levy and Lerman 1988; Hatemi-J and Roca 2006; Guidi and Ugur 2014). Different global regions have different economic conditions, so the degree of investment risk is also different. Investors should diversify their investments in different countries and regions to avoid major losses due to the deterioration of the political and economic environment in a certain region. Within this study, we consider cross-asset and cross-country diversification.

Portfolio diversification across asset types

In addition to building a diversified portfolio across stocks within a domestic economy, portfolio managers can consider other asset classes, such as bonds and commodities, in seeking enhanced diversification benefits. Levy and Lerman (1988) find that the benefits of such diversification are substantial. With the same level of risk, U.S. investors who diversify into global bond markets are likely to earn an average return more than double that of a U.S. bond portfolio. McDonald and Solnik (1977) conduct an empirical study of gold in portfolio diversification. They find that both gold and gold mining stocks can be beneficial for portfolio diversification. Sarafrazi et al. (2014) argue for the benefits of a portfolio that is diversified with commodities gold, silver, and oil. Lean and Wong (2015) find that gold is good for stock portfolio diversification but not for bond portfolios. Guesmi et al. (2019) find that hedging strategies involving gold, oil, emerging stock markets and Bitcoin reduce a portfolio's volatility, as compared to the volatility of a portfolio composed of gold, oil, and stocks from emerging market stocks only.

However, there are some opposing views. Cotter et al. (2017) find that, for all portfolio strategies, commodities and currencies do not improve the investment opportunity set for the investor with an existing portfolio of stocks, bonds and T-bills, and an investment horizon of one month. Their results are in line with Daskalaki and Skiadopoulos (2011), and also consistent with empirical evidence that the financialization of commodity markets has weakened their diversification potential (e.g., Domanski and Heath 2007; Tang and Xiong 2012).

Portfolio diversification across international stock markets

There is a large amount of literature examining the benefits of diversifying across international stock markets. De Santis and Gerard (1997), using a conditional CAPM, report that from 1970 to 1994, the expected return of international diversification to US investors averaged 2.11% per year. Gilmore and McManus (2002) show that US investors can obtain benefits from diversifying into Czech, Hungarian, and Polish stock markets. Li et al. (2003) find that the international diversification benefits remain substantial for U.S. equity investors even when they are prohibited from short-selling in emerging markets. Hatemi-J and Roca (2006) reveal that diversifying internationally between the (then) world's three largest financial markets (U.K., U.S., and Japan) can increase risk-adjusted returns. Driessen and Laeven (2007) find that the benefits of investing abroad are largest for investors in developing countries, including when controlling for currency effects, and the gains from international portfolio diversification appear to be largest for countries with high country risk for the period 1985-2002. They also provide evidence that diversification benefits vary over time as country risk changes, although they note that these diversification benefits decrease for most countries over their sample period. They argue that this is mainly due to an increase in return correlations between local and global markets and a decrease in the variances of local market returns.

Meric et al. (2008) study the portfolio diversification implications of the co-movements of sector indexes in the U.S., U.K., German, French, and Japanese stock markets in bull and bear markets. They find that, in a bull market, investors can obtain more benefits with global diversification than with domestic diversification even if they invest in the same sector in different countries as opposed to investing in

different sectors within the same country. In a bear market, the sectors of different countries tend to be more closely correlated and country diversification opportunities are limited. Coeurdacier and Guibaud (2011) find that investors do tilt their foreign holdings toward countries that offer better diversification opportunities. Christoffersen et al. (2014) find that correlations have trended upward significantly for both developed and emerging markets, while they also find some evidence that adding emerging markets to a developed markets-only portfolio increases diversification benefits. Guidi and Ugur (2014) find that the South-Eastern European (SEE) stock markets offer diversification benefits for international investors with time horizons of less than three years. Zafaranloo and Sapian (2013) find the lack of a long-term relation between five Asian emerging markets (Malaysia, Thailand, Indonesia, China, and India) and the U.S. market, although a short-run relation exists between Malaysia, Indonesia, and Thailand with U.S. The results thus suggest some diversification benefits for U.S. investors with Asian emerging markets over the long term. Oloko (2018) finds that there are potential gains for U.S. and U.K. investors by diversifying with Nigerian stocks during January 2004 to June 2015, while there exists the potential for financial risks to transmit from the U.S. and U.K. markets to the Nigerian market. Fletcher (2021) finds that international closed-end equity funds do not offer diversification benefits from January 1994 to October 2019. However, some out-of-sample diversification returns for such funds do vary by country.

It can be seen from the above literature that across different portfolio combinations and constituents as well as sample periods, different results arise. This paper seeks to evaluate these results again in the context of a more recent period, including COVID-19 and a U.S. bull market.

Data and descriptive statistics

We use monthly returns over the sample period from January 1995 to December 2021.[2] This period is divided into six sub-sample periods as detailed in Table 1. These sub-sample periods are classified into two broad categories involving three crisis periods and three non-crisis periods. The crisis periods include the dot-com burst period from April 2000 to December 2002, the Great Recession period from December 2007 to June 2009, and the COVID-19 health crisis period from December 2019 to December 2021. The non-crisis periods include the dot-com boom period from January 1995 to March 2000, the 2003-2007 period, and the 2009-2019 period.

Table 1 Sub-sample periods

	Starting date	Ending date
Dot-com boom	1995:01	2000:03
Dot-com burst	2000:04	2002:12
2003-2007	2003:01	2007:11
Great recession	2007:12	2009:06
2009-2019	2009:07	2019:11
COVID-19	2019:12	2021:12

Table 2 Portfolio types

	Components			
U.S. only	S&P 500			
Portfolio 1	S&P 500	10 YR T-Note		
Portfolio 2	S&P 500	MSCI EAEF	MSCI EM	
Portfolio 3	S&P 500	GOLD	OIL	10 YR T-Note

We consider three types of diversification opportunities for U.S. investors, which are listed in Table 2 and are compared against a U.S. only position, which involves the S&P500 Index as the portfolio.[3] The first diversified portfolio (Portfolio 1) consists of the S&P500 Index and U.S. 10-year Treasury Note using a 60/40 weighting (Markowitz 1952). The second (Portfolio 2), is an internationally diversified stock portfolio. This portfolio is constituted of the S&P500 Index, the EAFE Index, and the EM Index. The third portfolio (Portfolio 3) is constructed across different asset classes and is constituted of the S&P500 Index, gold, oil, and the 10 YR T-Note. The currency of all series is the U.S. dollar.

Figure 1 presents the time-series plots of each of the data series, while summary statistics are reported in Table 3. Within Fig. 1, we can see notable market events. This includes the dot-com crash period (2000 to 2002) and the Great Recession (from 2007-2009), in which there are clear falls in the S&P500, EAFE Index, and EM Indexes and the oil price. Each of these series also exhibit a fall at the beginning of the COVID-19 period, although they all recover quickly. It is worth noting that since 2009, the S&P 500 Index has shown a significant upward trend, despite a momentary drop associated with COVID-19, while the EAFE index shows a slight upward trend with large

[2] The choice of 1995 as a starting point is motivated in looking to provide a balance between crisis and non-crisis periods, thus starting at the beginning of the dot-com run period and before the crash. In addition, the EM index underwent notable changes (additions) during the mid-1990s, where the number of markets included doubled. This, equally, may affect the behavior of the index before this period.

[3] The S&P500 index can, in itself be argued to be a cross-sector diversified portfolio.

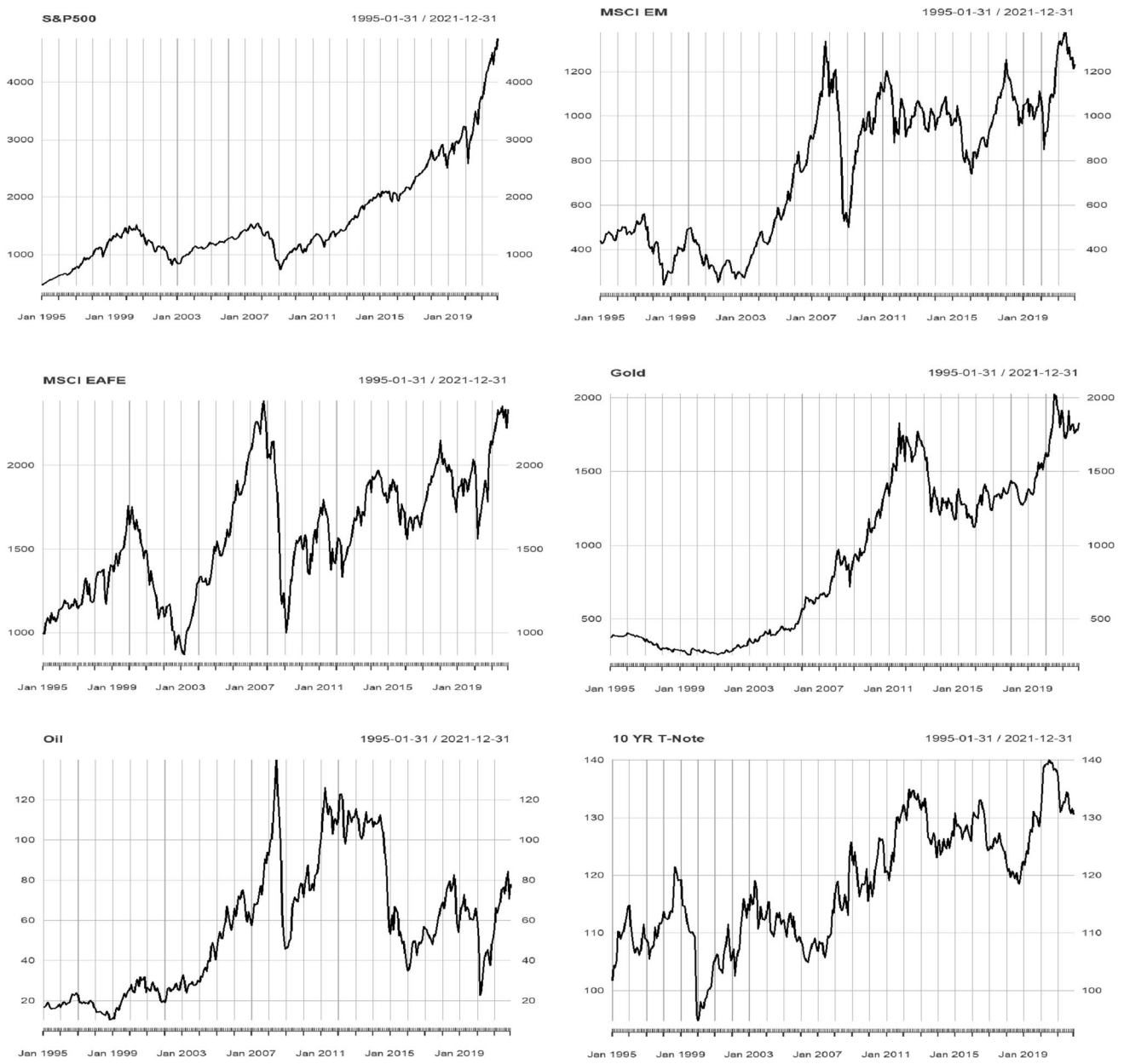

Fig. 1 Time series movements of all variables

fluctuations. From 2009 to 2011, the EM Index increased, but after that, has not shown any clear upward trend.

In regard of the non-index series, for the 10-year Treasury Note, we can see a rise during the dot-com crash period and, following a slight decrease from 2003 to 2007, a sharp rise during the Great Recession. We again see a rise during the COVID-19 period when the index series fell. Gold has an obvious upward trend from 1999 to 2012, and then a slight decline until 2016 before rising at the COVID-19 period. The movement of both the Treasury Note and gold are consistent with them being viewed as potential hedging or safe haven series for periods of stock market stress. While the oil series exhibits the same crash periods of the indexes, there is no other apparent trending behavior, but does fluctuate considerably during the sample period.

Table 3 presents descriptive statistics of the return of all the six variables over the full sample period. These are adjusted for inflation to produce real returns (see below), although for simplicity, we just refer to them as returns. Table 3 shows that the oil return series has the highest standard deviation indicating that it is the most volatile series. In contrast, the 10 YR T-Note return series appears as the least risky in having the lowest standard deviation. The S&P500, EAFE, EM, oil, and 10-year Treasury Note return series

Table 3 Summary statistics

	Stock return series			Asset return series		
	rS&P500	rMSCIEAFE	rMSCIEM	rGOLD	rOIL	r10YRTN
# obs	324	324	324	324	324	324
Minimum	−0.172	−0.205	−0.294	−0.183	−0.550	−0.125
Maximum	0.127	0.153	0.168	0.162	0.399	0.086
1. Quartile	−0.018	−0.026	−0.030	−0.026	−0.049	−0.010
3. Quartile	0.034	0.032	0.042	0.030	0.068	0.009
Mean	0.006	0.002	0.003	0.004	0.008	−0.001
Median	0.011	0.006	0.005	−0.001	0.011	−0.001
Stdev	0.043	0.047	0.064	0.046	0.098	0.018
Skewness	−0.639	−0.574	−0.690	0.200	−0.358	−0.808
Kurtosis (excess)	1.191	1.534	2.143	1.061	4.179	7.958
JB Test	42.243	50.891	89.830	18.127	247.740	905.170
P-value	0.000	0.000	0.000	0.000	0.000	0.000

rS&P500 The real return on the S&P500 index, rMSCIEM The real return on the MSCI EM (Emerging Market) index, rMSCIEAEF The real return on the MSCI EAFE (Developed Market) index, rGOLD The real return on GOLD index, rOIL The real return on OIL index, r10YRTN The real return on 10-year Treasury Note

Table 4 Mean and standard deviation across all periods

	rS&P500		rMSCIEAFE		rMSCIEM	
	Mean	Stdev	Mean	Stdev	Mean	Stdev
Whole period	0.006	0.043	0.002	0.047	0.003	0.064
Dot-com boom	0.018	0.042	0.007	0.041	0.001	0.072
Dot-com Burst	−0.017	0.053	−0.019	0.047	−0.016	0.070
2003-2007	0.007	0.025	0.013	0.031	0.024	0.050
Great recession	−0.024	0.070	−0.028	0.086	−0.021	0.117
2009-2019	0.009	0.036	0.003	0.043	0.002	0.050
COVID-19	0.016	0.055	0.006	0.056	0.006	0.058
	rGOLD		rOIL		r10YRTN	
	Mean	Stdev	Mean	Stdev	Mean	Stdev
Whole period	0.004	0.046	0.008	0.098	−0.001	0.018
Dot-com boom	−0.006	0.035	0.008	0.092	−0.002	0.022
Dot-com Burst	0.005	0.035	0.008	0.105	0.003	0.019
2003-2007	0.012	0.044	0.020	0.080	−0.002	0.017
Great recession	0.010	0.079	−0.005	0.140	−0.001	0.027
2009-2019	0.004	0.048	0.001	0.078	0.000	0.014
COVID-19	0.006	0.045	0.024	0.174	−0.002	0.013

rS&P500 The real return on the S&P500 index, rMSCIEM The real return on the MSCI EM (Emerging Market) index, rMSCI EAEF The real return on the MSCI EAEF (Developed Market) index, rGOLD The real return on GOLD index, rOIL The real return on OIL index, r10YRTN The real return on 10-year Treasury Note

are all skewed to the left, while the gold return series is skewed to the right. The value of (excess) kurtosis is positive and high for all series. Together these statistics indicate non-normality, and this is supported by the Jarque-Bera test statistic. Among the six return series, only the 10-year Treasury Note has an average negative monthly real return. Furthermore, among the three stock return series, the S&P500 is

the best performer, although oil produces the highest average monthly real return across all series.

As noted above and in Table 1, we consider different sample periods.[4] Table 4 presents the average monthly real return and standard deviation of each series over the six sub-periods and, for comparison, the full sample period. Only during crisis periods of the dot-com bubble crash and Great Recession do the three stock index series have a negative average (real) monthly return. For the COVID-19 health crisis, no stock series has an average negative return, and this is consistent with the short-lived nature of the associated stock price fall. Indeed, the return for this period is similar to non-crisis periods. For the oil and gold series, the average monthly return is positive in each sub-period (except the dot-com boom for the former and the Great Recession for the latter series). The average monthly return on the 10-year Treasury Note is positive during the dot-com crash and the post-Great Recession recovery but is otherwise negative. This same series always exhibits the lowest standard deviation for all sub-periods, while oil is always the most volatile series across all periods.

Methodology

Portfolio design

We consider four investment opportunities for U.S. investors. The first is the U.S. only investment, which can be considered as domestic diversification and uses the S&P500 index. Portfolio 1 consists of the S&P500 Index and the U.S. 10-Year Treasury Note. Here, we adopt the well-known pension funds distribution principle, allocating 60% weight to the S&P500 Index and 40% weight to the U.S. 10-Year Treasury Note. Portfolio 2 is an internationally diversified portfolio constructed using the S&P500, EAFE, and EM Indexes. Portfolio 3 is a cross-asset diversified portfolio consisting of the S&P500 Index, the U.S. 10-Year Treasury Note, and the commodities of gold and oil. For Portfolios 2 and 3, we consider two investment strategies. First is an equal-weighted portfolio (EWP) strategy, and second is the mean-variance portfolio (MVP) strategy.

Portfolio calculations

We use the U.S Consumer Price Index (CPI) to calculate the inflation rate ($R_{\text{inflation}}$), which is used for deflating the nominal return on equity index (R_{index}), bonds (R_{bond}), gold (R_{gold}), oil (R_{oil}), and T-bill (R_f) series to obtain the real index return (r_{index}), real bond return (r_{bond}), real gold return (r_{gold}), real oil return (r_{oil}), and real T-bill return (r_{f}). The monthly returns for each series are calculated in the usual way:

$$R_t = \frac{P_t - P_{t-1}}{P_{t-1}} \times 100\% \tag{1}$$

where R_t denotes the simple monthly return at time t, P_t denotes the index price at time t, and P_{t-1} denotes the index price at time $t-1$.

We then deflate the nominal monthly return (R_t) into real monthly return (r_t):

$$r_t = \frac{1 + R_t}{1 + R_{\text{inflation}}} - 1 \tag{2}$$

The expected return on each investment portfolio is calculated as:

$$E(r_P) = \sum_{i=1}^{N} w_i r_{i,t} \tag{3}$$

With the excess return calculated as:

$$E(r_e) = r_t - r_f \tag{4}$$

where r_t is the real monthly return for all variables and r_f is the real monthly T-bill return. The Sharpe ratio (SR) is then calculated as:

$$\text{SR} = \frac{E(r_e)}{\sigma_r} \tag{5}$$

where σ_{r} is the standard deviation of the real return.

Equal-weighted and mean-variance portfolio

In constructing the portfolios for Portfolio 2 and 3, we consider two strategies. First, an equal-weighted portfolio (EWP) in which the same proportion is invested in each asset within the portfolio. In an EWP strategy, each asset in the portfolio holds a weight $w_i = 1/N$. Second, is the mean-variance portfolio (MVP), which aims to identify the portfolio that provides the highest returns for a given level of risk.

The EWP strategy can be expressed as the solution of the following equations.

$$w = \begin{pmatrix} w_1 \\ w_2 \\ \cdots \\ w_N \end{pmatrix} \tag{6}$$

[4] Full summary statistics are available upon request for each of these sub-sample periods.

where w is the $N \times 1$ vector of portfolio weights. In the equal-weighted portfolio, $w_1 = w_2 = \cdots = w_N$.

$$E(r) = \begin{pmatrix} E(r_1) \\ E(r_2) \\ \cdots \\ E(r_N) \end{pmatrix} \tag{7}$$

where $E(r)$ is the expected return and:

$$E(r_P) = (E(r))^{\top} w \tag{8}$$

where $E(r_P)$ is expected return on portfolios and $(E(r))^{\top}$ is the transpose of the expected return on assets.

After calculating the expected return for the equal-weighted portfolio, we write the variance-covariance matrix of the return as follows:

$$\Sigma = \begin{pmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} & \cdots & \sigma_{1N} \\ \sigma_{21} & \sigma_{22} & \sigma_{23} & \cdots & \sigma_{2N} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \sigma_{N1} & \sigma_{N2} & \sigma_{N3} & \cdots & \sigma_{NN} \end{pmatrix} \tag{9}$$

where Σ is the variance-covariance matrix of the asset returns. The elements on the leading diagonal of Σ are the variances of each of the component asset returns. The off-diagonal elements are the corresponding co-variances.

The MVP strategy can be expressed as the solution of the following equations:

$$\max \left(\frac{(E(r))^{\top} w - r_f}{\sqrt{w^{\top} \sum w}} \right) \tag{10}$$

where w represents the weight invested in each asset, $w^{\top}$ is the transpose of the weight on assets, $(E(r))^{\top}$ is the transpose of the expected return, and Σ represents the corresponding covariance matrix of the returns. The numerator of the objective function denotes the excess returns of the investment over that of a risk-free rate (r_f) and the denominator represents the risk of the investment. The objective is to maximize the Sharpe ratio.

In both EWP and MVP strategies, we exclude short sales by assuming the following general constraint:

$$\sum_{i=1}^{N} w_i = 1, 0 \le w_i \le 1 \tag{11}$$

In-sample rolling windows and out-of-sample exercise

To examine the performance of the portfolios, we consider two approaches in order to enhance the robustness of the results. We first build portfolios for the full sample and each sub-period for each of our strategies (i.e., four fixed weight and two optimized portfolios) and compare their results. Second, to account for any 'look-ahead' bias and to add robustness to the results, we generate out-of-sample portfolios. Here, we utilize 24-month rolling windows to construct a portfolio over the sample period for each portfolio strategy, thereby creating 300 rolling windows across our sample set. At the end of the month T ($T = t + 23,$ and $t = 1 \ldots$ n), we use the return series from the month t to month t + 23 (i.e., the previous 24 months) to derive the in-sample estimates of the parameters for each strategy. This allows calculation of the in-sample performance for the previous 24 months. Using these in-sample values, including the calculated optimal portfolio weight ($w_{i,T}$), we then construct a portfolio for the next, out-of-sample, month. For example, in our sample, the first in-sample estimation window is from January 1995 to December 1996, and we use the optimal weight derived from this in-sample to estimate the out-of-sample portfolio results for January 1997. This rolling procedure operates through the rest of the sample period.

Transaction costs

In addition to the out-of-sample performance, we implement a one-way transaction cost (C) of 0.05% for each trade, according to Hsu et al. (2018). We define $r_{i,T}$ as the real return of the *i-th* asset in month T, and set $\sum_{i=1}^{N} r_{i,T} w_{i,T}$ as the real portfolio return (i.e., the gross return) before rebalancing at the end of month T. When the portfolio is re-balanced in the beginning of month T + 1, it yields a trade in each asset with a magnitude of $|w_{i,T+1} - w_{i,T}|$, where $w_{i,T}$ is the optimal portfolio weight of each asset in the end of month T, $w_{i,T+1}$ represents the calculated optimal portfolio weight in each asset in the beginning of month T + 1. We set C as the proportional transaction costs (0.05%), and then the trading costs for all assets are $C \times \sum_{i}^{N} |w_{i,T+1} - w_{i,T}|$. Therefore, the net return after the transaction costs for each portfolio strategy in month T + 1 is calculated as:

$$E(r)^p = \left(1 + \sum_{i=1}^{N} r_{i,T+1} w_{i,T+1} \right) \left(1 - C \times \sum_{i}^{N} |w_{i,T+1} - w_{i,T}| \right) - 1 \tag{12}$$

where $r_{i,T+1}$ is the real return in month T + 1 for each asset. We consider the gross return as the situation when then transaction cost (C) is zero.

Empirical results

Correlations

In computing optimal, mean-variance, efficient portfolios, the correlations between assets are needed. Table 5 provides

Table 5 Correlations

	Cor S&P500 - MSCI EAFE	Cor S&P500—MSCI EM	Cor MSCI EAFE—MSCI EM
Whole period	0.592	0.476	0.603
Dot-com boom	0.398	0.358	0.413
Dot-com burst	0.682	0.633	0.617
2003-2007	0.564	0.496	0.654
Great recession	0.789	0.661	0.825
2009-2019	0.623	0.488	0.632
COVID-19	0.693	0.467	0.587

	Cor S&P500 – GOLD	Cor S&P500 – OIL	Cor S&P500 – 10YRTN
Whole period	0.006	0.145	−0.106
Dot-com boom	0.004	−0.088	0.165
Dot-com burst	−0.057	0.087	−0.299
2003-2007	0.116	−0.139	−0.115
Great recession	−0.088	0.287	−0.076
2009-2019	0.037	0.302	−0.145
COVID-19	0.220	0.427	−0.060

	Cor GOLD – OIL	Cor GOLD – 10YRTN	Cor OIL – 10YRTN
Whole period	0.124	0.142	−0.109
Dot-com boom	0.055	0.023	0.010
Dot-com burst	0.235	0.167	−0.068
2003-2007	0.163	0.030	0.016
Great recession	−0.006	0.263	−0.275
2009-2019	0.131	0.213	−0.193
COVID-19	0.220	0.267	−0.247

these correlations both for the full sample and each sub-sample period. The results in Table 5 show that the correlation between the S&P500 Index, EAFE Index, and EM Index is higher than the correlation between the S&P 500 Index, gold, oil, and 10-year Treasury Note, for both the full sample and each sub-sample period. Further, we find that the correlation between S&P500 and EAFE is lower during the 1995-2000 period and then jumped from 0.40 to 0.68 with the dot-com bubble burst. Afterward, it declines before increasing through the remainder of the sample. A similar pattern is observed between the S&P500 and EM, although the correlation plateaus more after the Great Recession period.

The correlation between the S&P500 index and gold is low throughout the sample and is negative for two of the sub-periods. Notwithstanding, there is a notable increase in value in the last period. The correlation between the S&P500 index and oil is also low at the start of the sample (but greater than with gold) and demonstrates a notable step change from the Great Recession period onwards. The correlation between the S&P 500 and the U.S. 10-Year Treasury Note, except during the 1995-2000 period, is negative throughout. As noted above, the correlation with gold and the 10-Year Treasury Note indicate the potential to hedge against stock market risks.

The results in Table 5 support the argument of a time-varying correlation and for which the correlation between stock markets in a crisis period is higher than in a non-crisis period (Roll 1988; Bertero and Mayer 1990; King and Wadhwani 1990; Solnik et al. 1996; Butler and Joaquin 2002; Guidi and Ugur 2014). We also observe a general upward trend in the correlation between the S&P500, EAFE, and EM Indexes, while correlations also appear to strengthen between the S&P500 and the alternative assets, albeit negatively with the 10-Year Treasury Note.

Portfolio comparisons

We build three diversified portfolios for U.S. investors to compare against the U.S. only portfolio. Portfolio 1 consists of the S&P500 and U.S. 10-year Treasury Note. For Portfolio 1, we use a well-known portfolio allocation that invests

Table 6 The results for the four portfolio benchmarks

	Port. Alloc. S&P500 (%)	Real risk-free rate (%)	Ave.ret. (%)	Real excess return (%)	Std dev (%)	Sharpe ratio (%)	Changes from the last period Ave.ret (%)	Std dev (%)	Sharpe ratio (%)
Panel A. U.S. only									
Whole period	100.00	−0.01	0.63	0.64	4.32	14.76			
Dot-com boom	100.00	0.23	1.78	1.55	4.16	37.21			
Dot-com Burst	100.00	0.08	−1.67	−1.75	5.27	−33.18	−194.05	26.55	−189.18
2003-2007	100.00	0.01	0.68	0.67	2.50	26.71			
Great recession	100.00	−0.12	−2.44	−2.32	6.99	−33.19	−459.81	178.91	−224.25
2009-2019	100.00	−0.09	0.91	1.01	3.62	27.78			
COVID-19	100.00	−0.22	1.58	1.81	5.52	32.68	73.45	52.51	17.64

	Portfolio allocation S&P500 (%)	10 YR T-Note (%)	Real risk-free rate (%	Ave.ret. (%)	Real excess return (%)	Std dev (%)	Sharpe ratio (%)	Changes from the last period Ave. ret (%)	Std dev (%)	Sharpe ratio (%)
Panel B. Portfolio 1										
Whole period	60.00	40.00	−0.01	0.34	0.35	2.54	13.71			
Dot-com boom	60.00	40.00	0.23	0.98	0.76	2.70	28.06			
Dot-com Burst	60.00	40.00	0.08	−0.89	−0.96	2.78	−34.64	−190.11	3.24	−223.44%
2003-2007	60.00	40.00	0.01	0.31	0.30	1.53	19.70			
Great recession	60.00	40.00	−0.12	−1.49	−1.37	4.11	−33.27	−579.29	168.51	−268.85
2009-2019	60.00	40.00	−0.09	0.53	0.62	2.05	30.39			
COVID-19	60.00	40.00	−0.22	0.87	1.09	3.12	35.07	64.15	51.80	15.40

	Portfolio allocation S&P500 (%)	MSCI EAEF (%)	MSCI EM (%)	Real risk-free rate (%)	Ave.ret. (%)	Real excess return (%)	Std dev (%)	Sharpe ratio (%)	Changes from the last period Ave.ret (%)	Std dev (%)	Sharpe ratio (%)
Panel C. Equally-weighted Portfolio 2											
Whole period	33.00	33.00	33.00	−0.01	0.37	0.37	4.74	7.90			
Dot-com boom	33.00	33.00	33.00	0.23	0.86	0.63	4.50	14.08			
Dot-com Burst	33.00	33.00	33.00	0.08	−1.73	−1.80	5.21	−34.65	−300.19	15.57	−346.01
2003-2007	33.00	33.00	33.00	0.01	1.45	1.44	3.23	44.61			
Great recession	33.00	33.00	33.00	−0.12	−2.43	−2.31	8.64	−26.68	−267.21	167.29	−159.81
2009-2019	33.00	33.00	33.00	−0.09	0.48	0.57	4.02	14.20			
COVID-19	33.00	33.00	33.00	−0.22	0.92	1.14	5.18	22.09	93.46	28.98	55.58

Table 6 (continued)

	Portfolio allocation				Real risk-free rate (%)	Ave.ret. (%	Real excess return (%)	std dev (%)	Sharpe ratio (%)	Changes from the last period		
	S&P500 (%)	GOLD (%)	OIL (%)	10 YR T-Note (%)						Ave.ret (%)	Std dev (%)	Sharpe ratio (%)
Panel D. Equally-weighted Portfolio 3												
Whole period	25.00	25.00	25.00	25.00	− 0.01	0.43	0.44	3.29	13.25			
Dot-com boom	25.00	25.00	25.00	25.00	0.23	0.44	0.21	2.75	7.81			
Dot-com Burst	25.00	25.00	25.00	25.00	0.08	− 0.02	− 0.10	3.15	− 3.17	− 105.20	14.83	− 140.55
2003-2007	25.00	25.00	25.00	25.00	0.01	0.92	0.91	2.53	35.90			
Great recession	25.00	25.00	25.00	25.00	− 0.12	− 0.49	− 0.37	5.34	− 7.00	− 153.97	111.16	− 119.51
2009-2019	25.00	25.00	25.00	25.00	− 0.09	0.33	0.42	2.86	14.81			
COVID-19	25.00	25.00	25.00	25.00	− 0.22	1.10	1.33	5.40	24.55	234.73	88.83	65.70

60% in the S&P 500 and 40% in the U.S. 10-year Treasury Note. Portfolio 2 invests in S&P 500, MSCI EAFE Index (a developed market index), and MSCI EM Index (emerging markets index). Portfolio 3 consists of the S&P500 and three assets, including gold, oil, and U.S. 10-year Treasury Note. To examine the performance of each portfolio, as well as obtaining the return and standard deviation (to measure risk), we use the Sharpe ratio (S.R.; Sharpe 1966), which presents the risk-adjusted return.

Performance of equally-weighted portfolios

Table 6 presents the performance results for the S&P500 index with the three diversified portfolios, where the cross-market (Portfolio 2) and cross-asset (Portfolio 3) are equal weighted. Over the full sample period, all four portfolios have a positive average real monthly returns and positive Sharpe ratios. During the three non-crisis periods, each portfolio also has a positive average real monthly return and positive Sharpe ratios. During the dot-com burst period and the Great Recession, all four portfolios have negative average real monthly returns and Sharpe ratio. In contrast, during the COVID-19 health crisis, the same portfolios have positive average real monthly return and Sharpe Ratio.

Comparisons between the four portfolio benchmarks

Table 7 presents a more direct comparison between the four portfolios over the different periods, with a ranking based on the Sharpe ratio. Each panel within the table presents results for the full and different sub-sample periods. Here, we can see that the U.S. only stock portfolio is the best performer (achieves the highest Sharpe ratio) across the full sample period. This is also the case for the dot-com run-up period and the post-Great Recession period of 2009-2019. The U.S. only portfolio ranks second during the dot-com crash and COVID-19 period and never ranks last. Portfolio 1 (the traditional stock-bond portfolio) does not provide a diversification benefit compared to the U.S. only, performing worse in each sub-period with the exception of the COVID-19 period (although the Sharpe ratio is similar in the dot-com and Great Recession crisis period). The cross-market stock Portfolio 2 often performs the worst (including worse than the U.S. only portfolio). This is the case for the full sample period and three of the six sub-sample periods. However, it does provide the best performance during the dot-com burst recovery period of 2003-2007. The cross-asset Portfolio 3 also typically performs poorly (ranking 3 or 4) but does achieve the highest Sharpe ratio during the dot-com burst and the Great Recession periods, suggesting advantages during crisis periods.

In considering the crisis periods, the average monthly real returns for all four portfolios are negative during the

Table 7 Comparisons between the four portfolio benchmarks for different periods

	Ave.ret (%)	Std dev (%)	Sharpe ratio (%)	Rank	Changes from the U.S. only		
					Ave.ret (%)	Std dev (%)	Sharpe ratio (%)
Panel A. The full period							
U.S. Only	0.63	4.32	14.76	1			
Portfolio 1	0.34	2.54	13.71	2	−45.82	−41.19	−7.10
Equally-weighted Portfolio 2	0.37	4.74	7.90	4	−41.59	9.86	−46.46
Equally-weighted Portfolio 3	0.43	3.29	13.25	3	−31.80	−23.67	−10.24
	Ave.ret (%)	Std dev (%)	Sharpe ratio (%)	Rank	Changes from the U.S. only		
					Ave.ret (%)	Std dev (%)	Sharpe ratio (%)
Panel B. The sub-sample periods							
Panel B-1 The Dot-com boom period							
U.S. only	1.78	4.16	37.21	1			
Portfolio 1	0.98	2.70	28.06	2	−44.60	−35.25	−24.58
Equally-weighted Portfolio 2	0.86	4.50	14.08	3	−51.47	8.19	−62.15
Equally-weighted Portfolio 3	0.44	2.75	7.81	4	−75.10	−34.01	−79.02
	Ave.ret (%)	Std dev (%)	Sharpe ratio (%)	Rank	Changes from the U.S. only		
					Ave.ret (%)	Std dev (%)	Sharpe ratio (%)
Panel B-2 The Dot-com Burst period							
U.S. only	−1.67	5.27	−33.18	2			
Portfolio 1	−0.89	2.78	−34.64	3	46.92	−47.18	−4.39
Equally-weighted Portfolio 2	−1.73	5.21	−34.65	4	−3.30	−1.21	−0.02
Equally-weighted Portfolio 3	−0.02	3.15	−3.17	1	98.62	−40.12	90.86
	Ave.ret (%)	Std dev (%)	Sharpe ratio (%)	Rank	Changes from the U.S. only		
					Ave.ret (%)	Std dev (%)	Sharpe ratio (%)
Panel B-3 The 2003-2007 period							
U.S. only	0.68	2.50	26.71	3			
Portfolio 1	0.31	1.53	19.70	4	−54.19	−38.88	−26.23
Equally-weighted Portfolio 2	1.45	3.23	44.61	1	114.05	29.06	67.02
Equally-weighted Portfolio 3	0.92	2.53	35.90	2	35.19	0.93	34.40
	Ave.ret (%)	Std dev (%)	Sharpe ratio (%)	Rank	Changes from the U.S. only		
					Ave.ret (%)	Std dev (%)	Sharpe ratio (%)
Panel B-4 The great recession period							
U.S. only	−2.44	6.99	−33.19	3			
Portfolio 1	−1.49	4.11	−33.27	4	38.98	−41.16	−0.25
Equally-weighted Portfolio 2	−2.43	8.64	−26.68	2	0.53	23.69	19.60
Equally-weighted Portfolio 3	−0.49	5.34	−7.00	1	79.72	−23.58	78.90
	Ave.ret (%)	Std dev (%)	Sharpe ratio (%)	Rank	Changes from the U.S. only		
					Ave.ret (%)	Std dev (%)	Sharpe ratio (%)
Panel B-5 The 2009-2019 period							
U.S. only	0.91	3.62	27.78	1			
Portfolio 1	0.53	2.05	25.78	2	−41.95	−43.32	−7.21
Equally-weighted Portfolio 2	0.48	4.02	14.20	4	−47.82	10.90	−48.89
Equally-weighted Portfolio 3	0.33	2.86	14.81	3	−63.88	−21.00	−46.67

Table 7 (continued)

	Ave.ret (%)	Std dev (%)	Sharpe ratio (%)	Rank	Changes from the U.S. only		
					Ave.ret (%)	Std dev (%)	Sharpe ratio (%)
Panel B-6 The COVID-19 period							
U.S. only	1.58	5.52	32.68	2			
Portfolio 1	0.87	3.12	35.07	1	−45.06	−43.58	7.30
Equally-weighted portfolio 2	0.92	5.18	17.76	4	−41.80	−6.21	−45.66
Equally-weighted portfolio 3	1.10	5.40	24.55	3	−30.30	−2.18	−24.89

The rankings are based on the size of the Sharpe ratio

periods of the dot-com bust and the Great Recession but positive during the COVID-19 period, this perhaps reflects the economic support mechanisms that governments implemented as well as the fact that certain sectors (e.g., technology and pharmaceuticals) performed well during this period. Notwithstanding this, we can see that market volatility (standard deviation) is similar to that in previous crisis periods.

Comparison between the equally-weighted portfolios and optimized portfolios

In the above analysis, Portfolios 2 and 3 are constructed using equal-weights. Here, we mean-variance optimize each portfolio in order to obtain the asset weights, with the results presented in Table 8 (we only present these new results as those for the U.S. only and Portfolio 1 already discussed).

In Panel A of Table 8, we find that in the optimized Portfolio 2, across both the full and sub-periods, no weight is allocated to the EAFE market, with the exception of the post-dot-com recovery period (2003-2007). We can also observe that, with optimization, the Sharpe ratios for Portfolio 2 are increased over the equal-weight Portfolio 2 (see the last three columns for a comparison) across the full and sub-sample periods. Considering the results more specifically, over the full sample period, the optimized Portfolio 2 allocates all the weight to the S&P500, with an average monthly real return and Sharpe Ratio that are 71 and 87% higher than for the equal-weight Portfolio 2, respectively. During the dot-com boom (1995-2000), the post-Great Recession recovery and the COVID-19 periods, again all the portfolio weight is allocated to the S&P500. In contrast, for the dot-com crash and the Great Recession periods, all the portfolio weight is allocated to the EM index, while a 72% weight is allocated to EM during the 2003-2007 period (with 28% to EAFE). Notwithstanding the different weights, the portfolio continues to exhibit negative returns and Sharpe ratio during the dot-com burst and Great Recession.

Panel B of Table 8 presents the results for the optimized cross-asset portfolio (Portfolio 3). Over the full sample period, the allocated weights are 61% to the S&P500, 33% to gold, and 5% to oil but with no allocation to the U.S. 10-year Treasury Note. The Sharpe ratio of the optimized Portfolio 3 is higher than that of the equal-weight Portfolio 3 both over the full sample and each of the six sub-sample periods. This can be mainly attributable to the higher average monthly real returns generated by optimizing Portfolio 3, while the standard deviations are both higher and lower across different sample periods. The notable exception is the COVID-19 period, where the portfolio return is lower, but so is the standard deviation, which still leads to a higher Sharpe ratio. Through optimization, over the full sample period, the average monthly real return of the optimized Portfolio 3 is 0.57%, which is 31% higher than the equal-weight Portfolio 3, with its Sharpe ratio 30% higher. In considering the sub-samples, during both the dot-com burst and Great Recession crisis periods, the optimized Portfolio 3 allocates no weight to the S&P500. However, during the COVID-19 crisis, a weight of 40% is allocated to the S&P 500. Furthermore, the average monthly return and Sharpe ratio are positive through all periods. In comparing the two optimized portfolios presented in Table 8, we can observe that Portfolio 3 outperforms Portfolio 2 over the full and each sub-period, except during 2003-2007, where there is a minimal difference.

Table 9 displays comparisons between the U.S. only, Portfolio 1 and two optimized portfolios across the different periods. From this, we can conclude the following main findings. First, the optimized Portfolio 3 (cross-asset) not only ranks first over the whole sample period but also in five sub-sample periods, with only the 2003-2007 period, where it is second preferred. Second, only the optimized Portfolio 3 has a positive average real monthly return and Sharpe ratio during the dot-com burst and the Great Recession periods, which could help U.S investors hedge risks during these two crisis periods. Third, the optimized Portfolio 2 typically outperforms the U.S only portfolio, whereas the equal-weight Portfolio 2 does not, although performance is lower than the optimized Portfolio 3.

Overall, by comparing the results in Tables 7 and 9, we conclude the following findings. First, the cross-asset diversified portfolio (Portfolio 3) offers substantial diversification benefits for U.S investors over both the full sample and

Table 8 Performance for the optimized Portfolio 2 and optimized Portfolio 3

	Portfolio allocation			Real risk-free rate (%)	Ave.ret. (%)	Real excess return (%)	Std dev (%)	Sharpe ratio (%)	Changes from Equally-weighted Portfolio 2		
	S&P500 (%)	MSCI EAFE (%)	MSCI EM (%)						Ave.ret (%)	Std dev (%)	Sharpe ratio (%)
Panel A. Optimized Portfolio 2											
Whole period	100.00	0.00	0.00	−0.01	0.63	0.64	4.32	14.76	71.21	−8.97	86.77
Dot-com boom	100.00	0.00	0.00	0.23	1.78	1.55	4.16	37.21	106.07	−7.57	164.21
Dot-com burst	0.00	0.00	100.00	0.08	−1.58	−1.65	6.89	−24.03	8.61	32.31	30.65
2003-2007	0.00	28.18	71.82	0.01	2.07	2.06	4.29	47.94	42.37	32.71	7.48
Great recession	0.00	0.00	100.00	−0.12	−2.06	−1.94	11.40	−17.01	15.08	31.97	36.25
2009-2019	100.00	0.00	0.00	−0.09	0.91	1.01	3.62	27.78	91.64	−9.83	95.67
COVID-19	100.00	0.00	0.00	−0.22	1.58	1.81	5.52	32.68	71.83	6.62	47.96
	Portfolio allocation				Real risk-free rate (%)	Ave.ret. (%)	Real excess return (%)	Std Dev (%)	Sharpe ratio (%)	Changes from Equally-weighted Portfolio 3		
	S&P500 (%)	GOLD (%)	OIL (%)	10 YR T-Note (%)						Ave.ret (%)	Std dev (%)	Sharpe ratio (%)
Panel B. Optimized portfolio 3												
Whole period	61.31	33.33	5.36	0.00	−0.01	0.56	0.57	3.31	17.16	30.54	0.42	29.56
Dot-com boom	90.31	0.00	9.69	0.00	0.23	1.69	1.46	3.78	38.57	281.11	37.64	394.15
Dot-com burst	0.00	29.30	6.14	64.57	0.08	0.39	0.31	1.84	16.90	1782.25	−41.83	633.94
2003-2007	62.81	18.68	18.52	0.00	0.01	1.03	1.02	2.29	44.47	11.91	−9.58	23.89
Great recession	0.00	100.00	0.00	0.00	−0.12	1.00	1.12	7.70	14.51	301.53	44.28	307.13
2009-2019	48.39	3.60	0.00	48.01	−0.09	0.43	0.53	1.70	30.97	31.45	−40.48	109.06
COVID-19	39.38	8.68	0.00	51.94	−0.22	0.57	0.80	2.19	36.38	-48.08	−59.48	48.19

Table 9 Comparisons between the U.S. only, Portfolio 1 and two optimized portfolios

	Ave.ret (%)	Std dev (%)	Sharpe ratio (%)	Rank	Changes from the U.S. only		
					Ave.ret (%)	Std dev (%)	Sharpe ratio (%)
Panel A. The full period							
U.S. Only	0.63	4.32	14.76	2			
Portfolio 1	0.34	2.54	13.71	4	−45.82	−41.19	−7.10
Optimized Portfolio 2	0.63	4.32	14.76	2	0.00	0.00	0.00
Optimized Portfolio 3	0.56	3.31	17.16	1	−10.96	−23.34	16.29
	Ave.ret (%)	Std dev (%)	Sharpe ratio (%)	Rank	Changes from the U.S. only		
					Ave.ret (%)	Std dev (%)	Sharpe ratio (%)
Panel B. The sub-sample periods							
Panel B-1 The Dot-com Boom period							
U.S. only	1.78	4.16	37.21	2			
Portfolio 1	0.98	2.70	28.06	4	−44.60	−35.25	−24.58
Optimized Portfolio 2	1.78	4.16	37.21	2	0.00	0.00	0.00
Optimized Portfolio 3	1.69	3.78	38.57	1	−5.10	−9.17	3.66
	Ave.ret (%)	Std dev (%)	Sharpe ratio (%)	Rank	Changes from the U.S. only		
					Ave.ret (%)	Std dev (%)	Sharpe ratio (%)
Panel B-2 The Dot-com Burst period							
U.S. only	−1.67	5.27	−33.18	3			
Portfolio 1	−0.89	2.78	−34.64	4	46.92	−47.18	−4.39
Optimized Portfolio 2	−1.58	6.89	−24.03	2	5.59	30.71	27.59
Optimized Portfolio 3	0.39	1.84	16.90	1	123.15	−65.17	150.93
	Ave.ret (%)	Std dev (%)	Sharpe ratio (%)	Rank	Changes from the U.S. only		
					Ave.ret (%)	Std dev (%)	Sharpe ratio (%)
Panel B-3 The 2003-2007 period							
U.S. only	0.68	2.50	26.71	3			
Portfolio 1	0.31	1.53	19.70	4	−54.19	−38.88	−26.23
Optimized Portfolio 2	2.07	4.29	47.94	1	204.74	71.28	79.50
Optimized Portfolio 3	1.03	2.29	44.47	2	51.28	−8.73	66.50
	Ave.ret (%)	Std dev (%)	Sharpe ratio (%)	Rank	Changes from the U.S. only		
					Ave.re (%)t	Std dev (%)	Sharpe ratio (%)
Panel B-4 The great recession period							
U.S. only	−2.44	6.99	−33.19	3			
Portfolio 1	−1.49	4.11	−33.27	4	38.98	−41.16	−0.25
Optimized Portfolio 2	−2.06	11.40	−17.01	2	15.53	63.23	48.75
Optimized Portfolio 3	1.00	7.70	14.51	1	140.86	10.26	143.71
	Ave.ret (%)	Std dev (%)	Sharpe ratio (%	Rank	Changes from the U.S. only		
					Ave.ret (%)	Std dev (%)	Sharpe ratio (%)
Panel B-5 The 2009-2019 period							
U.S. only	0.91	3.62	27.78	2			
Portfolio 1	0.53	2.05	25.78	3	−41.95	−43.32	−7.21
Optimized Portfolio 2	0.91	3.62	27.78	2	0.00	0.00	0.00
Optimized Portfolio 3	0.43	1.70	30.97	1	−52.52	−52.98	11.48

Table 9 (continued)

	Ave.ret (%)	Std dev (%)	Sharpe ratio (%)	Rank	Changes from the U.S. only		
					Ave.ret (%)	Std dev (%)	Sharpe ratio (%)
Panel B-6 The COVID-19 period							
U.S. only	1.58	5.52	32.68	3			
Portfolio 1	0.87	3.12	35.07	2	−45.06	−43.58	7.30
Optimized Portfolio 2	1.58	5.52	32.68	3	0.00	0.00	0.00
Optimized Portfolio 3	0.57	2.19	36.38	1	−63.81	−60.36	11.30

The rankings are based on the size of the Sharpe ratio

individual sub-sample periods regardless of whether investors chose equal-weighting or mean-variance optimization. Second, across the full sample, the traditional stock-bond approach (Portfolio 1) does not provide much in terms of diversification benefit compared to the U.S. only position with a similar Sharpe ratio. Third, the equal-weighted Portfolio 2 (internationally diversified stock portfolio) outperforms the U.S. only (S&P500 Index) only over a small number of selected sub-samples. Fourth, when considering the whole sample period, the optimized Portfolio 2 does provide better diversification benefits for U.S. investors. However, when examining the six sub-sample periods, we find that while before 2009 the optimized Portfolio 2 does benefit U.S. investors, this is no longer the case after 2009. This arises due to the performance of the S&P500 index compared to the EAFE and EM indices and thus the weight of the former in the portfolio.

Table 10 presents a set of analysis designed to provide robustness to our results from two perspectives. First, we conduct a series of rolling windows in order to generate out-of-sample values to construct the portfolios. Second, we consider the effect of transaction costs within portfolio performance. More specifically, in Table 10, the in-sample results are based on 24-month rolling windows (with 300 windows in total) with the average values over these windows reported for the return, standard deviation, and Sharpe ratio. In the out-of-sample exercise, we use the estimates from the rolling windows to produce the next months (one-step ahead) portfolio, including the estimated correlation. That is, with each rolling window, we optimize based on the in-sample values to build our portfolio for the subsequent month. Moreover, with regard to the out-of-sample results, the gross return is the average return based on each period without considering transaction costs, while the net return is the average return that takes into account the transaction costs, where the one-way transaction cost is considered to be 0.05%. The turnover (trading magnitude) for each portfolio during the monthly rebalancing for the out-of-sample exercise is presented in Table 11.

The results in Table 10 reveal two broad conclusions. First, if we consider the in-sample results, they support those previously noted. Specifically, the optimized Portfolio 3 produces the highest Sharpe ratio over the full sample and for each of the sub-samples. Furthermore, it is the only portfolio that achieves a positive Sharpe ratio, including in the crisis periods. Elsewhere, the optimized Portfolio 2 generally performs well, ranking either second or third, however, during the post-Great Recession recovery, it underperforms compared to all other portfolios. Again, the equal-weighted portfolios are outperformed by the optimized ones. The U.S. only portfolios, both the S&P500 and stock and bond only, are lower ranked in term of their Sharpe ratio across the full sample and each sub-sample, with the exception of the post-Great Recession period. Second, if we consider the out-of-sample results, then we see differences emerging. Here, we see much less consistency in the preferred portfolio over the different periods. For the full sample period, the optimized Portfolio 2 (across international stock markets) achieves the highest Sharpe ratio. Across the sub-samples, we observe the S&P500 only portfolio achieving a Sharpe ratio ranked in the top three, in the dot-com boom period (ranked first), the post-Great Recession (second) and COVID-19 (third), while in the remaining periods, it ranks in the bottom three. This volatility in performance is matched in the other portfolios. However, it is noticeable that in the two periods of negative returns (dot-com crash and the Great Recession), it is the diversified (cross-market and cross-asset) portfolios that are preferred. In comparing the gross and net returns, we can observe that the cross-asset portfolio sees the highest amount of transaction costs (and therefore, trading), which damages its performance. This result is supported by the turnover for each portfolio during monthly rebalancing reported in Table 11. Notably, Table 11 shows that the optimized Portfolios 2 and 3 trade more than other portfolios over the full and sub-sample periods, especially when compared with equal-weighted Portfolios 2 and 3.

Table 10 Comparisons of the in- and out-of-sample results

	In-sample			Out-of-sample			
	Ave.ret. (%)	Std dev (%)	Sharpe ratio (%)	Gross return (%)	Net return (%)	Std dev (%)	Sharpe ratio (%)
Panel A. The full period							
U.S. only	0.52	4.11	12.82	0.54	0.54	4.43	12.66
Portfolio 1	0.37	3.17	15.68	0.28	0.28	2.58	11.69
Equally-weighted Portfolio 2	0.54	0.53	8.44	0.35	0.35	4.88	7.62
Optimized Portfolio 2	0.90	4.91	25.18	0.77	0.70	5.35	13.53
Equally-weighted Portfolio 3	0.35	3.77	11.13	0.41	0.41	3.40	12.65
Optimized Portfolio 3	1.08	3.31	32.93	0.35	0.23	4.22	6.08
	In-sample			Out-of-sample			
	Ave.ret. (%)	Std dev (%)	Sharpe ratio (%)	Gross return (%)	Net return (%)	Std dev (%)	Sharpe ratio (%)
Panel B. The sub-sample periods							
Panel B-1 The Dot-com Boom period							
U.S. only	1.79	4.32	38.54	1.77	1.77	4.97	30.68
Portfolio 1	1.23	3.30	31.75	0.89	0.89	3.16	20.63
Equally-weighted Portfolio 2	0.87	4.32	21.78	1.01	1.01	5.46	14.14
Optimized Portfolio 2	1.79	4.29	38.61	1.70	1.65	4.93	28.64
Equally-weighted Portfolio 3	0.41	2.65	7.18	0.25	0.25	3.33	0.26
Optimized Portfolio 3	1.79	4.20	39.73	1.42	1.36	4.52	24.88
	In-sample			Out-of-sample			
	Ave.ret. (%)	Std dev (%)	Sharpe ratio (%)	Gross return (%)	Net return (%)	Std dev (%)	Sharpe ratio (%)
Panel B-2 The Dot-com burst period							
U.S. only	− 0.45	5.03	− 11.78	− 1.67	− 1.67	5.27	− 33.18
Portfolio 1	− 0.45	3.90	− 15.72	− 0.89	− 0.89	2.83	− 34.13
Equally-weighted Portfolio 2	− 0.63	4.86	− 10.95	− 1.73	− 1.73	5.29	− 34.11
Optimized Portfolio 2	− 0.22	6.10	− 5.14	− 1.37	− 1.58	5.86	− 28.24
Equally-weighted Portfolio 3	− 0.11	3.71	− 6.50	− 0.02	− 0.02	3.20	− 3.16
Optimized Portfolio 3	1.48	7.00	18.74	− 1.12	− 1.26	7.70	− 17.41
	In-sample			Out-of-sample			
	Ave.ret. (%)	Std dev (%)	Sharpe ratio (%)	Gross return (%)	Net return (%)	Std dev (%)	Sharpe ratio (%)
Panel B-3 The 2003-2007 period							
U.S. only	0.23	3.31	14.43	0.68	0.68	2.50	26.71
Portfolio 1	0.11	2.40	10.71	0.31	0.31	1.55	19.24
Equally-weighted Portfolio 2	0.68	3.62	33.49	1.45	1.45	3.26	44.14
Optimized Portfolio 2	1.36	4.49	29.55	1.72	1.60	4.11	38.83
Equally-weighted Portfolio 3	0.77	3.08	26.38	0.91	0.91	2.53	35.69
Optimized Portfolio 3	1.10	2.57	45.64	0.67	0.54	2.92	18.04
	In-sample			Out-of-sample			
	Ave.ret. (%)	Std dev (%)	Sharpe ratio (%)	Gross return (%)	Net return (%)	Std dev (%)	Sharpe ratio (%)
Panel B-4 The Great Recession period							
U.S. only	− 0.95	4.05	− 17.77	− 2.44	− 2.44	6.99	− 33.19
Portfolio 1	− 0.66	3.10	− 17.77	− 1.46	− 1.46	4.20	− 31.99
Equally-weighted Portfolio 2	− 0.80	5.26	− 3.65	− 2.40	− 2.40	8.85	− 25.78
Optimized Portfolio 2	0.12	7.54	7.08	− 2.13	− 2.15	11.71	− 17.38
Equally-weighted Portfolio 3	0.35	5.17	11.91	− 0.47	− 0.47	5.45	− 6.47
Optimized Portfolio 3	1.07	3.75	29.13	− 1.16	− 1.44	7.01	− 18.77

Table 10 (continued)

	In-sample			Out-of-sample			
	Ave.ret. (%)	Std dev (%)	Sharpe ratio (%)	Gross return (%)	Net return (%)	Std dev (%)	Sharpe ratio (%)
Panel B-5 The 2009-2019 period							
U.S. only	0.64	3.91	25.32	0.91	0.91	3.62	27.78
Portfolio 1	0.27	3.01	21.76	0.53	0.52	2.06	30.15
Equally-weighted Portfolio 2	0.40	4.31	20.04	0.47	0.47	4.02	14.07
Optimized Portfolio 2	0.80	4.48	27.70	0.86	0.83	3.92	23.69
Equally-weighted Portfolio 3	0.22	3.96	9.68	0.33	0.32	2.86	14.62
Optimized Portfolio 3	0.86	2.71	39.25	0.51	0.40	2.90	17.20
	In-sample			Out-of-sample			
	Ave.ret. (%)	Std dev (%)	Sharpe ratio (%)	Gross return (%)	Net return (%)	Std dev (%)	Sharpe ratio (%)
Panel B-6 The COVID-19 period							
U.S. only	1.05	5.45	20.08	1.58	1.58	5.52	32.68
Portfolio 1	0.94	4.73	20.88	0.88	0.87	3.17	34.60
Equally-weighted Portfolio 2	0.76	5.28	18.23	0.93	0.93	5.28	21.78
Optimized Portfolio 2	1.05	5.45	20.08	1.58	1.58	5.52	32.68
Equally-weighted Portfolio 3	0.56	5.28	11.32	1.11	1.11	5.51	24.16
Optimized Portfolio 3	0.53	1.44	43.91	0.23	0.13	1.46	24.56

The in-sample results are the 24-month rolling window's average for each of the portfolio return, standard deviation and Sharpe ratio. The out-of-sample results are obtained as one-step ahead forecasts for the portfolio parameters. The gross return is the average return without considering transaction costs, while the net return takes account of a one-way transaction cost of 0.05%

Table 11 Average turnover for various portfolios

	U.S.-Only (%)	Portfolio 1 (%)	Equally-weighted Portfolio 2 (%)	Optimized Portfolio 2 (%)	Equally-weighted Portfolio 3 (%)	Optimized Portfolio 3 (%)
Whole period	0.00	1.89	1.59	13.01	3.94	23.95
Dot-com booming	0.00	2.14	2.59	10.06	3.89	9.95
Dot-com burst	0.00	2.69	1.73	41.52	4.06	30.19
2003-2007	0.00	1.29	1.39	22.12	3.24	26.31
Great recession	0.00	3.14	2.16	5.96	5.54	57.30
2009-2019	0.00	1.63	1.27	5.78	3.07	21.45
COVID-19	0.00	2.35	1.61	0.00	4.90	19.15

The average turnover refers to the trading magnitude in each portfolio during monthly rebalancing for the out-of-sample exercise

Summary and conclusion

This paper investigates whether U.S. investors should diversify their investment through different portfolio opportunities, including a stock (60%)-bond (40%) portfolio, an internationally diversified stock portfolio, and a cross-asset diversified portfolio, or simply invest in the U.S. stock market. We use monthly data to build the four investment portfolios over the period 1995-2021, while we also segmented the full sample period into crisis periods and non-crisis periods. The crisis periods include the dot-com burst, the Great recession, and COVID-19. Our dataset comprises six variables, three stock indices (S&P 500, MSCI EAFE and MSCI EM), and three non-stock assets (gold, oil and bonds). While the stock-bond portfolio has a fixed weight of 60%/40% of the S&P 500 Index and U.S. 10-year Treasury Note, respectively, the cross-stock and cross-asset portfolios are both equal-weighted and mean-variance efficient.

Descriptive statistics reveal that since 2009, compared with the EAFE and EM indices, the S&P500 index is the best performer with a higher average monthly real return and a lower standard deviation. This is further confirmed through

the portfolio optimization across international stocks. Before 2009, the international stock diversified portfolio allocates weights across the three index series. However, after 2009, optimization allocates all weight to the S&P500 index.

In examining the performance of the different portfolios, we report several key findings. Most importantly, the cross-asset diversified portfolio consisting of the S&P500, gold, oil, and the U.S. 10-year Treasury Note results in the best performing portfolio and outperforms alternative portfolio regardless of whether investors choose an equal-weighted or optimized portfolio. This result is consistent with some literature (e.g., Baur and McDermott 2010; McCown and Zimmerman 2006; Capie et al. 2005) that supports the inclusion of gold for its hedging properties. Equally, further work (Hamoud et al., 2011, 2013) finds that when oil is combined with precious metals in a diversified portfolio, it has the property of increasing returns and reducing risk. In comparing the equal-weighted and optimized portfolios, the latter is preferred, but as noted, the former does outperform the S&P 500 index. It is also of interest to note that in the optimized portfolio, over the full sample period, no weighting is allocated to the U.S. 10-year Treasury Note (similar to the reported in Hamoud et al., 2011, 2013). However, during two of the crisis periods, it is the dominant asset in the portfolio.

It is notable that the equal-weighted international stock market portfolio often performs worse than the S&P500 only portfolio. This is especially true over the full sample period and in the dot-com and COVID-19 crisis periods. In the optimized portfolio, it is of interest that the EAFE index is excluded, except for the post-Great Recession recovery period, indicating that adding developed markets to a U.S. portfolio does not help performance. Furthermore, after 2009, the optimized international stock portfolio only includes the S&P 500 (during the great recession, only the EM index is included). In seeking to understand this result, it is notable that since 2009, compared to the EAFE and EM indices, the S&P500 index is the best performer. A further reason might be that the correlation between international stock markets is increasing in recent years, which may eliminate international diversification benefits and increase shock transmission (e.g., Karolyi and Stulz 1996; Longin and Solnik 1995; Driessen and Laeven 2007; Koch and Koch 1991).

In seeking to consider the robustness of our results, we utilize rolling windows to reconsider the in-sample evidence and to allow construction of out-of-sample portfolios to avoid look-ahead bias. In addition, we incorporate a transaction cost into the out-of-sample portfolios. The results are broadly confirmed with the in-sample rolling portfolios, suggesting that the shorter formation period (and correlation) does not affect the performance of the portfolio. In the out-of-sample period, however, we find more mixed results. Although the cross-asset portfolio continues to perform well during the crisis periods, its performance is less supported in periods of stronger market behavior.

The key result here shows that the cross-asset portfolio performs the best across the different sample periods. In general, while the optimized portfolios provide higher diversification benefits than the equal-weighted portfolios, the equal-weighted cross-asset portfolio does outperform the optimized international stock market portfolio across certain periods. A further interesting result it that compared with the dot-com burst and the Great Recession, the COVID-19 health crisis did not have an evident impact on the return of the four portfolios, although it increased the volatility of each. However, the caveat to these results is that in the out-of-sample exercise, the performance of the cross-asset portfolios is relatively weaker during periods of market growth and is subject to a larger amount of trading than other portfolios. It remains an avenue for future research to consider further how the in-sample benefits can be obtained out-of-sample.

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Rong Huang is a doctoral student in her final year within the Division of Accounting and Finance at the University of Stirling. Her specialism focuses on international portfolio construction and diversification as well as the response of international assets to monetary policy changes.

Dimos Kambouroudis is a Senior Lecturer in Finance within the Division of Accounting and Finance at the University of Stirling. His research primarily focuses on modelling and forecasting of asset market volatility and has published in international journals in this area.

David G. McMillan is a Professor of Finance within the Division of Accounting and Finance at the University of Stirling. His research interests include forecasting asset returns and volatility, modelling the linkages between asset prices and macroeconomic variables and examining the behaviour of financial and investor ratios. He has published widely on these topics in international journals.